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THE EDITOR-IN-CHIEF MESSAGE

This journal gathers publications from surveying practices namely Quantity Surveying, Property Surveying, Geomatics and Land Surveying and Building Surveying. The publication of ISrJ gives opportunity to the researchers, academicians, practitioners as well as students to share their research outcomes. We have covered many topics in the last few volumes under the current editorial but there is still a vast area within these surveying practices waiting to be explored.

JOURNAL OBJECTIVES

International Surveying Research Journal (ISrJ) is an international journal dedicated to the publication of theoretical and empirical refereed articles, case studies or critical literature review in thefield of surveying research and development. The scope of the journal covers development and application of the surveying practices globally. The purpose of the **International Surveying Research Journal (ISrJ):**

- To provide a unique international forum for new research findings in the surveying research.
- To reflects recent development and application of surveying practices.
- To encourage knowledge sharing among researchers, academics, and practitioners.
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- To stimulate research in the various surveying disciplines.

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Editor's Message

Welcome to International Surveyors Journal (ISrJ) Vol. 13, Issue December 2023 for the Royal Institution of Surveyors Malaysia (RISM). This journal gathers publications from surveying practices namely Quantity Surveying, Property Surveying, Geomatics and Land Surveying and Building Surveying. The publication of ISrJ gives opportunity to the researchers, academicians, practitioners as well as students to share their research outcomes. We have covered many topics in the last few volumes under the current editorial but there is still a vast area within these surveying practices waiting to be explored. This particular issue consists of Seven (7) selected papers reviewed by the editorial committee and international experts on current topics which include Challenges and Solutions in Managing Higher Educational Institutions (HEI) Spaces, Tahfiz Schools' Facilities and Relationship to Malaysia's Learning Environment: A Systematic Literature Review, Measurement Model of Critical Success Factors for Adoption of Energy Management Practices in Public Universities in Malaysia, Validation of 3D Reconstruction of Building Model between DSLR and Mirrorless Cameras using Close-range Photogrammetry, The Impact of Abandoned Housing Projects on the Society and the Environment in Klang, Selangor, Introducing Virtual Reality (VR) in Retrofitting of the Existing Building: A Literature Review and Are Green Buildings Always Green?. We wish to extend our appreciation to all our contributors who have sent articles to date and we will try to include in future issues of ISrJ.

Do drop a message and request if there are specific surveying topics of particular interest. Thank you for the readership and hope it is beneficial to all.

Sr Hj. Ahmad Suhaimi Abdul Majid
Advisory Editor,
December 2023

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ARTICLES:

CHALLENGES AND SOLUTIONS IN MANAGING HIGHER EDUCATIONAL INSTITUTIONS (HEI) SPACES

Nik Elyna Myeda & Christine Chin Li Fung

Abstract

This study aims to improve the educational institutional building spaces among public universities by exploring the issues and challenges faced and proposing effective space management solutions for HEIs. The methodology entailed the literature review of space management to identify effective space management key factors. Subsequently, the study adopts a qualitative approach for both data collection and analysis. The analysis is mainly based on the data gathered from face-to-face interviews and observations made on HEI case study buildings. The findings proved that effective space management contributes towards an improved FM service delivery of HEIs. The study concluded the challenges faced by the HEIs such as inefficient centralization, unorganised information, users' attitude, poor management of space, space wastage, lack of competency, insufficient staff, unmatched space capacity and lack of budget. Recommendations highlight the effective space management key factors like leadership, communication, information, and practical tools to solve the challenges and improve the practice. Although the dataset is narrowed down to two case studies, they provide detailed and real-scenario-supported solutions and feedback. The paper is particularly beneficial for the professionals responsible for the space design and management of buildings, particularly institutions.

Keywords

Facilities management, space management, higher education institutions, space utilization, space challenges, institutional buildings

Introduction

Spaces are essential assets for an organisation. The management of space along with its relationship with people and business activities are core emphases to delivering great success for organisations (IWFM, 2022). Shared spaces play a vital role in enriching the user experience at buildings (Brinkoe and Nielsen, 2018). Space management is one of the key elements in Facilities Management (FM) (Jayantha and Olandinrin, 2020; Abdullah et al., 2012) that plays an important function in organisations. A "space" is a physical resource owned and can fit various categorisations including an auditorium, lobby, library,

classrooms, laboratory, office, commercial building, basement parking, toilet, and warehouse. Space is considered part of the environment and a finite and valuable physical resource for an institution (Aziz *et al*., 2013), especially in the management of facilities within the built environment (Jayantha and Olandinrin, 2020). Space management is the management of spaces which control and supervise any physical space that a business or an organisation occupies (Micromain, 2017) and fits the purpose of FM in creating an environment that aligns with the organisation's primary objective and mission (Yu-Tian et al., 2015) as it enhances the performance of the organisations (Mazlan et al., 2015). Organisations manage their spaces efficiently to suit the user needs and workplace dynamics (Chua et al., 2022). The strategic objective of FM is to provide better infrastructure and logistic support to businesses (Myeda and Pitt, 2014), which fits with the acceptance that FM is an emerging service that can support and enhance business values (Myeda, 2014).

Space management can be carried out in multiple ways and every organisation has its space management system and standard guidelines (Micromain, 2017) to suit the complexities of their buildings. Space management scope may include facility or master planning, space planning, space configuration and reconfiguration, space allocation, space utilisation, space usage audit and monitoring (Shahabudin et al., 2012). The aim is to manage the physical resources effectively and efficiently to fulfil the space functions, whilst minimising the cost of operating and maintaining building spaces. Hence, the importance of managing space is not only in asset efficiency but also in operation and maintenance cost optimisation (Abdullah et al., 2013; Shahabudin et al., 2012).

Space management is imperative as one of the major components in FM due to space being the most expensive and valuable asset of an organisation or institution (Abdullah *et al.*, 2012; Ibrahim *et al*., 2012; UNSW Australia, 2016). It can also be seen as the management and use of the assets our buildings constitute (Brinkoe and Nielsen, 2018). While space can serve both as an advantage and a challenge for an organisation or institution (APPA, 2012), the determining factor lies in how it is managed. Effective space management involves maximising spaces beyond their intended functions, sometimes even generating revenue (Ibrahim et al., 2012). This approach aids in regulating an organisation's expenses to support its primary functions (Chua et al., 2022). Conversely, inadequate space management results in inefficient resource use, leading to issues such as space wastage, underutilization due to low occupancy rates, and space designs that do not align with their intended use (Shahabudin et al., 2012).

Educational institution facilities play a vital role in creating a conducive learning environment (Hassanain et al., 2012), and this encompasses the utilisation of space.

Space acquisition is costly, maintenance is expensive, and often space is underutilised (Ibrahim et al., 2012). However, when space is strategically managed, it can generate income. It acts as the platform on which institutions function, carrying immense value (APPA, 2012). In Higher Educational Institutions (HEIs), space has become a scarce and valuable resource that requires preservation. These institutions often have expansive spaces to accommodate the increasing number of students. These spaces encompass various categories: academic spaces (dedicated to research and teaching), administrative spaces (office areas for staff and lecturers), scheduled teaching spaces (such as classrooms, lecture halls, and labs), library areas, commercial zones (like bookshops, cafeterias, printing facilities), student living spaces (including sports centres, dormitories, and recreational areas), and various other university buildings (TEFMA, 2009).

Research Gap

Studies on HEI education and support services have shown that various challenges were centred upon the issue of infrastructure and spaces. As technology changes the way education is acquired (Liu et al., 2023), Boys (2014) highlighted how traditional learning spaces become less meaningful as the education delivery evolves. Ramli and Zain's (2018) study on HEI campus proved that a lack of attention was given to space and design of buildings which could contribute to the performance of HEIs.

Quinnell (2020) pointed out that most often, HEI spaces were built with no clear indication of students' needs. Goodyear (2020) highlights the importance of identifying and strengthening the educational infrastructure for design-led community engagement and creating impacts on what is needed. Asiyai (2012) highlighted that poor facilities lead to poor student attendance, which later reflected in the poor performance of students.

Although meeting the needs of facilities users of HEI may face significant challenges, it is imperative to contribute towards improved quality operation and satisfactory services (Hassanain et al., 2021).

Fadahunsi et al., (2019) suggest that space functions at HEIs can be improved with the advancement of tools, for instance, workspace management tools. Similarly, Asiabaka (2008) raised the need for effective management of facilities to support education delivery, which includes the utilisation, maintenance, improvement and audit of educational facilities

It was also exhibited that spaces were sometimes left unattended when the funding ceased, and universities were also seen to normally react to changes, rather than taking proactive actions (Boys, 2014). This was relatable to a study by Ibrahim *et al*. (2011), whereby the cost related to physical sources or building spaces is the second most

important budget after staff salary in HEIs. Budget cuts made to public universities in Malaysia have resulted in the deprivation of basic needs such as facilities and support services (Kamal, 2017).

There exist concerns about the conducive learning and teaching environment at institutions (Myeda and Mohd-Zambli, 2018). This puts pressure on HEIs to manage the usage of existing space more effectively before constructing new and costly buildings due to escalating construction costs, bad economic circumstances and the increase in the enrolments of students (Shahabudin *et al.*, 2012).

Therefore, this study seeks to identify the effective space management key factors by exploring the space management practices at HEIs, including understanding the issues and challenges faced in their practice.

Space Management

Ali et al. (2019) proved that physical environment comfort attributes like space management and layout affect HEI users' performance and productivity. Spaces are focused towards their roles in promoting physical movement that results in improvement among users (Pollard et al., 2022). Ibrahim et al. (2002) agreed that users' level of productivity is influenced by effective space management. The five main effective space management contributing factors are leadership, objectives, information, communication and practical tools (Ibrahim et al., 2011; Space Management Group, 2006). Space Management Project (SMP) (2006) promoted space efficiency in building design, benchmarking estate size and calculating cost & affordability, reviewing the specifications or standards of space management, developing frameworks to assess space needs, and space utilisation guidelines. Effective space management includes effective space allocation or relocation, effective space utilisation, effective space planning and whether the space meets the users' needs and wants (Li *et al.*, 2017). These are the key performance indicators of the space dimension commonly used to determine space management effectiveness. Several factors contribute to the successful effective space management as listed (APPA, 2012; Canfield and Graff, 2015; Ibrahim et al., 2011; NAO, 1996; Shahabudin *et al.*, 2012; TEFMA, 2009):

a) Leadership

- Developing clear policies and standards
- Staff involvement and competency
- Managing space during semester break
- Establishing space management committees

b) Information

- Database
- Space management evaluation
- Space utilisation audit
- Space functionality assessment

c) Communication

- Communication among space management staff
- Communication among the management team and users.

d) Practical tools

- Space charging model
- Central and computerised timetabling
- Space management software

e) Establishing space management committees

- Roles and responsibilities of committees
- Strategic design and management of space planning

f) Space management evaluation

- Consistent evaluation and monitoring

Feedback for improvement

HEIs could significantly benefit from strategic planning, such as employing workspace management tools to continually enhance the facilities for students (Fadahunsi et al., 2019). Utilising space management tools or techniques can improve space efficiency. For example, space inventory systems collect, gather and maintain the space by using codes, thereby assisting in efficient utilisation (Aziz *et al.*, 2013). A space charging model is a common tool in managing space cost and utilisation in HEIs. Benchmarking of allocation & standards and planning models are among the techniques used by HEIs to measure space usage and planning for current and future needs (TEFMA, 2009). A benchmarking technique used in space management is useful to assess how much space usage and space planning can be improved for future needs.

Space efficiency varies according to the form and complexities of buildings (Ilgin, 2023). Effective space management is crucial in preventing space-related issues in HEIs. Wastage of space occurs in HEIs due to the low utilisation rate (Abdullah *et al*., 2012). Proper management of space not only can prevent wastage but also minimise the high

cost associated with constructing new spaces (APPA, 2012; Ibrahim *et al*., 2012; Shahabudin *et al.*, 2012). The objective of this paper is to delve into factors and challenges of space management within HEIs, aiming to enhance the space management practice for HEIs.

Methodology

This study utilizes a qualitative methodology employing a case study approach focused on two specific public Higher Educational Institutions (HEIs) in Malaysia. Qualitative methodology is chosen due to its adherence to the scientific method, enabling the generation of new hypotheses and theories based on collected data (Apuke, 2017). Qualitative research serves to delve into issues and generate potential ideas for subsequent quantitative research (DeFranzo, 2011). Past studies related to spaces within HEIs have indicated that a case study methodology is a dependable means of collecting data (Ali et al., 2019; Myeda and Mohd-Zambli, 2018).

Malaysia boasts a total of 20 public universities, categorized into 5 research universities, 4 comprehensive universities, and 11 focusing universities. For this study, the selection criteria have been refined to concentrate on research universities, constituting a 40% representation (2 out of 5) of the total population. Research universities were specifically chosen due to their provision of a more extensive range of facilities, driven by their emphasis on research and innovation. The focus of this study was directed toward the faculties related to the Built Environment, acknowledging their unique hybrid and blended learning environment. The Built Environment faculties stand out for their diverse and non-conventional academic and learning spaces, as detailed in Table 1.

Table 1: Background of the HEI case studies

Case Study	**Faculty of Built Environment (FBE) HEI 1**		**Faculty of Built Environment (FBE) HEI 2**	
Type of building	Higher Educational Institution (HEI)			
Case Study	**HEI 1**	**FBE**	**HEI 2**	**FBE**
Age (years)	112	6	87	22 years
No. of buildings/blocks	381 blocks	1 block (10-storey)	Approx. 800 buildings	1 block

Case Study	Faculty of Built Environment (FBE) HEI 1		Faculty of Built Environment (FBE) HEI 2	
Land Area	803.63 acres	-	2738.18 acres	-
No. of Occupants	34,142	800	32,067	755
Teaching & learning spaces	Classrooms, lecture halls, discussion rooms, computer laboratories, science laboratories	Classrooms, discussion rooms, studios, laboratories	Classrooms, lecture halls, discussion rooms, computer laboratories, science laboratories	Classrooms, lecture hall, studios, laboratories, workshops
Interviewees	Central level: [Interviewee A] Officer, Property Management Unit, Department of Development & Estate Maintenance (DEM) Faculty level: [Interviewee B] FBE Architecture Assistant officer		**Central level:** [Interviewee C] Space & Building Section, Development Office & Asset Management (DOAM) **Faculty level:** [Interviewee D] FBE Assistant Engineer	

Table 1 illustrates that the Higher Educational Institutions (HEIs) follow a hierarchical approach, encompassing two levels: one managed by the department responsible for the campus's buildings and infrastructure, and the other overseen by the technical team operating within the individual faculties. The interviewees involved in the study had experience ranging from 3 to 8 years in managing space within these institutions.

Data for the research was gathered through interviews and observations to evaluate the space management practices within these two HEIs. The interviews were structured in a semi-structured format, aiming to gain insight into various aspects of space management practices, effective techniques, and the challenges faced by the institutions. The specific structure and content of the interview questions are outlined in Table 2.

Table 2: The Composition of Semi-Structured Interview Questions

Sections	Details
General Information	General questions on the job title, job scope and working experience of the interviewees. This further ensures that the interviewees have relevant backgrounds to make sure that the data collected are reliable.
Effective Space management	Information on the importance of effective space management practice within the institutions and the benefits
Current Practice on Space Management	Feedback on the current space management practices i.e tools and systems used in space management
Challenges	Issues and challenges faced in the management of space within the institution, as well as the occupants' attitude towards the usage of space. Recommendations on the solutions to solve those challenges were also included.

The expected outcomes from both the interviews and case study observations are pivotal in acquiring a comprehensive comprehension of space management practices in Higher Educational Institutions (HEIs). This understanding is fundamental to achieving the objectives of this research, which include establishing key factors for effective space management, identifying issues and challenges in space management, and proposing relevant solutions.

The collected data underwent qualitative analysis, encompassing the transcription of interview data and documentation of observation findings. As per Taylor & Gibbs (2010), qualitative data analysis involves the transformation of gathered qualitative data into explanations and interpretations, accomplished through two fundamental processes: narrative composition and the identification of recurring themes. Figure 2 illustrates the adopted data analysis method based on the qualitative analysis principles advocated by Taylor & Gibbs (2010).

Upon scrutinizing the data, the gathered information, characterized by its non-standardized and intricate nature, necessitates a process of condensation (summarization), grouping (categorization), restructuring, and identification. This effort aims to establish relationships among categories, forming a cohesive narrative that supports a more meaningful analysis.

For this study, specific categories have been selected to organize the data, including factors contributing to effective space management, current practices observed in space management, and challenges in implementing effective space management. This structured categorization allows for a more comprehensive and coherent analysis of the data.

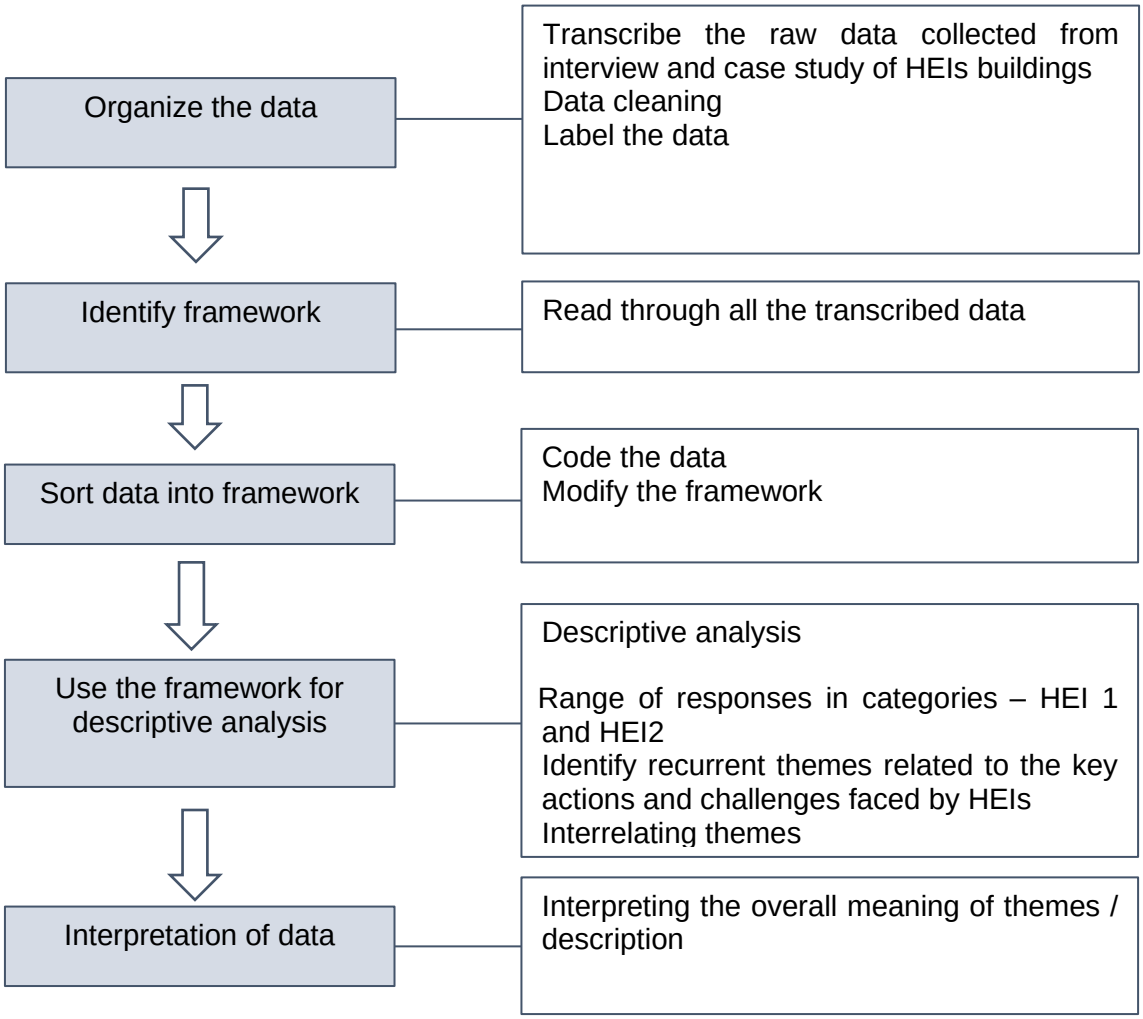


Figure 1: Qualitative data analysis process (Source: Adopted from Taylor & Gibbs, 2010)

Findings

Current Practices of Space Management

(a) Case study 1 (HEI 1) implements both manual and online systems for the assets, facilities and space management for all the campus buildings.

- Two other digital systems used were *Space e-Reservation System* and *Campus Point* for facilities and space booking purposes. *Space e-Reservation System* is an online room booking system used by the campus community to book spaces i.e. classrooms, discussion rooms, meeting rooms, lecture halls and laboratories. This system provides a quick platform to ease the booking process. Meanwhile, *CampusPoint* is a one-stop centre for selected facilities booking for campus community usage and public rental purposes. A manual booking system is also used for selected spaces like the FBE classrooms and studios, which were not listed in either *AMS* or *CampusPoint*. According to Interviewee B, this is applied at FBE, where booking by the faculty members needs to be done via email.
- Interviewee B claimed that the FBE technical department is responsible to register and tag the inventory of all facilities and rooms onto *AMS*.
- Interviewee A mentioned that the institution has been conducting space usage audits for selected faculties to monitor space planning usage and monitoring i.e. classroom usage.
- Both interviewees informed that they faced a similar data management issue like overlapping of space data stored by the three different online systems databases.

  In short, HEI 1 utilises digital, computerised, and manual systems for the asset and facilities management of the institution.
- The online system used was the government system known as Asset Management System (AMS). According to Interviewee A, AMS is used as a computerised space inventory system to store space data of all the spaces available at the institution. This system has been implemented ***for*** the past 11 years to date, with four upgrades throughout the period. Training for system usage and updates was provided to all the technical staff involved in the asset management task force. The AMS manages information related to assets and facilities inventory including tagging, coding, quantity and status tracking for spaces and facilities owned by the institution.

(b) Case study 2 (HEI 2) uses a manual system instead of any dedicated online systems for the management of space, assets and facilities campus-wide.

- Space booking forms need to be manually filled by users. All the space data such as coding of space, quantities, functions, and status of spaces were recorded and stored manually.
- Public members who are interested to use or rent the institution must proceed to email the person in charge of the space.
- However, Interviewee C mentioned that HEI 2 plans to use the *MySPATA system* - a system introduced by the Public Works Department (PWD) of Malaysia to manage and maintain the government's non-movable assets such as spaces, buildings, and lands. HEI 2 was in the process of inserting data into the *MySPATA system*.
- HEI 2 has conducted space audits in the past, only upon request by the faculties. The space audits were categorised into space audits and space usage audits. Space usage audit is done based on the operating hours and occupancy rate. Meanwhile, space audit refers to the space layout and the total number of occupants. Space audit is important to determine the sufficiency of space and identify space issues like underutilisation or overutilization. Space audit results determine the sharing need for vacant or unused spaces among the adjacent faculties for teaching and learning activities.
- ***The major issue faced was the data migration process, which is a time-consuming process, and they were in lack of resources to work on this. The amount of existing data was also overwhelming considering all was done manually.***

Table 3: summarises the current practices of space management at both HEI 1 and 2.

Case Studies	**HEI 1**	**HEI 2**
Space Management Unit/ Departments	Property Management Division, Department of Development & Estate Management (DEM) On-site team: Architecture Asst. Officer, Technicians	Space & Building Section, Development Office & Asset Management (DOAM) On-site team: Asst. Engineer, Technicians
Staff involved	15 3	6 3
Space Management Systems/ Tools	**Manual system**: Some facilities; classrooms & studios (through email to respective personnel) **Online system**: Asset Management System (AMS) Space e-Reservation System (for staff & students only) CampusPoint (One Stop Centre for Facilities Booking - applied to the public)	**Manual system:** Manual form: room booking procedure Provide space rental service (apply through email to respective faculties) **Online system**: None In the process of migrating to the MySPATA system
	Online system: All space data is stored in AMS	**Manual system:** All space data is stored manually Space data integrated with CAD drawings
	Data management - Overlapping of space data in the online system databases	Data migration - Too much space data needs to be migrated onto the new system. Time-consuming task and lack of resources.

Space Management Challenges

Understanding the space management challenges faced by HEIs will enable the study to investigate the root cause of the problems faced. This way, the study can refine the accurate recommendations to further improve the space management practice. Both institutions use different practices of space management systems and face different challenges in managing their spaces:

(a) Inefficient Centralisation

Feedback from the interviewees denotes that the biggest challenge faced in space management is **inefficient centralisation** in terms of management. HEI 1 interviewees claimed that not all the staff and faculties are using the same system implemented. Although the training was provided to support the system in place, some of the staff still prefer to use the manual system. This is due to the lack of guidance from the institution in giving commands to the technical staff involved in the asset management practice. Also, the lack of space management strategy is due to the moving goals and aims of the higher management. Having a space management strategy addresses flexibility and responsiveness in meeting the space design's new requirements and demands. Top management strategies with clear policies and guidelines for managing the space and facilities within the campus lead to effective space management.

(b) Unorganised Information

Information is highly required for a comprehensive and up-to-date database. While having digital and computerised systems at HEI 1 in place, problems related to data management still exist. HEI 1 faced data overlapping issues in the databases, whereby certain spaces were tagged with two different codes. There was also a lack of information updates on the system by the faculty personnel, including information on space function usage. Additionally, the status of certain spaces being left vacant was not updated in the systems or informed to the space manager at the Property Management Unit of the institution. Lack of information updates on room capacity, functionality, space user and space usage caused adverse effects on the utilisation rate. Unorganised information makes it difficult for institutions to see the effect of space management practices (Ibrahim, Zahari, *et al.*, 2011; Shahabudin *et al.*, 2012). Another integral part of the information is the space evaluation exercise, whereby constructive feedback feeds into future improvement. HEI 1 never conducted any space evaluation exercise but relies on the Helpdesk service where campus users can lodge complaints on this platform.

(c) Poor management of space

Poor management of space was recorded at both HEI 1 and HEI 2, which led to underutilised spaces. HEI 1 interviewees signified that this is due to an improper space utilisation audit being conducted at the institution. Space utilisation audits can determine underutilised or over-utilised spaces. The establishment of a space management committee across the campus was a major challenge due to its absence at HEI 1. This was believed due to the long process required to set up such an establishment. The role of the space management committee is important in ensuring conformity with space standards and regulations.

(d) Space wastage

HEI 1 interviewees believed that their spaces were not optimised to their full benefit, which subsequently caused **space wastage**. Space wastage is caused by spaces being underutilised, poorly managed, poorly measured and poorly designed (APPA, 2012; Ibrahim *et al.*, 2002). Interviewee B suggested that the spaces can be rented out during semester break to maximise the capacity and use but are hampered by a lack of manpower and the rising cost of wages for the manpower on duty - which led to inefficient space management at the faculty. Indirectly, this caused organisations to bear the high cost of operation and maintenance (Ibrahim *et al*., 2002; Ibrahim *et al*., 2012).

(e) Users' attitude

HEI 1 interviewees agreed that **users' attitudes** toward using space create space issues. This was due to a lack of awareness of the importance of effective space management. For example, users prefer to use bigger rooms despite the small capacity needed. Users also tend to not cancel their booking when not in use. This issue was identified through space usage audits where inconsistencies of data and information were spotted. Interviewee B mentioned that FBE studios are difficult to share with the public due to security issues and a high sense of ownership by the FBE students. The behaviour and mindset of space users hinder effective space management (Shahabudin *et al.*, 2012). For instance, mismatched room booking capacity, low student attendance, and personal teaching rooms despite the unsuitable capacity are among the attitude issues mentioned by Nao (1996). Lack of communication and perception of space management was common too.

(f) Lack of Budget

HEI 2 claimed their biggest challenge was the **lack of budget**. This was due to the non-existent of any online or computerised system at HEI 2 before the decision to adopt the government system recently launched at that time. Space management system requires high cost for the system development and maintenance; however, this shall deliver great benefits if invested and managed efficiently, as agreed by Interviewee C. Space is expensive for both operating and construction costs. For some of the campus facilities not located within the campus, costs could be different according to the type of facilities in which they were housed. This accords with Ibrahim et al. (2012) that space is expensive and the highest expenditure in an organisation.

(g) Insufficient staff

HEI 2 had **insufficient staff**, with only 6 staff under the Space and Building section to manage the campus spaces. These staff were also tasked with other job scopes on top of space management roles. The interviewees claimed that most of their tasks focused on registering the assets, facilities, and space information into the MySPATA system that will be used soon. Many HEI2 old buildings require building measurement exercises for CAD drawing purposes and require longer time and preparation, which hampers the speed of online system implementation. Interviewee C predicted that the MySPATA system shall benefit and assist them in managing the space better, albeit requiring a longer time for preparation.

(h) Unmatched Space Capacity

Interviewee D of HEI 2 claimed that they faced **unmatched space capacity** issues. The faculty must allocate students more than the optimum capacity of the studios and classrooms. For instance, the original capacity of a studio was 40 students but now occupies up to 45 students. This has caused dissatisfaction among the students and staff and indirectly affects their learning process and environment. There was no space extension or refurbishment project conducted at HEI2 due to budget constraints. Interviewee D further anticipated that this problem lies in the lack of information synchronisation between the space capacity, student intake, and enrollment process. Although space audits and space usage audits were conducted by HEI 2, it appears that there is a gap between the space audit and space management policies implemented. Lack of synchronisation between guidelines and actual space area may happen if users are not involved in these guidelines and policies in managing space (Ibrahim *et al*., 2011).

The increased number of student intake policies by the institution or HEI policies has caused space management difficulties. HEI 2 interviewees believed that an improved space audit exercise might solve this problem.

(i) Lack of Staff Competency

The **lack of competent staff involved in space management** was experienced by both institutions. Only a few staff at HEI2 were equipped with knowledge of drawing building plans and architectural software like AutoCAD at HEI 2. This has unfortunately slowed down the process of inserting data into the MySPATA system. The non-establishment of the space management committee at HEI 2 left the institution with no guidance on the competency standard. Similarly, the lack of competency among staff was also highlighted by HEI 1. Both institutions indicated a lack of space planning guidelines. The interviewees emphasised budget constraints - a vital barrier that hinders the initiative towards continuous competency enhancement training. Lack of relevant knowledge and no background in the space management field among the staff (Shahabudin *et al*., 2012) may result in adverse results for the management. Staff that are not well trained to use the newly implemented space management techniques are often found to find it hard to control, manage and adapt to the systems. Despite the availability of technology and tools in the market for space charging models and timetabling, space management problems due to the lack of expertise, training, and practice in using the techniques implemented. Table 4 compares the qualitative results obtained from both case studies on the space challenges faced.

Table 4: Space management challenges faced by case study buildings

HEI 1	HEI 2
Inefficient Centralisation	Lack of Budget
Poor Management of Space	Unmatched Space Capacity
Users' Attitude	Insufficient Staff
Lack of Staff Competency	Lack of Staff Competency
Space Wastage	
Unorganized information	

The identified challenges faced range from factors related to centralization, information, poor management of space, space wastage, users' attitude, budget, insufficient staff, space capacity and lack of staff competency. Different space management practices and complexities in different case studies led to different challenges. This caused space issues to be common in HEIs due to the ineffective management of space and the users' attitude toward space utilisation. These identified challenges can be considered as barriers and explain the reasons behind ineffective and inefficient space management. Hence, to achieve effective space management, the challenges faced must be mitigated following the recommendation of effective space management key factors.

Recommended Effective Space Management Key Factors

The study also approached the interviewees on their insights on the suggested effective space management key factors.

Interviewee A (HEI 1) highlighted that with effective space management in place, the space usage within the campus can be improved as space usage problems and space management issues can be identified and managed from early on. Proper and consistent space planning, execution, and monitoring help to reduce their operation and maintenance costs. Additionally, space can be an asset to generate income through space rental services. This is proven by both case studies in earning extra income through space rental. Effective space management increases users' satisfaction level towards space optimization. This study proposes the key factors or actions: leadership, information, communication, and practical tools.

(a) Leadership

For **HEI 2,** the Space and Building section under the Development Office and Asset Management (DOAM) is responsible for the campus' space management. Leaders are the executives in the management of institutions. Leaders or top management of any organisation play an important role in achieving effective space management. As institution leaders, they should understand that spaces should be adaptable to changes (Wexler and Oberlander, 2021). Leaders need to develop clear policies and standards, plan and manage space during the semester break, establish space committees, and hire competent staff.

Interviewee A (HEI 1) agrees that institutional policies and a space management committee need to be established to achieve effective space management. A clear policy of space management developed by the institution will ease the management of space

effectively as it provides guidelines for the technical staff to manage space according to the guidelines. Clear policies and standards are essential to ensure all staff involved understand and adhere to them accordingly. Staff involved should have relevant knowledge and need to be well-trained to use the space management software and tools and this should be monitored by leaders. Leaders are also responsible for working towards the formation of a space management committee. The roles of the space management committee include developing and reviewing space management strategy, developing clear guidelines for space usage and function determination, monitoring space use and regulating evaluation exercises to gather user feedback.

(b) Information

A good database on space should include information like room size, types, location, unique identifier, primary user, facilities, capacity and all this information must be updated regularly. Current practices of the space management system must always be reviewed and evaluated regularly. Information like this is vital in assisting organisations to identify problems towards better management of space. **Interviewee A (HEI 1)** emphasises that space data like coding, function, and usage status must be updated regularly in the computerised inventory system. Any space issues identified by the on-site personnel must be reported and updated by the management. Integration of space information is integral to ensuring the smooth management of spaces and ease of the operation and maintenance process (Wen et al., 2021).

The interviewee suggested that the management shall do a yearly space audit to identify under-utilised spaces. Space utilisation surveys should be conducted regularly to collect and gather space usage information. This helps to identify space utilisation problems such as underutilised or overused space and eventually, solutions can be identified to improve them. Space functionality assessment should be carried out to identify the designation of appropriate space according to the intended functions. The space function must match its design for optimisation. Hence, space information must always be reviewed and updated consistently for effective space management. A space management committee should be established in any organisation to effectively manage the space. The roles of the space management committee include developing and reviewing space management strategy, developing clear guidelines for the users to use space appropriately, monitoring space use and getting feedback from users on their perspective and satisfaction as well as assessing space needs for current and future purposes.

(c) Communication

Communication meant communication among space management staff and communication among staff and users. Effective communication and cooperation among the space management staff are vital as miscommunication tends to lead to unnecessary spending due to poor management of space. This was highlighted by **Interviewee A from HEI 2**, whereby the institution management must give a clear command of the management of space to all the technical staff involved to maintain consistency. As mentioned earlier, centralisation is important, and it is one of the main challenges faced in space management **for HEI 1**. Therefore, communication is key to ensuring the centralisation of information and commands among the task forces.

Effective communication of space management policies to users is important to provide a clear understanding of spaces among the occupants. The management staff are responsible for conveying space rules and regulations to users. This is reflected in both case studies, whereby at **HEI 1**, clear rules and regulations were displayed in every academic space to inform users of proper space usage procedures. At **HEI 2**, clear instructions on the space booking procedures were disseminated to users accordingly. With clear instructions and communication, users shall have no issue proceeding with space bookings or cancellation procedures. Effective communication encourages a positive user mindset and awareness of space usage.

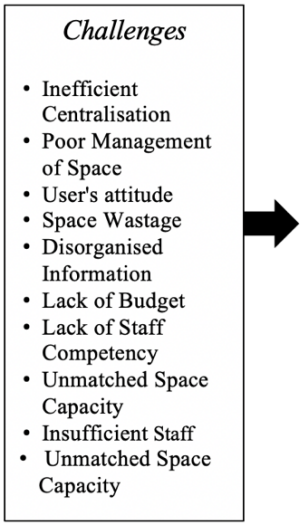
(d) Practical tools

Tools, just like other innovations or technology, are important in managing space. Tools assist the processes to collect, gather, update and track data relevant to space. Tools in the form of online systems and software can process and automate data for better decision-making. The comparison between both case studies highlighted the gap in data streamlining due to the lack of tools practised by HEI 2 compared with HEI 1. Tool also enables better space coordination and therefore eases the space charging arrangement. Space charging is a budgetary mechanism where space charge is levied on departments based on the amount of space being occupied (NAO, 1996). Space charging can be considered an effective tool, whereby space usage and the costs imposed can be calculated accordingly.

The need for having online or digital tools is reflected in the complexity of synchronising schedules from various departments or units. The tool operates the timetables and gathers data and feedback from users including complaints. It also helps to ensure the consistency and systematicity of space management within an institution or organisation. On the other

hand, computerised timetabling helps the administration to cope with the increased complexity of the students' course structures and academic programmes. Subsequently, having a practical tool surely eases the management of space for teaching and learning activities.

The summary of recommendations on actions and effective space management key factors responding to challenges is shown in Figure 1.



Effective Space Management Key Factors	Actions
Leadership	• Clear command from the management • Establishment of space management committee/ space management centre • Establish clear space management policies and guidelines • Involvement of competent staff and relevant units • Propose a skill enhancement training plans for the staff • Elevate the staff competency and performance • Devise budget planning and monitoring • To process budget allocation based on results/findings • Clear designation of job scopes and tasks
Communication	• Effective communication with users by explaining their obligations in using the space • Raise awareness of the importance of space management • Improve communication between space management staff and between staff and users • Communicate clear guidelines and booking procedures to avoid issues
Practical Tools	• Identify the tool needed for the space & facilities booking system to solve the issue of lack of staff or resource constraint • Implement tools to ease the management of spaces and rental coordination • Regular exercise of space utilisation and space audit to evaluate space status and support budget allocation • Improve space audit exercises to focus on the readiness for the implementation of the new digital/ online system
Information	• Consistent information updates to the system towards a comprehensive and up-to-date database. • Establish an information delivery process flow to the relevant management unit • Integration of information from various parties and platforms • Synchronisation of space information and space audit feedback with the policies related to space planning and student intake • Develop a manual space inventory system to enable smooth information management

Figure 1: Summary of key actions responding to space management challenges faced by HEIs

The feedback from these respondents is important in helping this study establish the appropriate actions that can be implemented to mitigate issues and problems related to space management. Most importantly, if taken proactively, these suggested actions can further elevate the facilities' performance of HEIs.

Conclusion

The growing need for effective space management can be fulfilled by organisations through proper planning and monitoring of space. Effective space management is determined by how the institution manages the space through space utilisation. This study highlighted the major challenges faced in HEIs namely inefficient centralisation, poor management of space, user attitude, space wastage, disorganised information, lack of budget, lack of staff competency, unmatched space capacity and insufficient staff. Since every space is different and valuable, the HEIs need to identify the best practice of space management according to the four key factors of effective space management, namely Leadership, Communication, Practical Tools, and Information.

The study outcomes revealed that space management is complex and consistently deals with an abundance of information. Hence, it requires extensive and comprehensive planning to be done systematically. Therefore, proactive **coordination and management of all parties** from the top management to the end users are vital for improvement.

Every HEI has its own distinct spaces and space usage requirements. Any HEI must identify the current and future space needs through proper planning and management towards establishing its space management policies and guidelines according to its space complexity and uniqueness. **Space management policies** are vital to serving as guidelines in managing space as well as addressing users' space needs.

To achieve effective space management, **space inventory management with an updated database** is of utmost importance. Accurate and updated space information of space leads to efficient planning and allocation of space and thus, improves the utilisation of space within the institutions. Without systematic space inventory management, difficulties in tracking the physical space may hamper the forecasting of the projected annual capital budget. In short, an accurate and updated database together with a systematic space inventory management is an effective space planning and management approach.

Working towards effective space management, **space evaluation and space utilisation audit** conduct must be on a more frequent basis so that the management is aware of their performance. **Effective communication** between management staff, as well as between staff and end users is crucial to prevent any misunderstanding of space needs, which

causes poor management of space. The available space owned by the institutions must be effectively managed to improve the utilisation of space and ensure cost effectiveness, especially for operational and maintenance costs.

The study delivers impactful implications for the built environment and FM, two major sectors enabling the effective function of the built facilities. This study also proposes future studies that explore a wider sampling involving both private and public HEIs in Malaysia to draw a comparison of the space management practice and the challenges faced. Future research can also investigate the human behaviour aspect in space usage to explore its influence on users' attitudes or explore different HEIs' space settings.

References

Abdullah, S., Ali, H.M., Sipan, I., Awang, M., Rahman, M.S.A., Shika, S.A. and Jibril, J.D. (2012), "Classroom Management: Measuring Space Usage", Procedia - Social and Behavioral Sciences, The Authors, Vol. 65 No. ICIBSoS, pp. 931–936.

Abdullah, S., Ali, H.M., Sipan, I. and Deakin, M. (2013), "Space Management: Measuring Teaching and Learning Space Performance", Vol. 8 No. 2.

Ali, A.S., Chua, S.J.L. and Lim, M.E.L. (2019), "Physical environment comfort towards Malaysian universities office employers' performance and productivity", Facilities, Vol. 37 No. 11/12, pp. 686-703. https://doi.org/10.1108/F-06-2016-0060.

APPA. (2012), Campus Space An Asset and a Burden. Available at: https://www.appa.org/wp-content/uploads/2019/06/APPA-2012-Thought-Leaders-FINAL.pdf

Apuke, O. D. (2017). Quantitative research methods: A synopsis approach. Kuwait Chapter of Arabian Journal of Business and Management Review, 33(5471), 1-8.

Asiyai, R. I., "Assessing School Facilities in Public Secondary Schools in Delta State, Nigeria," An International Multidisciplinary Journal, Ethiopia, Vol. 6 (2), serial no. 25, pp. 195-205 (2012).

Aziz, A.A., Hashim, A.E. and Baharum, Z.A. (2013), “Space Inventory Management in the Malaysian Public Universities”, Procedia - Social and Behavioral Sciences, Elsevier B.V., Vol. 85, pp. 246–257.

Boys, J. (2014). Building better universities: Strategies, spaces, technologies. Routledge.

Brinkoe, R. and Nielsen, S.B. (2018), "Multiplying the use of space and what it implies in practice: a cross-case analysis", Journal of Facilities Management, Vol. 16 No. 2, pp. 197-216. https://doi.org/10.1108/JFM-09-2017-0045

Canfield, T. and Graff, C. (2015), “The Dilemma of Aging Facilities : Strategies for Future-Proofing a Higher Education Campus”, Schneider Electric White Paper.

Chua, S.J.L., Myeda, N.E. and Teo, Y.X. (2022), "Facilities management: towards flexible work arrangement (FWA) implementation during Covid-19", Journal of Facilities Management, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JFM-09-2021-0101

DeFranzo, S. E. (2011). What’s the difference between qualitative and quantitative research? Retrieved February 21, 2018, from https://www.snapsurveys.com/blog/qualitative-vs-quantitative-research/Fadahunsi, J. O., Utom, J. A., Ochim, M. R., Ayedun, C. A., & Oloke, O. C. (2019, November). Benefits of the adoption of facilities management practices in tertiary institutions: a case study of covenant university. In IOP Conference Series: Materials Science and Engineering (Vol. 640, No. 1, p. 012032). IOP Publishing.

Goodyear, P. (2020). Design and co-configuration for hybrid learning: Theorising the practices of learning space design. British Journal of Educational Technology, 51(4), 1045-1060.

Hassanain, M.A., Iftikhar, A., Al-Hammad, A.-M., Alshibani, A., Ibrahim, A.M. and Abdallah, A. (2021), "POE of public higher education facilities in Saudi Arabia: lessons learned from three case studies", Property Management, Vol. 39 No. 2, pp. 250-276. https://doi.org/10.1108/PM-06-2020-0037

Hassanain, M.A., Alhaji Mohammed, M. and Cetin, M. (2012), "A multi-phase systematic framework for performance appraisal of architectural design studio facilities", Facilities, Vol. 30 No. 7/8, pp. 324-342. https://doi.org/10.1108/02632771211220112

Ibrahim, I., Zahari, W., Yusoff, W. and Bilal, K. (2002), “Responds to the Space Management Level in Higher Education Institutions”, Vol. 6, pp. 253–257.

Ibrahim, I., Yusoff, W.Z.W. and Bilal, K. (2012), “Space Management: A Study on Space Usage Level in Higher Education Institutions”, Procedia - Social and Behavioral Sciences, Elsevier B.V., Vol. 47, pp. 1880–1887.

Ibrahim, I., Yusoff, W.Z.W. and Sidi, N.S.S. (2011), “Space charging model: Cost analysis on classrooms in higher education institutions”, Procedia - Social and Behavioral Sciences, Elsevier B.V., Vol. 28, pp. 246–252.

Ibrahim, I., Zahari, W., Yusoff, W. and Bilal, K. (2012), “Space Charging Model : As an Effective Space Management Tool in Higher Education Institutions”, Advances in Management & Applied Economics, Vol. 2 No. 3, pp. 163–179.

Ibrahim, I., Zahari, W., Yusoff, W., Sharipah, N. and Sidi, S. (2011), “A Comparative Study on Elements of Space Management in Facilities Management at Higher Education Institutions”, International Conference on Sociality and Economics Development, Vol. 10, pp. 74–78.

Ilgın, H. E. (2023). A study on space efficiency in contemporary supertall mixed-use buildings. Journal of Building Engineering, 69, 106223.

IWFM (2022), Space planning and management. Available at: https://www.iwfm.org.uk/resource/space-planning-and-management.html

Jayantha, W.M. and Oladinrin, O.T. (2020), "Knowledge mapping of office workspace: a scientometric review of studies", Facilities, Vol. 38 No. 3/4, pp. 316-345. https://doi.org/10.1108/F-07-2018-0086Li, L., Yuan, J., Roper, K. and Zhou, Z. (2017), “A Multi-Stakeholder Delphi Study to Determine Key Space Management

Components for Elderly Facilities in China", Sustainability, Vol. 9 No. 9, p. 1565.

Kamal, S.M. (2017) How budget cuts affect public universities. Available at: https://www.malaymail.com/news/malaysia/2017/01/11/how-budget-cuts-affect-public-universities/1290061.

Liu S, Sun H, Zhuang J, Xiong R. (2023), The Impact of E-Learning Technologies on Entrepreneurial and Sustainability Performance. Sustainability.15(21):15660. https://doi.org/10.3390/su152115660

Mazlan, R. M. R. and Mohammed, A. H. (2015), Facilities Management Relevant Competencies for Malaysian Public School. Jurnal Teknologi. 74(2): 73-78.

Myeda, N.E. (2014) "Facilities management: the business enabler", Journal of Facilities Management, Vol. 12 Iss: 4 (SCOPUS)Micromain. (2017), "What is space management".

Myeda, N.E. and Pitt, M. (2014). Facilities management in Malaysia: understanding the development and practice", Facilities, Vol. 32 Iss: 9/10

Myeda, N.E., and Mohd-Zambli, N.A. (2018), Assessment of Building Maintenance Management in Public Boarding Schools, Journal of Building Performance, Vol 9 (2).

National Audit Officer (NAO). (1996), Space Management in Higher Education: A Good Practice Guide.

Pollard, B., Engelen, L., Held, F., & de Dear, R. (2022). Activity space, office space: Measuring the spatial movement of office workers. Applied Ergonomics, 98, 103600.

Quinnell, K. (2020), "Building a Better Space: Using Affordances to Build Better Locations of Study", Sengupta, E., Blessinger, P. and Cox, M.D. (Ed.) Designing Effective Library Learning Spaces in Higher Education (Innovations in Higher Education Teaching and Learning, Vol. 29), Emerald Publishing Limited, Bingley, pp. 167-190. https://doi.org/10.1108/S2055-364120200000029011.

Ramli, A., Zain, R. M., Campus, C., Chepa, P., & Bharu, K. (2018). The impact of facilities on students' academic achievement. Sci. Int. (Lahore), 30(2), 299-311.

Shahabudin, A., Hishamuddin Mohd, A. and Ibrahim, S. (2012), “Benchmarking Space Usage in Higher Education Institutes: Attaining Efficient Use”, Journal of Techno-Social, Vol. 4 No. 1, pp. 11–20.

Space Management Group. (2006), “UK Higher Education Space Management Project Space management project: Summary”, No. September 2006. Available at: http://www.smg.ac.uk/documents/summary.pdf

Taylor, C., & Gibbs, G. R. (2010). What is Qualitative Data Analysis (QDA)? Retrieved April 14, 2018, from http://onlineqda.hud.ac.uk/Intro_QDA/what_is_qda.php

TEFMA. (2009), “Space Planning Guidelines”, pp. 1–60.

UNSW Australia. (2016), “UNSW Space Standards”, No. May, pp. 1–23.

Wen, Y., Tang, L.C.M. and Ho, D.C.W. (2021), "A BIM-based space-oriented solution for hospital facilities management", Facilities, Vol. 39 No. 11/12, pp. 689-702. https://doi.org/10.1108/F-10-2019-0105

Wexler, M.N. and Oberlander, J. (2021), "COVID-19 as a super crisis: implications for place management", Journal of Place Management and Development, Vol. 14 No. 4, pp. 481-496. https://doi.org/10.1108/JPMD-09-2020-0093

Yu-Tian, T., Weng-Wai, C. and Hj. Ninggal, M. T. (2015). Healthcare Facilities Settings: An Overview of Environmentally-induced Stress on Health. Jurnal Teknologi. 74(2): 93-99.

TAHFIZ SCHOOLS' FACILITIES AND RELATIONSHIP TO MALAYSIA'S LEARNING ENVIRONMENT: A SYSTEMATIC LITERATURE REVIEW

Nor Amin Mohd Radzuan, Mohd Asrul Hassin, Suriani Ngah Abdul Wahab, Irwan Mohammad Ali & Wan Samsul Zamani Wan Hamdan.

Abstract

The school administration, private sector, and Malaysian government are continually looking for approaches to improve Tahfiz facilities (TF). Tahfiz schools are now part of Malaysia's education system. The government makes numerous efforts and initiatives to improve Tahfiz school facilities and academic accomplishments. Therefore, the value of school facilities in influencing students' tahfiz experiences cannot be denied. It delves into the various aspects of school facilities, such as academic facilities, fire safety measures, hostel accommodations, solar energy integration, and the Internet of Things (IoT). This paper reviews how these elements collectively contribute to the creation of an environment that fosters academic achievement, safety, and sustainability. It covers the literature published on SCOPUS between 2017 and 2023 and analyses the current state of knowledge about TF and the learning environment. The reviews used Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). It deals with data identification, evaluation, exclusion, and inclusion studies that have focused on TF and the learning environment. The findings also demonstrate the relationship between the identified TF and a conducive learning environment.

Keywords

Tahfiz school, Tahfiz facilities, Learning environment, Maintenance performance

Introduction

Over the years, Tahfiz schools in Malaysia have developed and changed significantly. These institutions, which primarily teach and emphasise memorising of the Quran, have evolved in line with broader shifts in the nation's educational system, society, and religious environment. Malaysia has a long history of tahfiz schools, many of which have their origins in the Islamic practice of memorising the Quran (Mohd Nawi et al., 2021). These institutions were often informal settings, frequently associated with mosques or other religious institutions, where students would study the Quran under the direction of qualified instructors in order to

memorise and recite it. There was a desire to formalise religious education as Malaysia's educational system evolved. To enhance infrastructure, develop curriculum, and train teachers, the Malaysian government and private organisations began funding Tahfiz schools. This assistance is intended to raise the level of education. In addition to emphasising Quran memorising in contemporary Tahfiz schools, character development, ethical principles, and the practical implementation of Islamic teachings are also emphasised (Yusop et al., 2020). This prompted the creation of officially recognised Tahfiz schools that could offer both religious instruction and a fundamental secular curriculum (Rafizan Jamil et al., 2023; Yusak et al., 2022). This change sought to balance religious and general education. The government eventually realised the value of this education and its contribution to the development of Muslims who are knowledgeable in Islamic principles. Tahfiz school started to be included in the formal educational system, enabling students to obtain both religious and secular education in the same setting.

Outside of the religious community, Tahfiz schools have gained popularity. They are seen as organisations that aid in the moral and spiritual growth of students, and they frequently take part in community involvement and charitable work. This broader strategy seeks to generate people who are not only knowledgeable about the Quran but also actively participate in society. The expansion of these educational institutions in Malaysia represents a dynamic process of adaptation and growth where traditional ideals meet contemporary educational needs. This evolution is still influencing how this education is delivered and incorporated into Malaysia's educational system.

Problem Statement

This study addresses the issue of inadequate facilities faced by Tahfiz schools. This circumstance will result in Tahfiz students pursuing their studies in an environment that needs more suitable conditions. The present situation can be pointed out to many privately operated Tahfiz schools that face significant financial constraints. The presence of incomplete facilities and inadequate maintenance contributes to a suboptimal learning environment for students and teachers. This study attempts to clarify the relationship between Tahfiz facilities (TF) and establishing a conducive learning environment.

Research Aim and Objectives

The purpose of this research is to review the material published on SCOPUS between 2017 to 2023 and summarise current knowledge on TF and the conducive learning environment. It introduces PRISMA, a proposed reporting item for systematic reviews and meta-analyses that focuses on data identification, evaluation, exclusion, and inclusion. Based on these reviews, it concentrates primarily on TF characteristics relevant to a conducive learning environment. The study begins with a brief description of the key terms ('Tahfiz school', 'Tahfiz facilities', 'Learning environment' and 'Maintenance performance'), followed by an explanation of the methods that were used. The systematic exploratory review's findings are then reported and discussed. Some suggestions for future research are provided.

School Facilities

School facilities (SF) play a crucial role in academic achievement. Many studies have discovered that well-maintained facilities support students' educational success. As stated by Abbadi et al., (2020) and Cindy et al., (2022) a well-maintained and aesthetically pleasing physical environment can positively influence students' attitudes toward learning. SF is increasingly important when it creates a sense of pride and belonging, which can motivate students to perform better academically. In their major study by Rivera & Lopez, (2019) and R. Zain, (2019), safe and secure facilities are fundamental for academic achievement. The above will improve confidence levels among the students and teachers. Therefore, proper maintenance ensures that potential safety hazards are addressed promptly, reducing the risk of accidents and disruptions that could interfere with learning. In school, providing comfortable and well-maintained classrooms is an ideal setting for focused learning. Adequate lighting, temperature control, and ergonomic seating contribute to an environment where students can concentrate on their studies. In another study by Ruhyana & Aeni (2019), the facilities attached to schools not only must be sufficient and well maintained but also clean and promote good hygiene practices, reducing the spread of illnesses that can lead to absenteeism. Healthy students are more likely to attend classes regularly and perform well academically. To make the atmosphere more efficient and harmonious, Tahfiz school also needs to be in line with today's digital age, access to technology is essential for academic success. SF is not just limited to the physical features of buildings but also the application of technology, such as computer labs and high-speed internet, which are vital for research and online learning. To further improve students' academic abilities and achievements, schools also provide resource centres to ensure that students have access to a wealth of educational materials. These facilities are crucial for students and eventually contribute to academic achievement.

According to Okoro et al., (2021), the condition of school facilities can influence the perception of the school in the community. A well-maintained school is more likely to attract community support, which can lead to additional resources and opportunities for students. In another research by Le et al., (2021), facilities with sustainable and energy-efficient features not only reduce operating costs but also provide opportunities for educational initiatives focused on environmental responsibility. Students can learn about sustainability through the school's physical environment. Proper maintenance and thoughtful design create an environment that supports students' physical, emotional, and educational needs, ultimately contributing to their success in school. In summary, school facilities have a profound impact on academic achievement.

Maintenance Performance

Maintenance performance (MP) is crucial for schools as it affects the learning environment, safety, and well-being of students and staff. According to Martín et al., (2021), Maintenance Performance (MP) is a comprehensive approach that encompasses several disciplines to assess and validate the value generated through maintenance investments and the fulfilment of stakeholders' needs inside an organisation. This perspective is strategically aligned with the overall organisation's objectives. Proper maintenance standards in educational institutions go beyond just facility upkeep, as they can greatly influence academic achievements, student satisfaction, and the reputation of the school. Providing a well-maintained school environment is essential for the physical and mental health of both students and staff. Maintenance is crucial to ensuring everyone's well-being and safety. Routine inspections and maintenance procedures for infrastructure, equipment, and facilities are proactive measures to prevent accidents, injuries, and health hazards (Zain, 2019).

It has been proven that regular maintenance practices greatly extend the lifespan of school buildings, equipment, and assets. If maintenance is not made a priority, malfunctions and premature degradation can occur, resulting in costly repairs over time. In Malaysia, schools are required to follow safety, accessibility, and health regulations and standards. Consistent maintenance is essential for ensuring that schools comply with these laws and avoid legal and regulatory issues. Educational institutions can improve their resource allocation and efficiency by implementing a budgeting system for maintenance, as well as promptly addressing any issues that arise. By taking preventive maintenance measures, the likelihood of unexpected expenses and urgent repairs can be reduced. Taat et al., (2021) found that, when the environment is clean, organised, and sufficiently equipped, educators tend to be more motivated and effective in their work. This allows them to focus on their instructional

responsibilities rather than being weighed down by ongoing maintenance tasks. Effective maintenance practices can help educational institutions overcome obstacles and minimise disruptions to the educational experience.

Maintaining a school with great care and attention can improve the overall image and reputation of the establishment. The strong commitment by the stakeholders to maintaining their SF and providing an exceptional learning environment will likely instil confidence among the community. Creating a conducive learning environment is crucial for effective teaching and learning processes(Ramzan et al., 2023; Shahlo Sayfulloevna, 2023). Proper maintenance of classrooms, libraries, labs, and other educational spaces is necessary to ensure that students have access to resources that support their academic growth. A school that prioritises maintenance shows its dedication to providing an excellent educational experience for its students.

Methods

A preferred reporting item for systematic reviews and meta-analyses (PRISMA) was performed using a methodology extensively used in the health and social sciences (Page et al., 2021). The identification of resources was initiated by searching the literature via the Scopus database published between 2017-2023 (figure 1). The combination of terms was used to explore the research in accordance with “Tahfiz school” keywords. Each article has been examined for information on the TF component and learning environment. By systematically searching the relevant literature, such reviews deliver identification, evaluation, exclusion, and inclusion of the current status of a field of research.

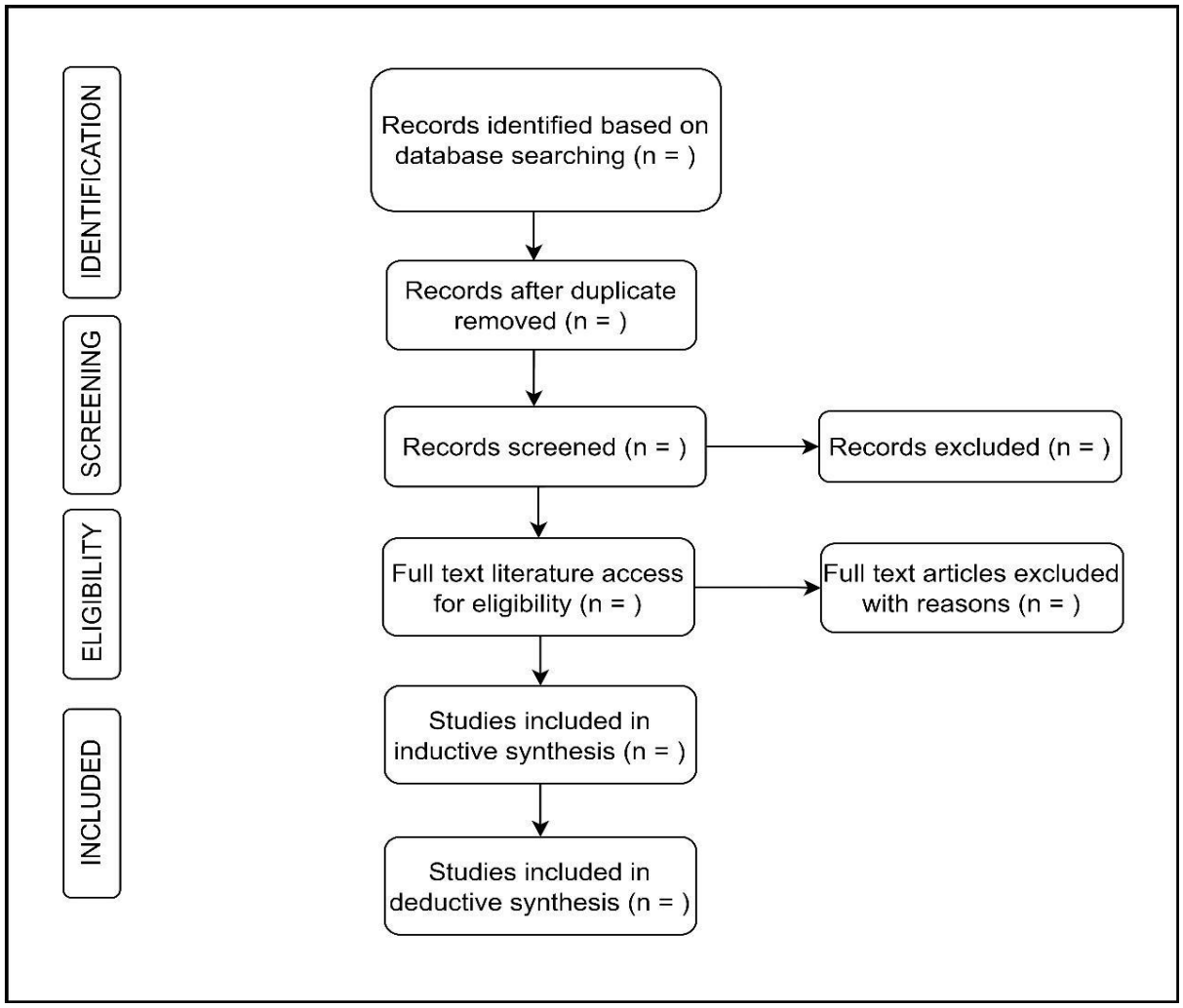


Figure 1: PRISMA Flow Chart (Page et al., 2021).

Results

Six (6) Scopus articles were examined in the study. Figure 2 summarises the research selection procedure, whereas Figure 3 shows the Scopus database query string in greater detail. A literature search using Scopus databases and search engines yielded 19 publications between 20017 and 2023. The following is a 5-year review of a recent publication. Despite mentioning the phrases "Tahfiz" and "School" in their titles, abstracts, and keywords, 13 articles were deleted since they were not in the subject of facilities and learning environment. One article (School design), ten articles (pedagogy and instruction), one article (social), and one article (Islamic financing) make up the proportion of the thirteen deleted articles. Six articles from five publications remained to be analysed with PRISMA.

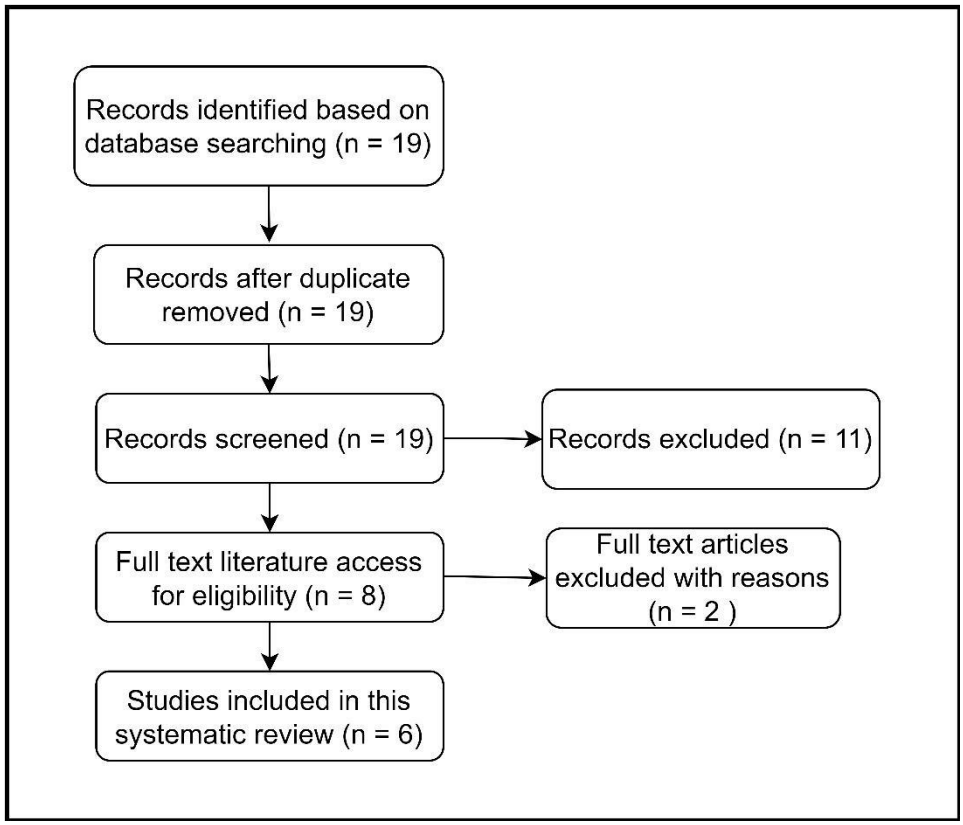


Figure 2: The study selection approach is depicted in the Flow Chart (Page et al., 2021).

The Scopus database query string shown in Figure 3, identified 19 publications from 2017 to 2023 with the title, abstract, and keywords Tahfiz and School. It covers the most recent 5 years of publication to get TF related publication trends.

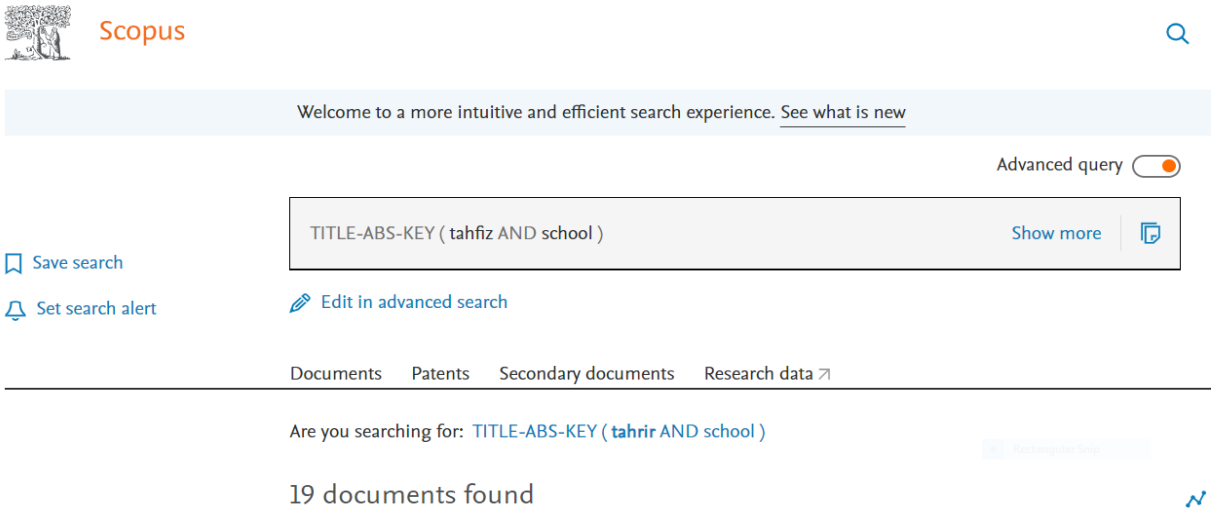


Figure 3. Scopus Database Query String.

Study Characteristics

Table 1 lists the study characteristics included in the review.

Table 1. The articles' characteristics of the included reviews

Paper	Author	Year	Subject	Tahfiz Facilities (TF) in relation to the Learning Environment
1	(Haron et al., 2021)	2021	Examining the teachers' pedagogical knowledge and learning facilities towards teaching quality	TF component: School Resource Center, Teaching aids and Classroom
2	(Taat et al., 2021)	2021	The influence of curriculum and school climate on the academic attitude of tahfiz students in Malaysia	TF component: Learning facilities, Teaching aids and Classroom
3	(Pazikadin et al., 2021)	2021	IoT-Based Solar Photovoltaic (PV) Real Time Monitoring System for Power Consumption on Maahad Tahfiz School	TF component: Solar monitoring system
4	(Haron et al., 2020)	2020	School"s Facilities and Achievement of Students in Ulul Albab Model Tahfiz Schools in Malaysia: A Mediating Roles of Satisfaction	TF component: School Resource Center, Teaching aids and Classroom
5	(Mamat et al., 2019)	2019	Modelling decision support system for selection Maahad Tahfiz Center using analytical hierarchical analysis	TF component: Hostel, Fire safety, Sport, and Academic facilities
6	(Ismail et al., 2019)	2019	Retaining quranic memorisation for huffaz at the Malaysian tertiary institutions: Key challenges and future IoT potentialities	TF component: IoT system

Tahfiz Facilities (Tf) Component

All (n=6) of the studies explored the required facilities to be provided to improve the learning environment at Tahfiz schools. Three studies by (Haron et al., 2021), (Taat et al., 2021), and (Haron et al., 2020) did the study concerning facilities related to the school resource centre, teaching aids and classrooms to be provided in Tahfiz School. The above-mentioned facilities are strictly important to ensure a conducive learning environment for the school. In addition, a study by Mamat et al., (2019), further mentioned that the learning environment at Tahfiz School can be improved by providing a conducive and safe living related to hostel, fire safety, sports, and academic facilities. The issue of safety for Tahfiz school is currently in the limelight of the Ministry of Education (MOE) where many issues such as school flaming contribute to fatal accidents. In contrast, a study led by Ismail et al., (2019) focused on using the Internet of Things (IoT) as a facility to support the learning environment that eventually improves student achievement. In order to achieve the environmental sustainability of the Tahfiz school, Pazikadin et al., (2021) proposed to utilise facilities with solar energy and reduce dependence on electricity. The identified TF component will be analysed further in order to determine a relationship with the school learning environment.

Summary Of The Main Results

This systematic review identified 6 studies to provide current evidence for TF that relate to the conducive and sustainable learning environment. Three (50%) studies focused on school resource centres, teaching aids, and classrooms. White remaining three studies (50%) concerned hostels, fire safety, sports facilities, IoT and the application of solar energy. These explained that the Tahfiz school is urgently required to be improvised and be at the same level as the national school in Malaysia.

Discussion

For a school to operate effectively and provide a conducive learning environment, it must have facilities in all areas, including classrooms, teaching aids, resource centres, sports facilities, fire safety facilities, Internet of Things (IoT) facilities, and solar energy installations. Students are psychologically and physically prepared for learning when they have a secure and comfortable place to recharge and replenish in a hostel. Students can concentrate on lessons and participate in the learning process more effectively in inadequately maintained, well-equipped, and comfortable classrooms. In addition, teaching tools such as projectors and interactive whiteboards allow instructors to provide engaging and instructive lessons that

enhance student learning and enjoyment. The provision of resource centres or libraries, which provide students with a tranquil, well-equipped environment for independent inquiry and study, enhances students' learning. Students need sports facilities alongside classroom education because they foster teamwork, physical health, and character development, all of which are critical to students' well-being. In an effort to improve the learning environment, regular maintenance, which reduces the risk of fire-related incidents, a safe environment is created for academic and hostel buildings.

To assure the development of school facilities is consistent with IR 4.0, the application of IoT technology can be improved in energy management, security, and maintenance practices. In turn, this creates a safer and more cost-effective learning environment. In order to substantiate the aforementioned claim, the implementation of solar energy systems should be considered as a viable solution to mitigate the school's energy usage and reduce its carbon footprint. When all of these elements are maintained, children are able to concentrate better, participate more actively in class, and feel safe, which fosters a positive learning environment. In conclusion, to ensure the safety and well-being of students, a well-maintained learning environment enhances their educational opportunities, thereby enhancing their academic performance and personal development. Additionally, the relationship between the TF and a conducive learning environment will be discussed. The characteristics of TF are summarised based on the six (6) publications identified by PRISMA analysis, as shown in Figure 4.

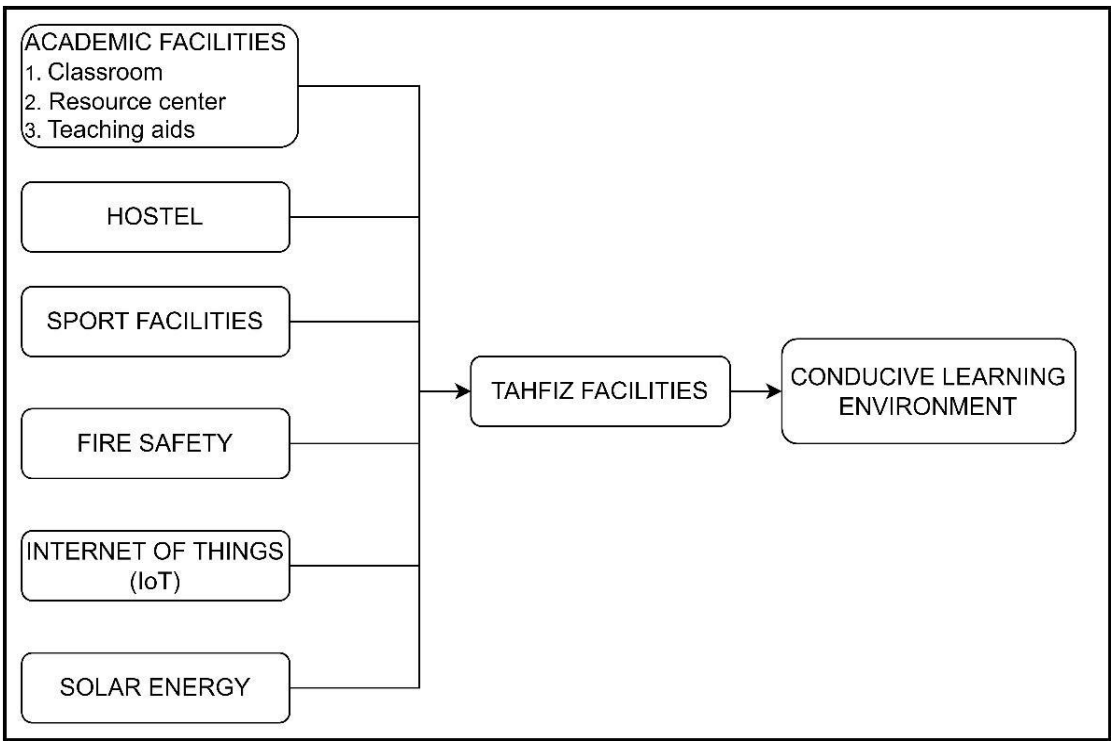


Figure 4. The Tahfiz facilities (TF) and relationship with a conducive learning environment

Strength Of The Review

The fact that this study is the most recent systematic review to present evidence regarding the Tahfiz facilities and the learning environment. It concludes the most recent 5 years of related publications. This review performed a comprehensive search from the Scopus database which is the largest and most reputable academic literature.

Limitation Of The Review

The current review has two limitations. First, as the concept of TF and learning environment is well established, this review should acknowledge the significant possibility of other studies published in other languages. This review may have missed potentially relevant literature. Second, due to the small number of articles included because the time frame is between 2017 to 2023, this review only considered recently published Scopus-indexed papers for the past 5 years.

Conclusion

In this review, we summarised the TF and their relationship to a conducive learning environment. The variables provided for TF in the research were included in our analysis. However, research on the subject is still extremely limited. As a result, additional in-depth investigations are required, particularly in TF and their relationship with the learning environment. The emerging research on TF will be significant in assisting the government's effort to enhance the establishment of Tahfiz schools in Malaysia. For future studies, TF can also include security aspects that are often an issue for Tahfiz schools, students, and stakeholder groups.

References

Abbadi, J., Mustanir, A., Jermsittiparsert, K., & Dawabsheh, M. (2020). School Facilities as a Potential Predictor of Engineering Education Quality: Mediating Role of Teaching Proficiency and Professional Development. *TEST Engineering & Management*, *82*, 3511–3521.

Cindy, A. H., Sugiyono, S., Usman, H., & Herwin, H. (2022). Factors that affect the optimisation of vocational high school facilities and infrastructure. *Cypriot Journal of Educational Sciences*, *17*(2), 586–600. https://doi.org/10.18844/CJES.V17I2.6847

Haron, M. Z., Zalli, M. M. M., Othman, M. K., & Awang, M. I. (2021). Examining the teachers' pedagogical knowledge and learning facilities towards teaching quality. *International Journal of Evaluation and Research in Education*, *10*(1), 1–7. https://doi.org/10.11591/ijere.v10i1.20780

Ismail, F. Z., Yusof, N. H., Osman, A. F. A., Embong, R., Abdelgelil, M. F. M., & Omar, N. (2019). Retaining quranic memorisation for huffaz at the malaysian tertiary institutions: Key challenges and future iot potentialities. *Proceedings - 2019 International Conference on Future Internet of Things and Cloud Workshops, FiCloudW 2019*, 26–30. https://doi.org/10.1109/FiCloudW.2019.00018

Le, A. T. H., Park, K. S., Domingo, N., Rasheed, E., & Mithraratne, N. (2021). Sustainable refurbishment for school buildings: a literature review. In *International Journal of Building Pathology and Adaptation* (Vol. 39, Issue 1, pp. 5–19). Emerald Group Holdings Ltd. https://doi.org/10.1108/IJBPA-01-2018-0009

Mamat, A. R., Mohamed, M. A., Azhar, A. F., Saany, S. I. A., Rawi, N. A., Amin, M. M., Kadir, M. F. A., & Nor, M. A. M. (2019). Modelling decision support system for selection maahad tafiz center using analytical hierarchal analysis. *Indonesian Journal of Electrical Engineering and Computer Science*, *13*(1), 35–40. https://doi.org/10.11591/ijeecs.v13.i1.pp35-40

Martín, M. G., Álvarez, A. P., Ordieres-Meré, J., Villalba-Díez, J., & Morales-Alonso, G. (2021). New business models from prescriptive maintenance strategies aligned with sustainable development goals. *Sustainability (Switzerland)*, *13*(1), 1–26. https://doi.org/10.3390/su13010216

Mohd Nawi, M. Z., Omar, M. R., & Mohd Nor, M. A. (2021). Sistem Pendidikan Tahfiz Di Malaysia, Pilihan Ibu Bapa Dan Warisan Pendidikan Islam Andalus: Satu Sorotan. *Asian People Journal (APJ)*, *4*(1), 132–147. https://doi.org/10.37231/apj.2021.4.1.241

Okoro, C. S., Nkambule, M., & Kruger, A. (2021). The state of restroom facilities as a measure of cleaning service quality in an educational institution. *Journal of Corporate Real Estate*, *23*(1), 55–68. https://doi.org/10.1108/JCRE-01-2020-0005

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Journal of Clinical Epidemiology*, *134*, 178–189. https://doi.org/10.1016/j.jclinepi.2021.03.001

Pazikadin, A. R., Ali, K., Rifai, D., Awang, N. A., Ghoni, R., & Mamat, N. H. (2021). IoT-Based Solar Photovoltaic (PV) Real Time Monitoring System for Power Consumption on Maahad Tahfiz School. *Lecture Notes in Electrical Engineering*, *746 LNEE*, 281–294. https://doi.org/10.1007/978-981-33-6926-9_24

Rafizan Jamil, S., Khairi, M., & Othman, H. (2023). Assessment And Recommendations On The Implementation Of Tahfiz Integrated Curriculum (Kbt). *International Journal of Modern Education*, *5*(17), 455–466. https://doi.org/10.35631/IJMOE.517035

Ramzan, M., Javaid, Z. K., Kareem, A., & Mobeen, S. (2023). Amplifying Classroom Enjoyment and Cultivating Positive Learning Attitudes among ESL Learners. *Pakistan Journal of Humanities and Social Sciences*, *11*(2), 2298–2308. https://doi.org/10.52131/pjhss.2023.1102.0522

Rivera, M. D., & Lopez, S. R. (2019). Some pennies are more equal than others: Inequitable school facilities investment in san Antonio, Texas. *Education Policy Analysis Archives*, *27*. https://doi.org/10.14507/epaa.27.4191

Ruhyana, N. F., & Aeni, A. N. (2019). Effect of Educational Facilities and Infrastructure in Primary Schools on Students' Learning Outcomes. *Mimbar Sekolah Dasar*, *6*(1), 43. https://doi.org/10.17509/mimbar-sd.v6i1.15225

Shahlo Sayfulloevna, S. (2023). Safe Learning Environment and Personal Development of Students. *International Journal of Formal Education*, *2*(3), 7–12. http://journals.academiczone.net/index.php/ijfe

Taat, M. S., Talip, R., & Mosin, M. (2021a). The influence of curriculum and school climate on the academic attitude of tahfiz students in Malaysia. *International Journal of Evaluation and Research in Education*, *10*(3), 807–815. https://doi.org/10.11591/ijere.v10i3.21275

Taat, M. S., Talip, R., & Mosin, M. (2021b). The influence of curriculum and school climate on the academic attitude of tahfiz students in Malaysia. *International Journal of Evaluation and Research in Education*, *10*(3), 807–815. https://doi.org/10.11591/ijere.v10i3.21275

Yusak, Y. M., Ikhwan, A., Razak, K. A., & Anwar, S. (2022). Implementation of the Tahfiz Al-Quran Education Program in Malaysian Polytechnics to Strengthen Islamic Studies. *An Interdisciplinary Journal of Human Theory and Praxis*, *5*(2), 55–69.

Yusop, R., Mahmud, R., Sabli, N., Fatma, N., Awang, A., Ghazali, N., Teknologi, U., & Selangor, M. (2020). Sources of Funding for Private Tahfiz Institutions in Kuala Selangor. In *International Journal of Innovation, Creativity and Change. www.ijicc.net* (Vol. 10). www.ijicc.net

Zain, R. (2019). The Impact Of Facilities On Student's Academic Achievement Assessment Model Of Halal Supply Chain Using Quality Function Deployment Approach View project. *Science International*, *30*(2), 299–311. https://www.researchgate.net/publication/337590619

Zulhilmi Haron, M., Muslim Md Zalli, M., Khairi Othman, M., & Isha Awang, M. (2020). School"s Facilities And Achievement Of Students In Ulul Albab Model Tahfiz Schools In Malaysia: A Mediating Roles Of Satisfaction. *International Journal Of Scientific & Technology Research*, *9*, 2. www.ijstr.org

Measurement Model of Critical Success Factors for Adoption of Energy Management Practices in Public Universities in Malaysia

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Abstract

The purpose of this research is to create a conceptual framework by identifying the independent variables associated with energy management (EM) practices and dependent variables associated with Key Performance Indicators (KPIs) towards a sustainable university. The analysis was carried out with the use of Partial Least Squares-Structural Equation Modelling (PLS-SEM), which described the measurement model in terms of the linkages between the Critical Success Factors (CSFs) group and the KPIs. A conceptual model is developed in this study based on 23 CSFs that are classified into five (5) CSF groups: Top Management Support (TMS), Comprehensive Energy Management Team (CEMT), Awareness (AWA), Strategic Maintenance Management (SMM), and Good Stakeholder Relationships (GSR), while KPIs are adopted from tenpoint action plan of The Talloires Declaration.

Keywords

Conceptual framework, energy management, Partial Least Squares-Structural Equation Modelling (PLS-SEM), Key Performance Indicators (KPI), conceptual model

Introduction

The globe is currently threatened by crises such as dwindling energy resources, climate change, and pollution and deterioration of the environment. Energy consumption has increased significantly in recent years, particularly in developing countries, and Malaysia is no exception due to its expanding population and modernization projects. Even universities are using more energy due to increased population and activity levels. As a result, the Malaysian Ministry of Higher Education has encouraged all universities to minimise their energy consumption, which has alarmed numerous groups. Additionally, energy management (EM) is critical to our national security, environmental well-being, and economic productivity. EM has been a critical tool in supporting universities in

reaching these critical goals for their short- and long-term survival and development. An increasing number of colleges are developing EM programs. Management is realising that if they do not have a strong EM plan, they are leaving a lot of money on the table. Universities in Malaysia may be able to reduce their energy use if new technologies and alternative energy sources are not hampered. A sustainable long-term plan for future energy demand is critical for the implementation of energy-efficiency programs.

In response to the limited success in enhancing EM towards sustainability, this study focuses on critical success factors (CSFs) for EM towards a Malaysian sustainable university and develops the association of identified CSF for EM with key performance indicators (KPIs) towards a sustainable university by constructing a CSFs structured model. Indirectly, identifying these CSF and how they relate to KPIs for a sustainable university can provide guidance for individuals engaged in evaluating which group traits are most relevant for EM in the context of a sustainable institution.

The purpose of this research is to create a conceptual framework for identifying characteristics critical to the effectiveness of EM approaches at Malaysian public universities. An appropriate scale is developed using structural equation modelling, evaluated for reliability and validity, and confirmatory factor analysis (CFA) is done to determine the model's fitness. As a result, the following are the study's objectives:

- To identify the independent variables associated with EM practices and dependent variables associated with KPIs towards a sustainable university based on a literature review;
- To develop a conceptual framework (relationship between the CSFs and the KPIs towards a sustainable university) based on the variables identified; and
- To conduct a measurement model using Partial Least Squares- Structural Equation Modelling (PLS-SEM)

Literature Review

Energy Management for Sustainable Universities in Malaysia

Malaysia's Ministry of Higher Education (MOHE) spends around ten million ringgit per year on power expenditures (Abdullah Saleh et al., 2015). The percentage of energy utilised by educational establishments is depicted in Figure. 1. The HVAC system (45%) consumed the most power in Malaysian university buildings, followed by the lighting system (42%), the water heating system (3%) and others (10%). As a result, the university is an excellent venue for strategic EM, which involves people at all levels in achieving energy policies and objectives. When EM is used, energy costs are often reduced by 5 to 15% (Choong et al., 2011; Iqbal et al., 2021).

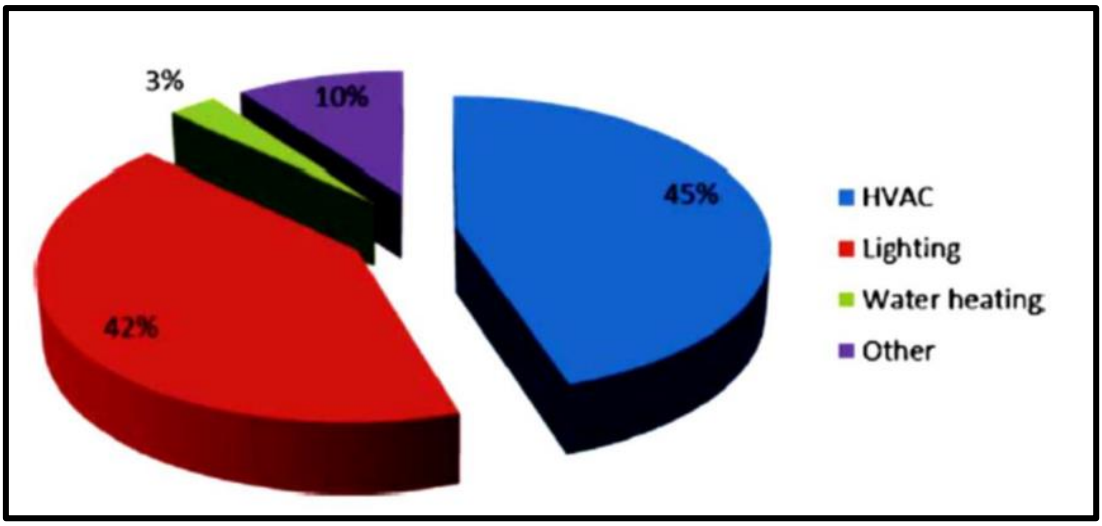

Figure 1. Percentage of Energy Usage in Malaysia University

(Source: Getu & Attia 2016)

Existing buildings may be turned into sustainable models with the same efficiency as new ones. Sustainability is defined as the process of meeting the needs of the current generation without jeopardising future generations' ability to do the same (Abdullah Saleh etal., 2015). According to Sala et al., (2015), sustainability indicates that the essential activities of a higher education are at least ecologically sound, socially just, and economically viable, and will remain so for future generations. A true university would emphasise these topics in its curriculum and research, preparing students to contribute to an ecologically sustainable and socially equitable society as productive citizens. According to this viewpoint, the most significant barrier to attaining a sustainable

university is concurrently improving the environment, society, and economics. As seen in Figure. 2, it is also known as the "Triple Bottom Line" (TBL) and is widely used by businesses to achieve sustainability.

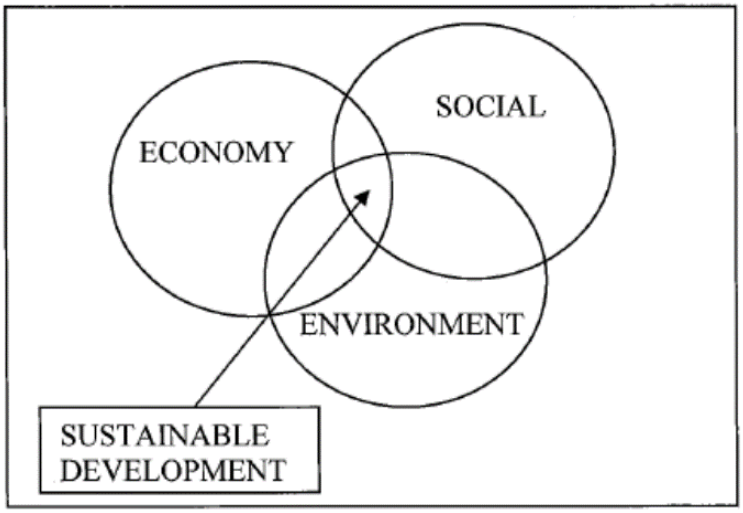

Figure 2. Integration of Environmental, Social and Economic Factors

(Source: Jungwon & Jiyoung 2015)

According to Sala et al. (2015), ignoring ecological imperatives poisons us, depletes our resources, and destroys crucial life support systems for human and animal existence. It is difficult to supply life's necessities, much alone meaningful work, unless the economic imperative is met. Our civilization will devolve into chaos unless we address the social imperative. Failure in one area is said to lead to failure in the other two. Many people, however, continue to view sustainable development primarily from an environmental standpoint. As a result, the notion of CSFs for EM towards a sustainable university is critical for improving energy management in universities, since it will represent performance in certain areas. As a result, the critical question emerged, "How well has an EM been practised towards sustainable universities without considering CSFs?"

Adoption Concepts

The approach used in this study is based on The European Foundation for Quality Management (EFQM) Excellence Model because it is a primary framework for developing sustainable excellence, allowing individuals in any organisation, particularly universities, to understand the relationships between what universities do as enablers and the KPI as the outcome used to achieve it (EFQM, 2022). The EFQM Excellence Model is a non-

mandatory framework of nine criteria, as seen in Figure 3. There are five 'Enablers' and four 'Results' in all. The criteria 'Enabler' discusses an organisation's actions. The criteria 'Results' examines an organisation's successes. 'Enablers' cause 'Results,' while 'Results' feedback helps to enhance 'Enablers'. The Model, which recognizes that there are numerous approaches to achieving long-term excellence in all aspects of performance, is based on the premise that: Excellent results in terms of Performance, Customers, People, and Society are achieved through Leadership driving policy and strategy, People, Partnerships, Resources, and Processes.

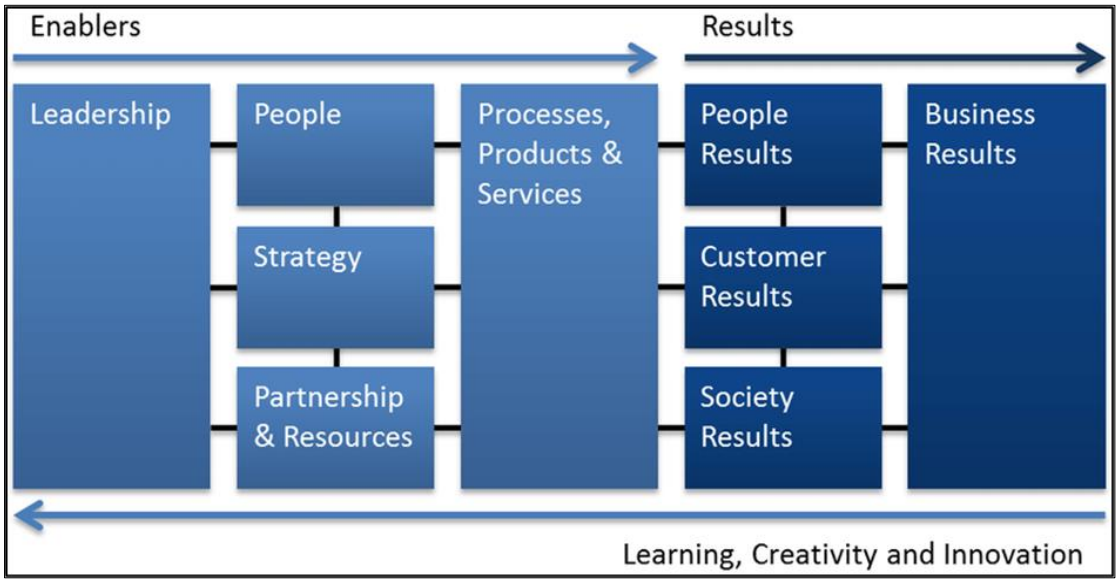

Figure 3. Relationship between Enablers and Outcomes as the Primary Paradigm for Sustainable Excellence

(Source: Deveci & Canitez 2018)

Energy Management CSFs Towards a Sustainable University

CSFs are first defined as the small number of areas where good outcomes will ensure the organization's successful performance. Given the findings of the CSF study, CSFs are important and frequently used. Existing research on context-sensitive frameworks (CSFs) has discovered several shared characteristics that might be used in emergency management (EM). However, "laundry lists" of CSFs continue to dominate the literature, rather than systematic and comprehensive clustering of CSFs. As shown in Table 1, all of the CSF features defined by international organisations and earlier researchers are categorised in this study by cluster.

To create goals and distribute resources, critical success factors (CSFs) are made apparent, notably management emphasis. CSFs, according to Bullen and Rockart (1981), are a natural and necessary input to the process of corporate strategic planning, providing significant insight into resource allocation or operational planning. According to Bullen and Rockart (1981), CSFs are an important input to the strategic planning process, and for an organisation to be successful, its strategy must be developed to allow it to succeed in areas where high performance is critical. "CSFs establish critical performance areas that are essential for the firm to achieve its goal," Kim (2022) stated Managers instinctively recognize and consider these essential aspects when creating objectives and directing operational activities and tasks that are critical to achieving those goals. When these key performance areas are made explicit, however, they serve as a reference point for the whole organisation. As a result, each activity or initiative done by the firm must ensure continual exceptional performance in these crucial areas; otherwise, the business may be unable to achieve its goals and, as a result, fail to fulfil its mission. CSFs, according to Mishra and Kumar (2021), are inextricably linked to an organisation's goal and objectives. CSFs, like other strategic planning components that have an indirect impact on strategy, have an impact on strategy through their impact on the organisation's ability to achieve its goals and their potential to enable mission achievement. The graphic shows the connection between CSFs and traditional strategic planning components.

To use the EFQM model as a framework, it must be modified and improved, as several researchers have done, including Vukomanovic and Radujkovic (2013) and Hdrolu (2019), who developed a conceptual framework for measuring business performance in construction based on the EFQM Excellence Model and Balanced Scorecard. Medne et al. (2020) modified it for projects, and the Project Excellence Model was born. In the EFQM excellence paradigm, the graphic displays the link between enablers and outcomes. The purpose of this conceptual framework is to highlight the relationship between the designated CSFs group for EM and the KPIs for a sustainable institution. The arrows in each CSFs category point to KPIs that contribute to a sustainable university. The identified critical success factors are organised into five sections in this approach: Top Management Support, Comprehensive EM Team, Awareness, Strategic Maintenance Management, and Good Stakeholder Relationships. Figure 4 depicts the conceptual framework in terms of the linkages between CSFs and KPIs for a sustainable institution. This study creates a conceptual model based on 23 CSFs divided into five CSF groups: Top Management Support (TMS), Comprehensive Energy Management

Team (CEMT), Awareness (AWA), Strategic Maintenance Management (SMM), and Good Stakeholder Relationships (GSR). In this model, the CSFs group is represented by an oval shape, whilst CSFs are represented by rectangular sections.

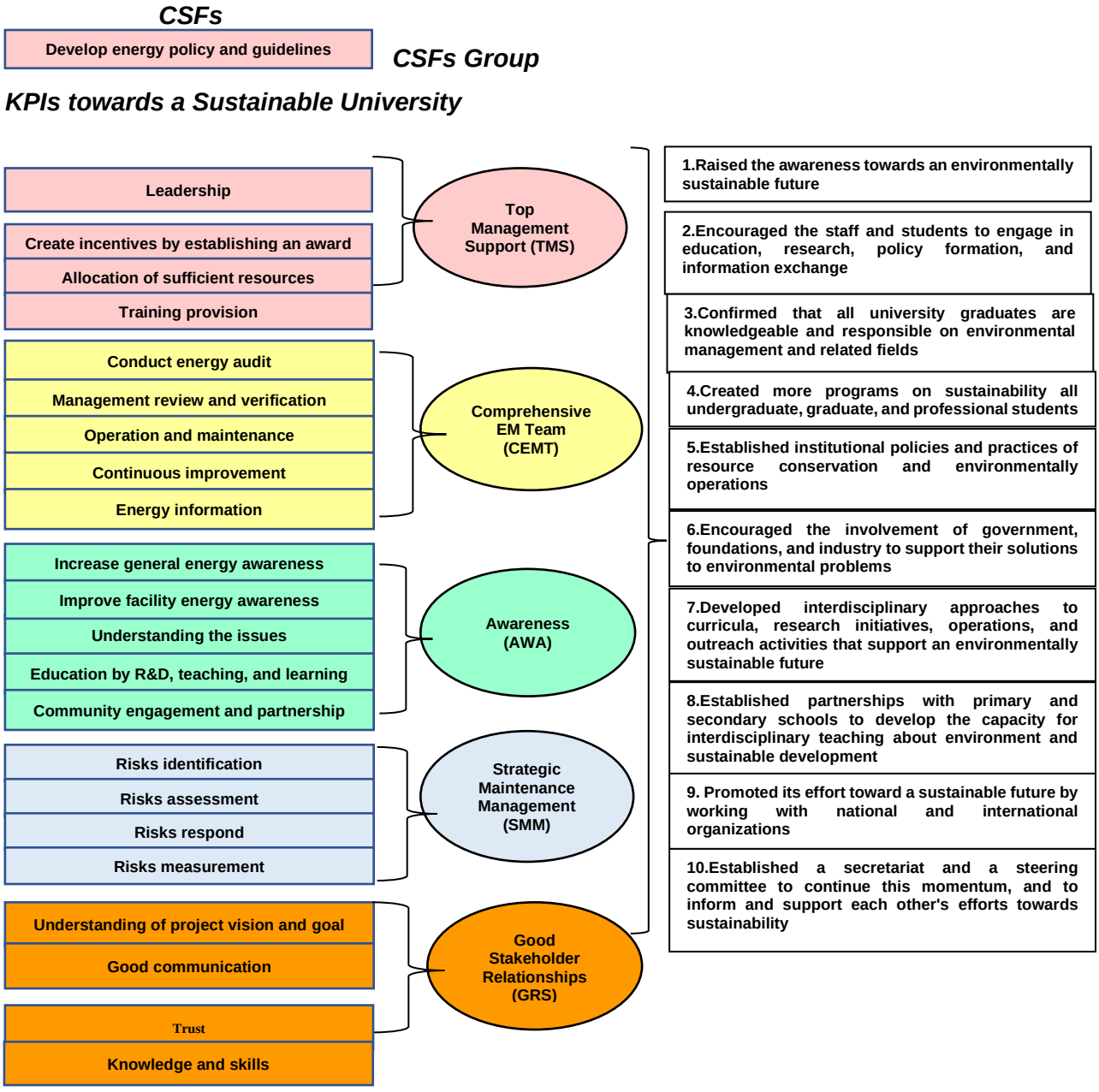

Figure 4. Conceptual Model

Table 1. Description of Constructs and Source of Measurement Instrument

Variable	Definition	Number of items in the construct (Dependent Variables)	Source
Top Management Support (TMS)	The active endorsement, participation, and dedication of senior executives or leaders inside an organisation towards a particular initiative, project, or strategic objective is referred to as top management support.	5	Fung Lo et al., (2021); Ahbabi et al., (2018); Hossain et al., (2023); Meddour et al.,(2019); Hasche et al., (2021)
Comprehensive Energy Management Team (CEMT)	A comprehensive EM team is a group of professionals inside a company tasked with controlling and optimising energy use and efficiency across all operational facets. Typically, the team consists of members from many departments and disciplines that collaborate to design and implement energy management plans and initiatives.	5	Hossain et al., (2021); Parvin et al., (2021);
Awareness (AWA)	Awareness in the context of EM practises refers to knowledge, comprehension, and acknowledgment of	5	Olanipekun & Iyiola (2020); Ahmed et al., (2017); Yen (2012);

	energy-related concerns, opportunities, and best practices. It requires awareness and knowledge regarding energy usage, efficiency, conservation, and the impact of energy use on the environment, costs, and sustainability.		Alkhayyal et al., (2019)
Strategic Maintenance Management (SMM)	Strategic maintenance management refers to the systematic risk management planning, organisation, and execution of maintenance activities inside an organisation in order to meet strategic goals. It entails creating and implementing maintenance strategies that match with the organisation's overall goals and objectives.	4	Rastagari & Salonen (2015); Zwoli´nska & Wiercioch (2022); Laulita (2021); Mong et al., (2018)
Good Stakeholder Relationships (GSR)	A positive and collaborative connection between persons or groups who have an interest in or are affected by a certain project, organisation, or initiative is referred to as a good relationship between stakeholders. Establishing and sustaining positive connections with stakeholders is crucial to the success of any activity and	4	Shengbin et al., (2023); Pererva et al.,(2021);Herremans et al., (2015); Petruzzelli & Badia (2023); Liu & Yin (2020)

	can result in a number of benefits.		
KPIs towards a Sustainable University	Organisations utilise key performance indicators (KPIs) to measure their progress toward certain objectives. KPIs can aid in evaluating and monitoring the sustainability initiatives of a university.	10	Adopted from The Talloires Declaration. It is a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at universities.

Measurement Model Assessment

During the measurement model phase, the PLS-SEM model is first tested. Henseler et al. (2009) offered four evaluation criteria. At the indicator and concept levels, these criteria include the examination of i) indicator reliability, ii) internal consistency reliability, iii) convergent validity, and iv) discriminant validity.

i. **Indicator Reliability**

Individual correlations between CSFs and the group of CSFs with which they are theoretically associated can be used to assess each CSF's validity. A link between CSFs and their specific CSF group is critical. The dependability of individual CSFs is measured by how much each CSF contributes to the CSFs group (Hair, 2011). CSFs with outer loadings of 0.70 or higher are considered exceptional (Henseler et al. 2009). CSFs with a loading value of 0.40 are appropriate for exploratory research, while those with a loading value less than 0.40 should be rejected, according to Hair et al. (2011). The outer loading cutoff value in this study is 0.40 and above. The loading value for the item risk identification (SMM1) was 0.253, as indicated in Table, and it was lowered as advised by Hair et al (2011). Furthermore, due to significant collinearity issues, a number of item loadings from the KPIs construct were deleted, including the perfect correlation of KPI3, KPI8, and KPI9 items. The analysis findings for all CSFs satisfied the requirement with

loading levels more than 0.40 after running the PLS-Algorithm twice. Finally, all CSFs have significant interactions with their particular CSF groups.

ii. **Internal Consistency Reliability**

The second reliability characteristic (CR) is evaluated using two measurements: Cronbach's Alpha (CA) and composite reliability. CA and CR reflect how well a group of CSFs analyses a single set of CSFs. While CA is widely used to examine the dependability of internal consistency, CR is regarded as a superior measure of internal consistency since it standardised various CSFs when the PLS-Algorithm is used (Henseler et al., 2009). Internal consistency dependability must be determined using a cut-off value of at least 0.60 and ideally 0.70. Cronbach (1951), Henseler et al. (2009). As demonstrated in Table, the first and last iterations of the PLS-Algorithm provide CA and CR values greater than 0.70. A single CSFs group is rated positively by all sets of CSFs.

iii. **Convergent Validity**

Convergent validity is one of the tests for the validity of a variable. Convergent validity refers to the variance gathered by a set of CSFs from its related CSFs as a result of measurement mistakes (Henseler et al., 2009). The Mean Extracted Variance (AVE) is assessed using this technique. The CSFs group to which it belongs, according to Henseler et al. (2009) and Hair et al. (2011), may explain at least half of the variance in CSFs. As a result, the proper AVE value is 0.50. The initial PLS-Algorithm run produced findings indicating that three constructs had AVE values less than 0.50. Low-loading items were deleted from the model. In the second application of the PLS-Algorithm, the AVE value was more than 0.50. In conclusion, this outcome shows that the measuring model used in the study displayed substantial convergent validity.

Table 2. Result of Loadings for Measurement Model

CSFs Group	Symbol for CSFs	PLS-Algorithm 1				PLS-Algorithm 2			
		Loading	AVE	CR	CA	Loading	AVE	CR	CA
Top Management Support (TMS)	TMS1	0.666	0.574	0.869	0.837	-	0.637	0.875	0.822
	TMS2	0.858				0.859			
	TMS3	0.783				0.792			
	TMS4	0.728				0.729			
	TMS5	0.819				0.831			
Comprehensive EM Team (CEMT)	CEMT1	0.555	0.666	0.907	0.887	-	0.753	0.924	0.893
	CEMT2	0.781				0.796			
	CEMT3	0.902				0.907			
	CEMT4	0.848				0.863			
	CEMT5	0.913				0.920			
Awareness (AWA)	AWA1	0.678	0.478	0.816	0.767	0.690	0.554	0.832	0.749
	AWA2	0.746				0.752			
	AWA3	0.731				0.739			
	AWA4	0.437				-			
	AWA5	0.786				0.801			
Strategic Maintenance Management (SMM)	SMM1	0.251	0.483	0.768	0.615	-	0.628	0.835	0.709
	SMM2	0.758				0.769			
	SMM3	0.809				0.817			
	SMM4	0.789				0.803			
Good Stakeholder	GSR1	0.767	0.492	0.787	0.663	0.959	0.779	0.875	0.746
	GSR2	0.806				-			

Relationships (GSR)	GSR3	0.727				0.799			
	GSR4	0.429				-			
Key Performance Indicators (KPIs)	KPI1	0.717	0.542	0.892	0.858	0.723	0.542	0.892	0.858
	KPI2	0.745				0.757			
	KPI4	0.684				0.688			
	KPI5	0.748				0.752			
	KPI6	0.749				0.751			
	KPI7	0.673				0.677			
	KPI10	0.799				0.801			

iv. Discriminant Validity

Discriminant validity is a type of concept validity in PLS-SEM. The amount to which a notion does not correlate with other measurements is referred to as discriminant validity (Hair et al., 2006). The two criteria used to confirm discriminant validity are cross-loadings and the Fornell-Larcker criterion. The AVE of each construct must be bigger than its squared correlations with any other construct, according to the Fornell-Larcker criterion (Fornell and Larcker, 1981). This was done by adjusting the correlation matrix's diagonal to the square root of the AVE. For appropriate discriminant validity, the diagonal elements in the relevant rows and columns must be bigger than the nondiagonal elements. The table shows the correlation matrix for the constructs. It shows that diagonal AVE values are larger than off-diagonal AVE values. As a result, the test supports the discriminant validity.

Table 3. Result of Discriminant Validity

CSFs Group	AWE	AWA	CEMT	GSR	KPIs	SMM	TMS
Awareness (AWA)	0.554	**0.743***					
Comprehensive EM Team (CEMT)	0.753	0.713	**0.862***				
Good Stakeholder Relationships (GSR)	0.779	0.534	0.505	**0.884***			
Key Performance Indicators (KPIs)	0.542	0.160	0.137	0.117	**0.726***		
Strategic Maintenance Management (SMM)	0.628	0.221	0.153	0.146	0.672	**0.773***	
Top Management Support (TMS)	0.637	0.476	0.511	0.432	0.208	0.119	**0.788***

*Diagonal AVE values are greater than off-diagonal AVE values; diagonal values are AVE values. Cross loadings are then used to evaluate discriminant validity. As seen in Table 3, cross loadings for all CSFs are higher on their respective CSF group than on the other group in the same row or column. This guarantees that the CSFs in each construct correspond to the CSFs group assigned to the construct, hence confirming the model's discriminant validity.

Table 4. Result of Cross Loadings

	Awareness	Comprehensive EM Team	Good S/holder R/ships	Key Performance Indicators	Strategic Maintenance Management	Top Management Support
CEMT2	0.750	**0.797**	0.471	0.114	0.109	0.378
CEMT3	0.543	**0.919**	0.427	0.109	0.146	0.456
CEMT4	0.596	**0.872**	0.415	0.151	0.149	0.482
CEMT5	0.550	**0.910**	0.431	0.071	0.111	0.430
KPI10	0.156	0.124	0.142	**0.812**	0.537	0.221
KPI1	0.103	0.115	0.083	**0.737**	0.503	0.153
KPI2	0.087	0.105	0.007	**0.766**	0.545	0.118
KPI4	0.134	0.081	0.122	**0.696**	0.500	0.136
KPI5	0.108	0.087	0.012	**0.763**	0.447	0.151
KPI6	0.104	0.107	0.104	**0.763**	0.446	0.127
KPI7	0.132	0.085	0.136	**0.698**	0.463	0.161
AWA1	**0.693**	0.380	0.360	0.081	0.191	0.353
AWA2	**0.762**	0.460	0.360	0.064	0.128	0.357
AWA3	**0.739**	0.315	0.335	0.122	0.187	0.320
AWA5	**0.851**	0.812	0.488	0.162	0.154	0.390
SMM2	0.175	0.122	0.120	0.419	**0.770**	0.085
SMM3	0.265	0.194	0.169	0.540	**0.821**	0.179
SMM4	0.098	0.057	0.067	0.607	**0.811**	0.026
GSR1	0.465	0.423	**0.963**	0.128	0.149	0.354
GSR3	0.524	0.532	**0.814**	0.061	0.097	0.472
TMS2	0.431	0.473	0.431	0.205	0.157	**0.860**

TMS3	0.335	0.284	0.186	0.179	0.091	**0.794**
TMS4	0.444	0.471	0.383	0.047	0.027	**0.741**
TMS5	0.374	0.480	0.433	0.147	0.042	**0.820**

The Partial Least Squares Structural Equation Modeling (PLS-SEM) model is established after evaluating (i) indicator reliability, (ii) internal consistency reliability, (iii) convergent validity, and (iv) discriminant validity at both the indicator and concept levels, as shown in Figure. 5.

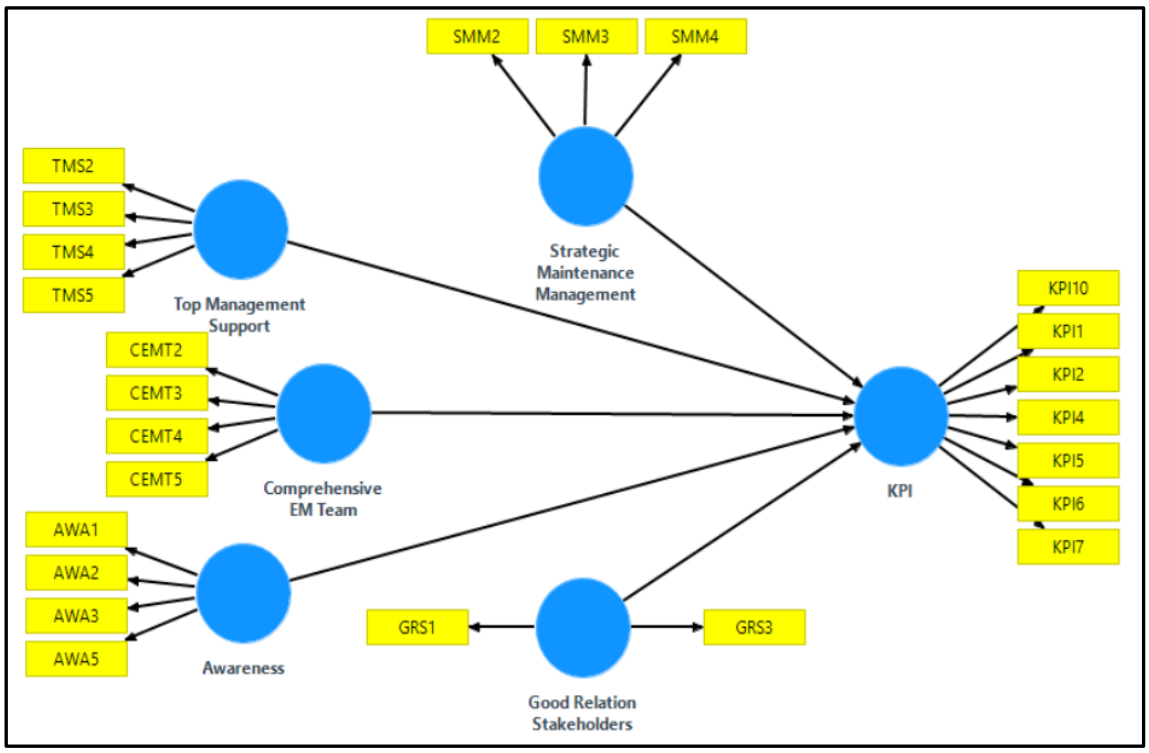

Figure 5. PLS-SEM Measurement Model

Conclusion

The goal of this study was to develop a comprehensive measurement model for the CSFs that impacts EM strategy adoption in Malaysian public institutions. A detailed examination of indicator reliability, internal consistency reliability, convergent validity, and discriminant validity resulted in an effective measurement model. The findings give valuable insights into the important parameters that are critical to the proper application of EM approaches in Malaysian public universities. The measuring model serves as a foundation for future research and policy development in educational institutions including EM methodologies. It offers a systematic strategy for discovering, analysing, and prioritising CSFs that can have a significant impact on energy efficiency and sustainability activities in public institutions. Stakeholders may better understand the interrelationships between the highlighted components and build plans to successfully enhance EM practices using this technique.

While the measuring model provides a solid framework, more studies should investigate the following topics to increase knowledge of EM methods in Malaysian public universities:

- Longitudinal Studies: Conduct longitudinal studies to assess the evolution of EM practices over time and understand how CSFs may change or adapt in response to various external and internal factors.

- Comparative Analysis: Conduct a comparative analysis between public and private universities to identify potential differences in the adoption of EM practices and the CSFs that influence them.

- Contextual Factors: Investigate the influence of contextual factors, such as institutional culture, financial constraints, and government policies, on the adoption of EM practices in public universities.

- Performance and Impact Analysis: Explore the relationship between the successful adoption of EM practices and its impact on energy consumption, cost

savings, greenhouse gas emissions reduction, and overall environmental sustainability.

- Interventions and Best Practices: Examine the effectiveness of interventions and best practices aimed at promoting EM adoption in public universities and identify successful case studies to serve as benchmarks for other institutions.

- Stakeholder Perspectives: Investigate the perceptions and attitudes of different stakeholders (e.g., administrators, faculty, staff, and students) toward EM practices to better understand their roles and involvement in the adoption process.

By addressing these topics, future study can contribute to the improvement of sustainable EM practices in public universities in Malaysia and around the world, as well as expand the knowledge base and policy formation.

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References

Abdullah Saleh A., Mohammed A.H., Abdullah M.N., (2015), Exploring Critical Success Factors of Energy Management for Sustainable Building in Malaysian University, 73:5, 24–31.

Ahbabi S.A., Singh S.K., Balasubramanian, S., Gaur S.S., (2019), Employee Perception of Impact of Knowledge Management Processes on Public Sector Performance, 23:2, 351-373.

Ahmed M.S., Mohamed A., Raad Z.H., Shareef H., Khalid K., (2017), Awareness on Energy Management in Residential Buildings: A Case Study in Kajang and Putrajaya, 12:5, 1280-1294.

Alkhayyal B., Labib W., Alsulaiman T., Abdelhadi A., (2019), Analyzing Sustainability Awareness among Higher Education Faculty Members: A Case Study in Saudi Arabia, 11:23, 6837.

Bullen, C. V., Rockart, J. F., (1981), A Primer on Critical Success Factors, 1220-1281.

Choong W.W., Mohammed A.H., Low S.T., (2011), Energy Management Key Practices: A Proposed List for Malaysian Universities, 2:4, 749-760.

Cronbach, L.J., (1951), Coefficient Alpha and The Internal Structure of Tests. 16, 93-96.

European Foundation for Quality Management, EFQM (2022).

Fornell, C.G., Larcker, D.F., (1981), Evaluating Structural Equation Models with Unobservable Variables and Measurement Error, 39-50.

Fung Lo, M., Tian, F., Lan Ng P.M., (2021), Top Management Support and Knowledge Sharing: The Strategic Role of Affiliation and Trust in Academic Environment, 25:9, 2161-2177.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E.,Tatham, R.L., (2006), Multivariate Data Analysis (6th Ed.).

Hair, J.F., Ringle, C., Sarstedt, M., (2011). PLS-SEM: Indeed a Silver Bullet, 19:2, 139-152.

Hasbolah F., Mohd Alwi N., Sani Mohamad M.H., (2018), Institutionalization of Performance Management System in A Malaysian Local Government From The Perspective of New Institutional Sociology, 15:2, 44-52.

Hannan M.A., Al-Shetwi A.Q., Jern Ker P., Begum R.A., Mansor M., Rahman S.A., Dong Z.Y., Tiong S.K., Indra Mahlia T.M., Muttaqi K.M., (2021), Impact of Renewable Energy Utilization and Artificial Intelligence in Achieving Sustainable Development Goals, 7, 5359-5373.

Hasche N., Höglund L. & Mårtensson M., (2021). Intra Organizational Trust in Public Organizations – The Study of Interpersonal Trust in Both Vertical and Horizontal Relationships From A Bidirectional Perspective, Public Management Review, 23:12, 1768-1788.

Henseler, J., Ringle, C., and Sinkovics, R., (2009), The Use of Partial Least Squares Path Modeling in International Marketing. Advances in International Marketing, 20, 277–320.

Herremans I.M., Nazari J.A., Mahmoudian F., (2015), Stakeholder Relationships, Engagement, and Sustainability Reporting. Journal of Business Ethics.

Hossain J., Aida. F. A. Kadir, Hanafi N., Shareef, H., Khatib, T., Baharin K.A. and Sulaiman M.F, (2023), A Review on Optimal Energy Management in Commercial Buildings, 16, 1609.

Iqbal, M., Ma, J., Ahmad N., Hussain K., Usmani, M.S. & Ahmad, M., (2021), Sustainable Construction through Energy Management Practices in Developing Economies: An Analysis of Barriers in the Construction Sector, 29, 90108–90127.

Kim, S., (2022), Critical Success Factors Evaluation by Multi-Criteria Decision-Making: A Strategic Information System Planning and Strategy, 13, 270.

Laulita N.B., (2021), How Organizational Culture Moderate the Effect of Total Productive Maintenance Practice on Operational Performance?, 20:2, 93-103.

Meddour H., Saoula, O., Abdul Majid A.H., Abu Auf M.A., (2019), Effects of Top Management Support on Knowledge Transfer and Sharing: The Mediating Role of Trust, 7:1, 2395-6518.

Medne, A., Lapina, I. and Zeps, A., (2020), Sustainability of a University's Quality System: Adaptation of the EFQM Excellence Model, 12:1, 29-43.

Mishra, R.S. & Kumar R., (2021), Effect of Critical Success Factors (CSFs) on the Organizational Performance, 5:6, 341-348.

Mong S.G, Mohamed S.F., Misnan M.S., (2018), Budgeting: A Strategic Approach to Achieve Value for Money in Maintenance Management, 331-340.

Olanipekun E.A., Iyiola C.O., (2020), A Study of Awareness and Electricity Use Behaviour of On-campus Residence Students in Nigeria, 54:2, 19-43.

Parvin K., Hossain Lipu M.S., Hannan M.A., Abdullah M.A, Pin Jern K., Begum R.A., Mansur M., Muttaqi K.M., Indra Mahlia T.M., Yang Dong Z., (2021), Intelligent Controllers and Optimization Algorithms for Building Energy Management Towards Achieving Sustainable Development: Challenges and Prospects, 9, 41577-41602.

Pererva P., Kobielieva T.,Tkachova N., Tkachov M., Diachenko T., (2021), Management of Relations with Enterprise Stakeholders Based on Value Approach, 19, 24-38.

Rastagari A., Salonen A., (2015). Strategic Maintenance Management: Formulating Maintenance Strategy, 18:1, 5-14.

Sala S., Ciuffo B., Nijkam P., (2015). A Systemic Framework for Sustainability Assessment, 119, 314–325.

Shengbin M.A., Zhongfu L.I., Long L.I., Mengqi Y., Xianfei Y., (2023). Exploring the Effect of Stakeholder Relationship Quality on Technological Innovation in Off-Site Construction: The Mediating Role of the Knowledge Sharing, 29:1, 1822-3605.

The Talloires Declaration 10 Point Action Plan: Association of University Leaders for a Sustainable Future.

Tripathy, M., (2018), Building Quality Teamwork to Achieve Excellence in Business Organizations, 5:3, 1-7.

Vukomanovic,M., Radujkovic, M., (2013), The Balanced Scorecard and EFQM Working Together in A Performance Management Framework in Construction Industry, 19:5, 1822-3605.

Yen N.S., (2012), *Energy Awareness and Energy-Use Behaviour of Students in Malaysian University*, Universiti Teknologi Malaysia: Master Thesis.

Žalėnien I., Pereira P., (2021), Higher Education for Sustainability: A Global Perspective, 2:2, 99-106

Zwoli´nska B., Wiercioch J., (2022), Selection of Maintenance Strategies for Machines in a Series-Parallel System. Sustainability, 14, 11953.

Validation of 3D Reconstruction of Building Model between DSLR and Mirrorless Cameras using Close-range Photogrammetry

Farid Munandar, Ahmad Norhisyam Idris*, Lau Chong Luh, Abdul Aziz Ab Rahman

Abstract

Digital Single-Lens Reflex (DSLR) and mirrorless cameras are the prevalent types of cameras available in the photography market. The main difference between these two is that DSLRs have an internal mirror that reflects light to the optical viewfinder whereas mirrorless cameras lack this mirror, using an electronic viewfinder or the rear LCD screen to display the image directly from the sensor. Although both types of cameras can be used in close-range photogrammetry (CRP) applications, mirrorless cameras have not been the subject of much research because the technology is still relatively new. Based on previous studies, the reliability of the cameras was assessed in terms of the accuracy and quality of 3D models generated. This research aimed to evaluate the quality visualization and accuracy of 3D model building generated from close-range photogrammetry. Two non-metric cameras; a Nikon D7000 DSLR and Sony A6400 mirrorless, were used to collect data on site. A proper planning of the camera network was performed to ensure that both cameras will have the same value of Ground Sample Distance (GSD), 1.0mm/pixel. The data collected were processed using multiple software in order to generate point clouds and 3D models. Generally, the 3D models created from both DSLR and mirrorless cameras exhibited some areas with missing gaps and details. However, the DSLR camera produced slightly superior results compared to the mirrorless camera. To validate the accuracy of the models, their dimensions were compared to the actual dimensions. The difference ranges between (5-10) mm and (8-15) mm for the Nikon D7000 and Sony A6400 respectively, resulting in Root Mean Square Errors (RMSE) of 0.006m and 0.010m. At the end of this work, it was found that close-range photogrammetry was sufficient to generate a 3D model with acceptable accuracy. The results provide useful information for professionals and researchers who aim to choose the most appropriate camera equipment for close-range photogrammetry applications, ultimately contributing to the advancement of digital mapping and architectural modeling.

Keywords: *3D model, close-range photogrammetry, DSLR camera, mirrorless camera*

Introduction

In recent years, the demand for realistic three-dimensional (3D) models has grown significantly across various industries, including animation, cultural heritage, industry, and medicine. Traditional topographic/photogrammetric surveys and laser scanning methods have been commonly used for 3D modeling (Lerma et al., 2004). Laser scanning has gained popularity due to its ability to swiftly acquire a significant amount of 3D data, providing a higher level of detail and metric accuracy compared to traditional methods. Similarly, photogrammetry, a technique that reconstructs 3D models from one or more images, has been widely used (Remondino et al., 2005). Close-Range Photogrammetry (CRP) is a measurement technology that utilizes images to extract 3D point clouds, enabling accurate

3D modeling and visualization (Remondino & El-Hakim, 2006). Due to its ease of use, precision, and time-saving advantages, digital close-range photogrammetry was essential for measured drawing projects and historical building documentation (Moyano et al., 2020).

The conventional methods for measuring and modeling buildings are often time- consuming and cannot create photo-realistic 3D models. They also have limitations in terms of data collection, causing errors and missing critical records for surface modeling. Moreover, the application of conventional procedures has resulted in a decrease in accuracy and precision when attempting to construct more complex architectural features such as minarets, domes, columns, mausoleums, and sculptures, which possess conical, spherical, or cylindrical shapes (Sari et al., 2020). Therefore, new methods such as CRP have been introduced to overcome these limitations (Fawzy, 2019). This technique relies on the fundamental concept of epipolar geometry which encompasses a four-step procedure including photo addition, point and image pair matching, and the generation of sparse and dense clouds (Yogender et al., 2020). CRP has gained attention in the past two decades for its ability to reconstruct 3D objects and collect 3D points with accuracy (Luhmann, 2010).

Photography activities have been profoundly altered by the innovation in camera sensors. DSLRs, which enable digital photography, have been utilized after the film era, and currently the mirrorless sensor is widely in use. A clear distinction between the two is the inclusion of a mirror mechanism, which modifies the manner in which the incoming beam towards the lens arrives at the sensor (Incekara et al., 2017).

This study aims to validate the use of Close-Range Photogrammetry for 3D reconstruction of building models between DSLR and mirrorless cameras. By analyzing the visual quality and accuracy of point cloud modeling, CRP's effectiveness as a technique for building model

reconstruction can be assessed. The findings of this study contributed to the validation of CRP using DSLR and mirrorless cameras which was reported as an efficient and accurate method for creating photo-realistic 3D models of buildings.

Literature Review

As its name suggests, photogrammetry applies the triangulation principle to metrology or measurement by using images as the primary medium. To create 'lines of sight' from each camera to points on the object, it entails shooting photographs from a minimum of two distinct locations. The three-dimensional coordinates of the places of interest are found by mathematically intersecting these lines of sight, which are sometimes called rays because of their optical nature. (Horswell, 2013). In the first place, the applications of film-based photogrammetry were used before the digital close-range photogrammetry (DCRP) is increasingly diverse, as digital imagery gradually replaces film in various conventional tasks (Clarke, 1995). The main component that influenced this method is the type of the camera used, quantity of control points and images. For example, Elhalawani et al., 2021 demonstrated that, when a metric camera is used in place of a flatbed scanner, the results are sufficiently accurate for El-Nasr Mosque façade, with a root mean square error (RMSE) of 46.7 mm. On the other hand, the characteristics and resolution of non-metric (digital) cameras determine their accuracy; a higher resolution corresponds to greater accuracy. In contrast, the best circumstances for obtaining an accurate mapping are six photos for the mosque façade with eight control points.

An additional evaluation was conducted with respect to the various camera types in order to facilitate close-range photogrammetric analysis on the rock surface. In order to compare the DSLR and mirrorless cameras, the difference values between the model and field coordinates, which were derived after photograph alignment, were utilized. The results of the accuracy analyses indicated that both cameras obtained values that were extremely similar, with no significant change in varying the quantity and distributions of control points from each other (Incekara et al., 2017).

Drofova et al., 2023 studied the comparisons between the DSLR and 360 cameras when using the photogrammetry approach for the 3D reconstruction of the object. It is likely that the two devices' applications for 3D modeling will differ due to their distinct constructions and photograph acquisition properties. It is believed that the 360-degree cameras woul

used mostly to record the surroundings and convert them into a virtual reality setting with ease. The DSLR camera remains a low-cost tool for using the multi-image photogrammetry technique on the ground to rebuild an object in three dimensions.

Methodology

This section describes the workflow to validate the use of Close-Range Photogrammetry (CRP) for 3D reconstruction of building models. The methodology comprises four phases beginning from Preparation, Data Acquisition, Data Processing, and lastly Data Analysis.

As the study was focused on modelling the structure of buildings in 3-dimensional structure, an abundance of literature study was done to achieve a full understanding regarding the subject. Taking into consideration the size, detail, and texture, a building located in UiTM Shah Alam as depicted in Figure 1 was chosen to be modelled.

Figure 1. Location of building used in the study

There are two (2) main types of equipment involved in this study which are; the Nikon D7000 DSLR and Sony A6400 mirrorless. The Digital Single Lens Reflex (DSLR) and mirrorless cameras are the most common types of cameras available in the photography market nowadays. The main difference between these two cameras is that DSLRs have

internal mirror that reflects light to the optical viewfinder whereas mirrorless cameras lack this mirror, using an electronic viewfinder or the rear LCD screen to display the image directly from the sensor. Although both types of cameras can be used in close-range photogrammetry (CRP) applications, mirrorless cameras have not been the subject of much research because the technology is still relatively new.

Camera calibration is a critical requirement for close-range photogrammetric measurement, mostly in consumer-grade digital cameras (Stöcker et al., 2015). This calibration was performed on the DSLR and mirrorless cameras to estimate the parameters related to the internals of the camera. Using Photomodeler software, multi-sheet calibration was carried out for both cameras, according to the steps provided in the software manual as illustrated in Figure 2. The process involves establishing the intrinsic and extrinsic parameters of the camera to ensure accurate and reliable measurements.

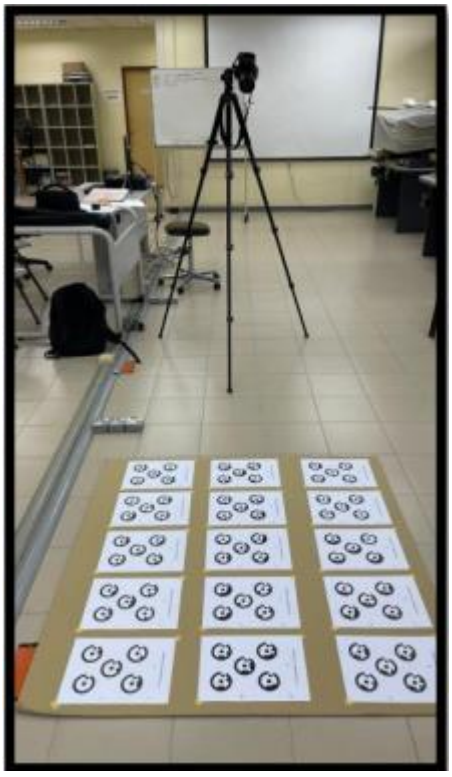


Figure 2. Camera calibration process

Close-range photogrammetry (CRP) technique was used to acquire data for this study. The term "photogrammetry" refers to the process of analysing and measuring an object to determine its shape and location using several photographs of the object. Photogrammetric

methods are promising tools to overcome such problems due to 3D reconstruction from overlapping images without disturbing the surface (Waldhäusl & Ogleby, 1994).

$$GSD = \frac{H \cdot \times Sw}{f \times IMw} \quad (1)$$

In close-range photogrammetric work, it is essential to maintain a reasonable image overlap, Ground Sample Distance (GSD), and base to depth ratio (b/d) ie., the distance between two camera positions to the distance between the camera and the object.

Initially, the maximum distance of the camera from the object was calculated using the GSD formula, before determining the b/d ratio that satisfies 1.0mm/pixel GSD and 80% image overlap. In this study, images were acquired using a Nikon D7000 DSLR and a Sony A6400 mirrorless, in a fully manual mode. Table 1 describes the main specification of the cameras. The cameras were attached on a tripod with a height approximately 1.50 m from the ground. In addition, the '3x3' photogrammetric capture rules (Hammoudi et al., 2012) were adapted to maximise the result's quality.

Table 1. Camera specifications used in the study

	DSLR Nikon D7000	**Mirrorless Sony A6400**
Number of images	76	132
Focal length	18 mm	50 mm
Resolution	16 MP	24 MP
Sensor	CMOS 23.6 x 15.6 mm	CMOS 23.6 x 15.6 mm
Base to depth ratio (b/d)	1/10	1/12

In this study, Agisoft Metashape software was used to create and detailed 3D models from the acquired 2D images. The software utilises the Structure from Motion (SfM) technique, where it analyses multiple overlapping images taken from different angles of the same subject or scene. By identifying common features in these images, it reconstructs the 3D structure and texture of the subject

The process of producing 3D models typically involves the following steps:

- Image Alignment: The software automatically identifies matching points in the images and aligns them to create a dense point cloud as shown in Figure 3. This step establishes the relative positions and orientations of the images, laying the groundwork for further processing.
- Point Cloud Generation: Agisoft Metashape then creates a dense point cloud, where each point represents a 3D position in space based on the information from multiple images. This point cloud forms the foundation of the 3D model.
- Point Cloud Filtering: To reduce matching errors and minimise the file size, a manual filtering process was employed. This involved removing outliers and unwanted regions from the data.
- Build Mesh: The 3D points within a dense point cloud were interconnected to create a network of triangles, resulting in a polygonal or mesh model that approximates the shape of the object.
- Build Texture: Agisoft Metashape applies the original images' textures onto the 3D mesh to produce a visually realistic 3D model with color information. This texture mapping enhances the model's visual fidelity.

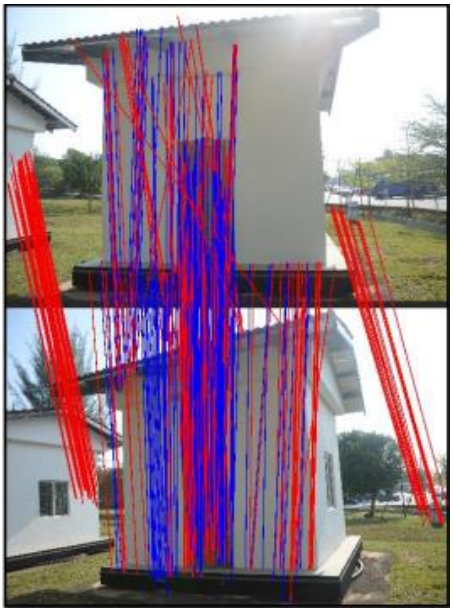


Figure 3. Automatic image matching process

Agisoft Metashape is widely used in various fields, such as architecture, archaeology, engineering, film production, and gaming, to create detailed 3D models of objects, buildings, landscapes, cultural heritage sites, and more. Its user-friendly interface, powerful processing capabilities, and accurate results make it a popular choice among professionals and enthusiasts working with photogrammetric techniques.

This study will validate the use of close-range photogrammetry for 3D building modelling based on:

- Point cloud visual Quality
- 3D building model accuracy

Point clouds generated from close-range photogrammetry methods may exhibit incompleteness or gaps. These gaps can arise from various factors, such as occlusions, texture-less objects, inadequate data collection, or flawed design (Alsadik, 2014). The point clouds from DSLR and mirrorless models were segmented to extract the structural elements and compared to each other, assessing the detail, resolution, and completeness of the structural elements.

To determine the accuracy of 3D models, the dimension of structural elements measured from the models were compared to the actual dimension measured on site. For 3D models measurement, the models were imported into CloudCompare and measured each dimension of the structural elements. As for the actual dimension, it was measured on site using a measuring tape. The Root Mean Squared Error (RMSE) for each model were calculated based on the following equation:

$$RMSE = \sqrt{\frac{\sum_{1}^{n} x - x_i}{n}} \quad (2)$$

Where n is the total number of samples, x is the model dimension, and x_i is the actual dimension. A total of twelve (12) samples were measured and compared. The samples consist of dimensions of the building's structural elements as shown in Figure 4.

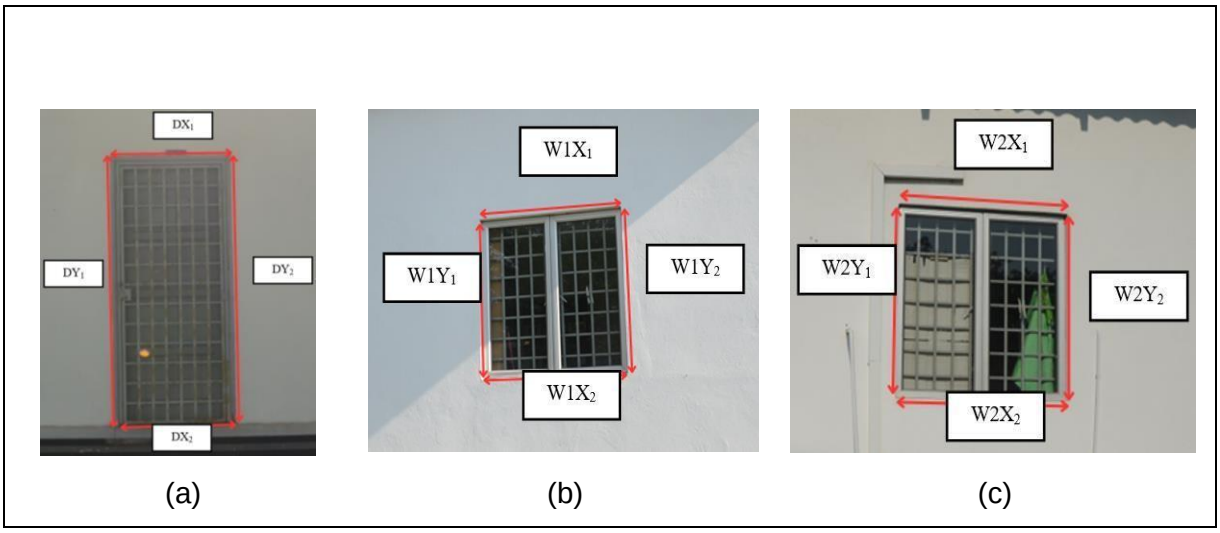
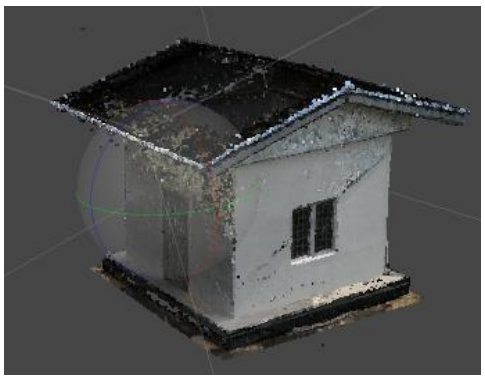


Figure 4. Labelled structural elements (a) Door (b) Window 1 (c) Window 2

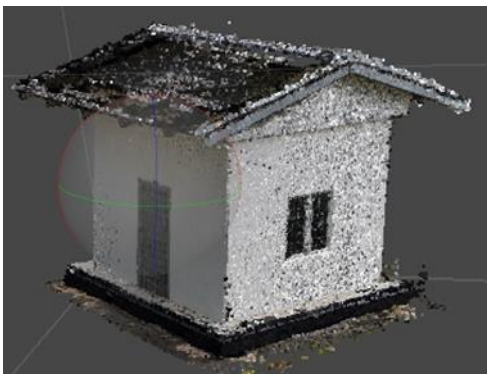
Results And Analysis

The reliability of close-range photogrammetry technique is extensively investigated by researchers across various modalities. This study intends to validate the use of non-metric cameras in close-range photogrammetry application for 3D modelling in terms of visual quality and model accuracy.

The point cloud processing part in Agisoft Metashape managed to produce 15 million points for the DSLR model, and 38 million points for the mirrorless model. From the visualization in Figure 5, both models resulting from DSLR and mirrorless cameras lack information on the roof because of the angle of view of the camera images. This is because street level imaging does not provide enough coverage because it cannot capture the upper parts of objects, such as buildings or facades due to the cameras located at ground level and cannot see above objects that are in the way (Thomson, 202



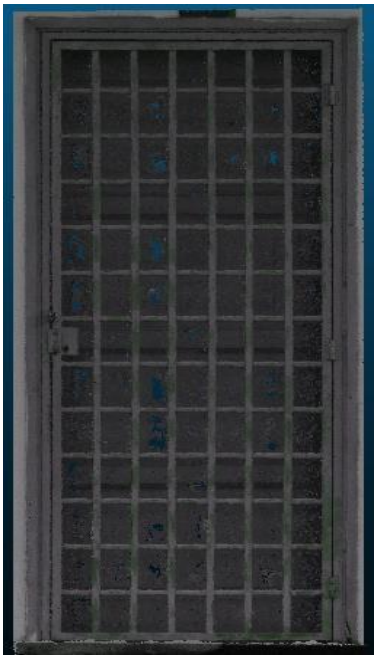
(a)



(b)

Figure 5. Generated point cloud in Agisoft Metashape (a) DSLR model (b) mirrorless model

Generally, both point clouds generated from DSLR and mirrorless camera images produced good results where the shape and dimension of the structural elements can be observed clearly. However, the mirrorless model produced a significantly greater number of point clouds than the DSLR. This might be due to the higher number of images acquired for the mirrorless model.

Element	DSLR	Mirrorless
Door		

Window 1		
Window 2		

Figure 6. Comparison of point cloud models based on the structural elements

In order to assess the accuracy, the 3D models were opened in CloudCompare and measurements of each model were taken. A total of 12 dimensions samples were measured and compared to the actual dimension of the building structure, resulting in error residual between 5-10 mm and 8-15 mm for the DSLR and mirrorless camera respectively as presented in Figure 7.

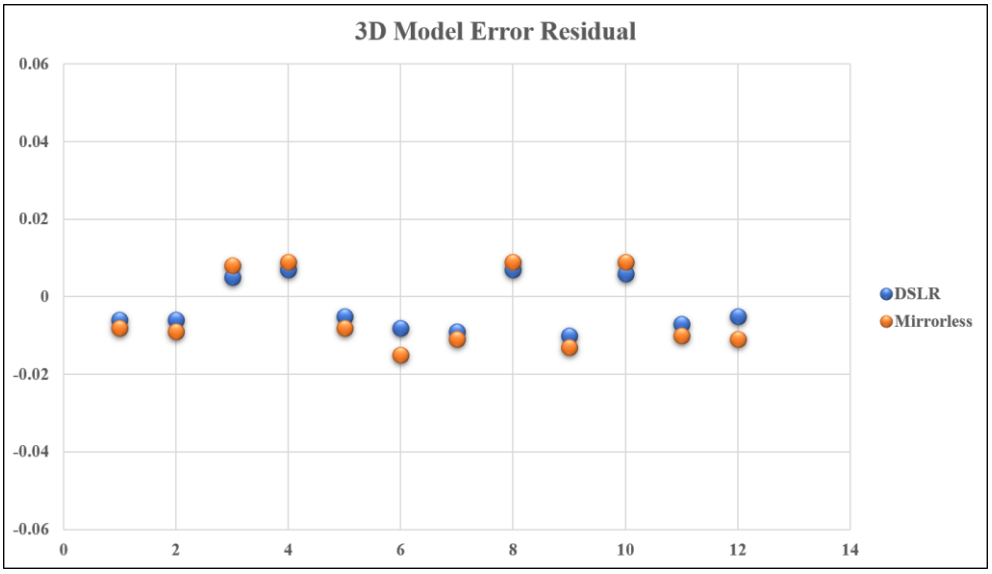


Figure 7. The error residual for DSLR and mirrorless 3D mode

Results for the model's accuracy are calculated by taking those values and applied in the proposed RMSE formula. Table 2 and Table 3 present the results for accuracy analysis. Based on the results, RMSE values are 0.006 and 0.010 for DSLR and mirrorless model respectively. These results are similar to previous study (Incekara et al., 2017) in which the DSLR camera produced subtly enhanced results than the mirrorlesss camera.

Table 2. Accuracy analysis for 3D model using DSLR camera

Dimension	Model Distance(m)	Actual Distance (m)	Residual (m)	
W1X1	1.188	1.192	-0.006	0.000036
W1X2	1.187	1.193	-0.006	0.000036
W1Y1	1.196	1.194	0.005	0.000025
W1Y2	1.198	1.194	0.007	0.000049
W2X1	1.191	1.196	-0.005	0.000025
W2X2	1.183	1.191	-0.008	0.000064
W2Y1	1.183	1.193	-0.009	0.000081
W2Y2	1.192	1.191	0.007	0.000049
DX1	0.940	0.945	-0.010	0.000100
DX2	0.942	0.936	0.006	0.000036
DY1	2.082	2.089	-0.007	0.000049
DY2	2.084	2.089	-0.005	0.000025
			RMSE	0.006922

Table 3. Accuracy analysis for 3D model using mirrorless camera

Dimension	Model Distance(m)	Actual Distance (m)	Residual (m)	
W1X1	1.193	1.192	-0.008	0.000001
W1X2	1.199	1.193	-0.009	0.000036
W1Y1	1.203	1.194	0.008	0.000081
W1Y2	1.209	1.194	0.009	0.000225
W2X1	1.204	1.196	-0.008	0.000064
W2X2	1.201	1.191	-0.015	0.000100
W2Y1	1.198	1.193	-0.011	0.000025
W2Y2	1.195	1.191	0.009	0.000016
DX1	0.944	0.945	-0.013	0.000001
DX2	0.940	0.936	0.009	0.000016
DY1	2.084	2.089	-0.010	0.000025
DY2	2.089	2.089	-0.011	0.000000
			RMSE	0.010214

Conclusion And Recommendations

In conclusion, this study evaluated the quality and accuracy of point clouds generated using close-range photogrammetry with DSLR and mirrorless cameras. The results demonstrate the potential of close-range photogrammetry in producing accurate and textured 3D building models. High-quality image processing options proved effective in densifying the point cloud, and it was found that consumer-grade digital cameras, in combination with close-range photogrammetry software, can yield satisfactory results without the need for advanced and expensive equipment.

The study emphasises the importance of visible random textures or patterns on surfaces for effective modelling using dense point clouds. The presence of such textures aids in capturing and reconstructing surface details, resulting in more reliable and high-quality models. Lighting conditions also play a crucial role, and balanced lighting is recommended for better results.

Based on the findings, several recommendations are proposed. Firstly, expanding the research scope to include indoor and outdoor sections of buildings with different sizes and designs can provide more reliable outcomes. Secondly, exploring additional datasets can help assess the effectiveness of different techniques, algorithms, or approaches in improving the quality, accuracy, and performance of 3D modeling using close-range photogrammetry. Lastly, incorporating a more extensive statistical analysis with diverse samples would enhance the understanding of the methodology's performance and outcomes.

Overall, this study contributes to the growing field of 3D modeling and highlights the potential of close-range photogrammetry as a viable and accessible method for generating accurate 3D models. Further research and advancements in this area can lead to improved techniques and applications in various industries

References

Alsadik, B. (2014). Guided Close Range Photogrammetry For 3D Modelling of Cultural Heritage Sites. https://doi.org/10.3990/1.9789036537933

Clarke, T. A. (1995). An analysis of the prospects for digital close-range photogrammetry. ISPRS Journal of Photogrammetry and Remote Sensing, 50(3), 4–7. https://doi.org/10.1016/0924-2716(95)91285-R

Drofova, I., Guo, W., Wang, H., & Adamek, M. (2023). Use of scanning devices for object 3D reconstruction by photogrammetry and visualization in virtual reality. Bulletin of Electrical Engineering and Informatics, 12(2), 868–881. https://doi.org/10.11591/eei.v12i2.4584

Elhalawani, M. A., Zeidan, Z. M., & Beshr, A. A. A. (2021). Implementation of close-range photogrammetry using modern non-metric digital cameras for architectural documentation. Geodesy and Cartography (Vilnius), 47(1), 45–53. https://doi.org/10.3846/gac.2021.11269

Fawzy, H. E. (2019). 3D Laser Scanning and Close-Range Photogrammetry for Buildings Documentation: A Hybrid Technique Towards A Better Accuracy. Alexandria Engineering Journal, 58(4), 1191–1204. https://doi.org/10.1016/j.aej.2019.10.003Fritsch D, Khosravani AM, Cefalu A, Stuttgart. Multi-Sensors and Multiray Reconstruction for Digital Preservation. https://www.researchgate.net/publication/265754677_MultiSensors_and_Multiray_Reconstruction_for_Digital_Preservation

Hammoudi K, Dornaika F, Soheilian B, Vallet B, McDonald J, Paparoditis N. Recovering Occlusion-Free Textured 3D Maps of Urban Facades by a Synergistic Use of Terrestrial Images, 3D point clouds and Area-Based information. Procedia Engineering [Internet]. 2012 Jan 1;41:971–80. Available from: https://doi.org/10.1016/j.proeng.2012.07.271

Incekara AH, Seker DZ, Delen A, Acar A. Investigating the Suitability Of Mirrorless Cameras In Terrestrial Photogrammetric Applications. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences [Internet]. 2017 Nov 13; Available from: https://doi.org/10.5194/isprs-annals-iv-4-w4-259-2017

Lerma JL, García AG, Geodésica E. 3D City Modelling and Visualization of Historical Centers. ResearchGate. 2004 Jan 1;

Luhmann, T. (2010). Close-range photogrammetry for industrial applications. ISPRS Journal of Photogrammetry and Remote Sensing, 65(6), 558–569. https://doi.org/10.1016/j.isprsjprs.2010.06.003

Moyano, J., Nieto-Julián, J. E., Bienvenido-Huertas, D., & Marín-García, D. (2020). Validation of close-range photogrammetry for architectural and archaeological heritage: Analysis of point density and 3d mesh geometry. *Remote Sensing*, *12*(21), 1–23. https://doi.org/10.3390/rs12213571

Remondino F, El-Hakim SF. Image-based 3D Modelling: a review. Photogrammetric Record [Internet]. 2006 Aug 7;21(115):269–91. Available from: https://doi.org/10.1111/j.1477-9730.2006.00383.x

Remondino F, Guarnieri A, Vettore A. 3D modeling of close-range objects: photogrammetry or laser scanning? [Internet]. Proceedings of SPIE. SPIE; 2005. Available from: https://doi.org/10.1117/12.586294

Sari, B., Hamal, S. N. G., & Ulvi, A. (2020). Documentation of complex structure using Unmanned Aerial Vehicle (UAV) photogrammetry method and Terrestrial Laser Scanner (TLS). Turkish Journal of LIDAR, 2(2), 48–54.

Stöcker C, Eltner A, Karrasch P. Measuring gullies by synergetic application of UAV and close-range photogrammetry — A case study from Andalusia, Spain. Catena [Internet]. 2015 Sep 1;132:1–11. Available from: https://doi.org/10.1016/j.catena.2015.04

Thomson, C. (2021). What are point clouds? 5 easy facts that explain point clouds. Vercator. https://info.vercator.com/blog/what-are-point-clouds-5-easy-facts-that-explain-point-clouds

Waldhäusl, P., & Ogleby, C. L. (1994). 3-Rules for simple photogrammetric documentation of architecture. ResearchGate. https://www.researchgate.net/publication/284326169_3-Rules_for_simple_photogrammetric_documentation_of_architecture

Yogender, Raghavendra, S., & Kushwaha, S. K. P. (2020). Role of Ground Control Points (GCPs) in Integration of Terrestrial Laser Scanner (TLS) and Close-range Photogrammetry (CRP). In Lecture Notes in Civil Engineering (pp. 531–538). Springer Singapore. https://doi.org/https://doi.org/10.1007/978-981-13-7067-0

The Impact of Abandoned Housing Projects on The Society and The Environment in Klang, Selangor

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Abstract

An abandoned housing project refers to a housing development that was started but remains incomplete for an extended period of over six months. The phenomenon of abandoned housing projects poses significant challenges to society and the environment in Klang, Selangor, Malaysia. This study aims to suggest potential solutions for abandoned housing projects in the region. Through literature, surveys, and case studies, the research explores the main causes of project abandonment, examines the social and environmental consequences, and suggests systematic solutions to address this pressing issue. To obtain precise information, a quantitative method involves distributing survey questionnaires to 120 respondents directly or indirectly affected by or knowledgeable about abandoned housing projects in Klang. The research findings reveal that abandoned housing projects in Klang, Selangor are primarily caused by developer-related issues and financial mismanagement. These projects have profound negative impacts on society, including the proliferation of fear, vandalism, and disturbances in society. Moreover, the environmental consequences of abandoned projects manifest through increased waste accumulation, vegetation overgrowth, flooding, and the disruption of natural habitats. This study provides valuable insights for policymakers, researchers, and practitioners to tackle the issue of abandoned housing projects effectively, safeguarding the well-being of residents and preserving the natural environment.

Keywords: Abandoned housing, Environment, Building, Development, Construction, Property

Introduction

In the region of Klang, Selangor, the challenge of abandoned housing projects has adverse effects on the local society and the environment. Malaysia is a developing nation with a robust economy encounters various obstacles such as global crises and economic fluctuations. Despite these challenges, Malaysia effectively manages them with the help of crucial sectors like construction and agriculture. Of these sectors, construction holds significant importance. It generates revenue, fosters employment opportunities, and contributes substantially to Malaysia's economic advancement (Alaloul, 2021). The Malaysian government allocates substantial attention to the construction industry as part of the nation's pursuit of comprehensive development. In the journey toward achieving developed nation status, the construction industry plays a pivotal role. Its significance extends beyond the construction of infrastructure like roads, ports, airports, and power plants. It also generates employment that directly impacts the lives of Malaysians. Even when technological advancements were limited, Malaysia recognised the vital role of this industry. Now, let us delve into a more specific yet significant issue within Malaysia's construction landscape, the problem of abandoned housing projects. This concern has far-reaching implications, affecting the economy, security, developers, buyers, society, the environment, and the entire industry.

In 2020, Malaysia faced a significant challenge in its construction sector and marked by the abandonment of 79 housing projects valued at RM5.57 billion (Huda & Hidayah, 2021). This issue persisted in 2021 with 75 abandoned projects reported (Ministry of Housing and Local Government, 2020). By September 2021, Selangor recorded the highest number of abandoned projects with 33 in total involving 17,724 housing units and 11,800 buyers (Huda & Hidayah, 2021; Ministry of Housing and Local Government, 2020). The data as of August 2021 revealed 111 abandoned housing projects in Selangor with 15,010 housing units awaiting rescue (Che Noh, 2021). Notably, Klang, Selangor faced the brunt of this issue, registering 39 abandoned housing projects involving 4,392 units (Che Noh, 2021). However, this study aims to propose potential solutions for mitigating issues related to abandoned housing projects in Klang, Selangor, Malaysia with a focus on their impact on both society and the environment. The research objectives include identifying the primary causes behind the abandonment of housing projects in Klang, examining the broader societal and environmental repercussions of such projects, and ultimately suggesting systematic solutions to address and alleviate these challenges.

Literature Review

Definition of Terms

In this context, a project refers to a specific task undertaken to achieve defined goals, typically managed by individuals or groups varying in scale and complexity (Yarbrough, 2021). Housing denotes where people reside, encompassing diverse types like houses, apartments, and more (Collins Dictionary, 2021; Properly, 2022). A housing project entails providing secure and comfortable dwellings for individuals with limited incomes, encompassing varied housing types like houses and apartments, undertaken by government or private entities (Law Insider, 2021).

An abandoned housing project arises when construction commences but needs to be completed. It needs more effort towards finalisation. Construction is designated as abandoned if it halts for at least six (6) consecutive months. This situation can emerge due to developers needing to fulfil their obligations (Dahlan, 2008). The term environment encompasses the entirety of our surroundings, including flora, fauna, water, air, and more, significantly influencing human life (Kumar, 2018). Society denotes a collective of individuals living together, making communal decisions and adhering to organised ways of life (Cambridge, 2023). Klang signifies a historically significant district in Selangor, Malaysia with its distinct local authority (Wikipedia, 2023).

In summary, an abandoned housing project in Klang, Selangor denotes an initiative initiated but left unfinished for over six (6) months that potentially impacts society and the environment often due to developers' failure to meet their responsibilities (Dahlan, 2008).

Review of Abandoned Housing Projects in Klang, Selangor, Malaysia

Housing projects are essential in Malaysia but abandoned ones are a growing issue. This worries the government and people because it involves many parties (Ahmad, 2021). Selangor had the highest number of abandoned projects in August 2021, even in debates like the Malaysia Plan (RMK12) (Noh, 2022).

In 2020, 75 projects with 17,724 houses and 11,800 buyers were abandoned (Ministry of Housing and Local Government, 2020). In 2021, Selangor had 79 projects valued at RM5.57 billion impacting 17,724 houses and 11,824 buyers (Husain & Hairom, 2021).

Selangor has had the most abandoned projects since 2015 and Klang is a significant contributor (Noh, 2022). In 2021, Klang saw 111 abandoned projects, mostly older ones,

without clear records (Che Noh, 2022). Klang's high population leads to many projects which can lead to overdevelopment and abandoned projects (Ariffin et al., 2018).

Criteria of Abandoned Housing Projects

In the year of 2020, the Ministry of Housing once again issued criteria for abandoned housing projects to raise awareness in society about the occurrence of abandoned housing projects. The criteria are as follows: (Ministry of Housing and Local Governance, 2020)

i. Not finished throughout the sale and purchase agreement (S&P) or outside of it and no significant activity at the construction site for six (6) consecutive months.

ii. In accordance with Section 218 of the Companies Act of 1966, the winding-up petition was filed in the High Court.

iii. The company is placed under an officer of receiver and manager

iv. The developer informs the Housing Authority in writing of his incapacity.

v. According to Section 11 (1) (a) of Act 118, the Minister of Urban Well-being, Housing and Local Government said the project had been abandoned.

Main Causes of Abandoned Housing Projects

Klang's population is growing rapidly, reaching 937,296 in 2023 (Zhuji, 2023), driving the need for more housing. However, attempting to accommodate everyone can lead to abandoned projects due to excessive development (Ariffin et al., 2018).

Abandoned housing projects in Klang are often associated with overdevelopment. Meeting the high demand for homes can lead to taking on too many projects, straining resources and commitments, ultimately resulting in unfinished work (Ariffin et al., 2018).

Furthermore, poor financial management is identified as a significant reason for abandoned projects according to the Selangor State Assembly (Selangor State Assembly, 2016). Incorrect cost calculations can strain developers, leading to problems and project abandonment. Sound financial management is vital to prevent this issue.

Table 1. Main Causes of Abandoned Housing Projects

Causes	Elaboration	Source
Overpopulation	Klang has lots of people needing homes. However, building too much in one place can leave projects unfinished.	(Zhuji, 2023) (Ariffin et al., 2018)
Excessive Development	Abandoned housing projects in Klang are due to excessive rush in meeting high demand. Taking on too many projects strains resources and commitments, causing unfinished work.	(Ariffin et al., 2018)
Developer	Many abandoned housing projects in Klang are linked to certain developers. They've been flagged by the Selangor State Assembly for their role in multiple abandoned projects, adding to the problem.	(Selangor State Assembly, 2015)
Poor Financial Management	Selangor State Assembly says bad money management is a main cause of abandoned projects. Wrong cost calculations strain developers. Big cost differences can lead to problems or project abandonment.	(Selangor State Assembly, 2016)

The Impact of Abandoned Housing Projects on The Society.

Abandoned housing projects profoundly impact society (Ariffin et al., 2018). Their neglected state unintentionally invites illicit activities such as drug use, homelessness, sexual assault/rape, or vandalism. This environment also disrupts the local ecosystem, drawing in wild animals and causing potential conflicts between wildlife and humans (Ariffin et al., 2018).

Moreover, the allure of exploration for children poses serious dangers as neglected structures harbour significant hazards, raising the risk of accidents, injuries, and tragedies (Stuart, 2009). Addressing these challenges is crucial to safeguard the well-being of both the society and the environment.

Table 2. The Impact of Abandoned Housing Projects on The Society

Impact	Elaboration	Source
Illicit Activities	Empty housing projects can unintentionally become havens for illicit activities, particularly drug use, homelessness, sexual assault/rape or vandalism, due to their neglected state.	(Ariffin et al., 2018)
Wild Animals Roam	Abandoned housing projects draw in wild animals, causing problems in the local ecosystem and possible conflicts with people. This space imbalance can put both groups at risk.	(Ariffin et al., 2018)
Attracting Children (Danger for Children)	The allure of abandoned housing projects might draw curious children seeking exploration. However, these alluring prospects are laden with dangers. The neglected structures harbour significant hazards, raising the risk of accidents, injuries, and tragedies.	(Stuart, 2009)

The Impact of Abandoned Housing Projects on The Environment.

Abandoned housing projects have a detrimental impact on the environment (Ariffin et al., 2018). Their neglect contributes to various issues including compromised air and water quality due to the release of pollutants and the breakdown of construction materials. These projects often become dumping grounds, leading to improper waste disposal and environmental harm (Ariffin et al., 2018). Poor drainage and neglect elevate the risk of local floods, threatening properties and the overall environment (Ismail, 2018). Moreover, the stagnant water in unfinished structures creates breeding grounds for mosquitoes, heightening disease transmission risks (Ariffin et al., 2018). The visual and psychological impact of abandoned projects also diminishes property values and neighbourhood appeal (Lim, 2018). Finally, the susceptibility to landslides due to improper construction practices and lack of maintenance further underscores the negative environmental consequences of abandoned housing projects (Lim, 2018).

Table 3. The Impact of Abandoned Housing Projects on The Environment

Impact	Elaboration	Source
Air and Water Quality	Abandoned housing projects harm air and water quality. Neglected sites gather debris, releasing pollutants into the air and water. Breakdown of materials like paint and chemicals worsens the issue, hurting air and water quality over time.	(Ariffin et al., 2018)
Emergence of Unintended Waste Zones	Abandoned projects often turn into dumping grounds. Neglect leads to improper waste disposal, harming the environment and nearby areas.	(Ariffin et al., 2018)
Escalation of Flood Risks	Poor drainage and neglected sites increase the risk of local floods, endangering properties and the environment.	(Ismail, 2018)
Mosquito Infestations	Stagnant water in unfinished structures lets mosquitoes multiply, raising disease risk.	(Ariffin et al., 2018)
Impact on Property Valuations	Unfinished structures lower neighbourhood appeal, reducing property demand and values.	(Lim, 2018)
Vulnerability to Landslides	Weak soil and erosion from lack of care increase landslide risk in heavy rain.	(Lim, 2018)

Methodology

The case studies involve observations of abandoned housing projects in Klang, Selangor focusing on data that helps to understand the specific circumstances surrounding these abandoned projects and their effects on society and the environment. Questionnaire surveys among 120 respondents targeted living near the abandoned housing projects in Klang, Selangor were conducted to gather primary data. The questionnaires are designed to collect information on various aspects including demographic details, the causes of abandoned housing projects, their impact on society and the environment and suggestions for addressing this issue.

The collected data from these 120 respondents are analysed using quantitative methods including descriptive statistics such as frequencies, percentages, means, and standard deviations. This analysis allows identifying patterns, trends, and correlations related to the impact of abandoned housing projects on society and the environment. By employing a quantitative approach through case study analysis and responses of 120 respondents, this study aims to suggest a potential solution for abandoned housing projects in Klang, Selangor.

Case Study

In the first case study, an abandoned residential housing project located at Jalan Kopi, Meru, Klang, Selangor. This project was abandoned after 2021 with approximately 60% of the construction completed primarily focusing on structural work. The project comprises 12 semi-detached houses spread across 24 lots each covering an area of 374.69 m². Situated near a residential area and Surau Darul Aman, the site is now overgrown with vegetation and the front area has been converted into an oil palm plantation.

The second case study is an abandoned housing project at Jalan Nenas, Meru, Klang, Selangor. This project was abandoned in 2016 with only 30% of the essential structural work completed. It consists of 24 double-storey houses and was initially launched in 2013 with a promised completion date in 2016. However, it is currently in poor condition and poses a risk of collapsing.

In the third case study, an abandoned double-storey housing project located at Bukit Kapar, Klang, Selangor. This project has been experiencing ongoing abandonment since 2010, despite reaching an 80% completion status primarily focusing on the solid structure.

It comprises 22 double-storey houses across 44 lots and is situated in Taman Desa Bukit Delima, adjacent to Jalan Bukit Cerakah, Malaysia. This project was initiated in 2010 with the intended completion date set for 2015 but was abandoned due to financial issues faced by the developer and leaving the solid structure in place.

Result And Discussion

Respondents Demographic

The survey was conducted with 120 respondents regarding abandoned housing projects in Klang which presents several notable findings. Firstly, a significant proportion of respondents fall into the 34 to 41 age group (25%), indicating a considerable presence of middle-aged individuals, followed closely by young adults aged 26 to 33 (21.67%). The gender distribution shows that 69.17% are male, while 30.83% are female, suggesting a gender imbalance in survey participation. Regarding employment, 33.33% work in the private sector, 30.83% are government employees, 20.83% have their businesses, and 3.33% are self-employed, with an additional 11.67% falling into the "Other" category, reflecting diverse job backgrounds. Regarding residency duration in Klang, 30.83% have lived there for 11-15 years, and 25% for 1-5 years, while 21.67% have been residents for 6-10 years. Around 55% of respondents rent their homes, and 45% own them, indicating diverse perspectives on abandoned housing projects. Household sizes vary, with 28.33% in households of 3 people, 20.83% in households of 2 people, 16.67% in households of six or more people, 14.17% in households of five people, and 9.17% in four people. Notably, 52.5% of respondents live less than 100 meters from the abandoned housing project, while 5% express disapproval of its presence. These findings underscore the importance of considering the diverse perspectives of different demographic groups in addressing the issue of abandoned housing projects in Klang.

Table 4. Respondents Demographic

Variables	Percentage	Variables	Percentage
Age		Type of housing	
18 to 25 yo	18.33%	Ranted	55%
26 to 33 yo	21.67%	Owner	45%
34 to 41 yo	25.00%		
42 to 50 yo	17.50%		
50 and above	17.50%		
		Number of people living in the household	
Gender			5.83%
Male	69.17%	1	20.83%
Female	30.83%	2	28.33%
		3	9.17%
		4	14.17%
		5	16.67%
		6 or more	5.00%
		I do not live in Klang	
Job Affiliation			
Government Servant	30.83%	Distance from Case Study.	
Private	33.33%	Less than 100 meters	52.50%
Own Business	20.83%	100 meters to 500 meters	20.00%
Self-Employee	3.33%	500 meters to 1 kilometre	9.17%
Other	11.67%	1 kilometre to 5 kilometres	9.17%
		More than 5 kilometres	4.17%
		I am not aware of any abandoned housing projects	5.00%
Years lived in Klang			
Less than 1 year	15.00%		
1-5 years	25.00%		
	21.67%		

6-10 years	30.83%	
11-15 years	5.00%	
16-20 years	0%	
More than 20 years	5.00%	
I do not live in Klang		

Main Causes for Housing Projects Being Abandoned in Klang, Selangor

Based on the survey responses, it is evident that the main reasons for housing projects being abandoned in Klang, Selangor are primarily attributed to internal problems within the developer, which received a significant percentage of 74.17% and had the highest mean rank of 22.25. This suggests that issues related to the developer's management, decision-making or execution of the project are the primary culprits for project abandonment.

In contrast, other factors such as excessive development (25%) and poor financial management (0.83%) were also cited as contributing factors but to a much lesser extent, with mean ranks of 7.5 and 0.25, respectively. Overpopulation did not receive any significant percentage indicating that it is not a prominent factor in the abandonment of housing projects in Klang, Selangor.

In conclusion, most respondents believe that internal problems within the developer organisation, as indicated by the highest mean rank, are the primary reasons behind housing projects being abandoned in Klang, Selangor. This emphasises the importance of addressing and improving the developer's internal processes and management to prevent future project abandonment.

Table 5. Main Causes for Housing Projects Being Abandoned in Klang, Selangor

	Suggestion Answer	Percentage	Mean Rank
1	Internal Problem in Developer	74.17%	22.25
2	Excessive Development	25%	7.5
3	Poor Financial Management	0.83%	0.25
4	Overpopulation	0%	0

Impact of Abandoned Housing Projects on The Society in Klang, Selangor

Firstly, it is evident that abandoned housing projects in the area have a significant psychological impact on the society. The mean score of 3.83 for "Causing fear in the surrounding people (Horror)" suggests that most respondents either agree or strongly agree that these projects create fear and anxiety among residents. This fear can negatively affect society's well-being and mental health, increasing stress and discomfort.

Secondly, wild animals roaming around abandoned housing projects is another concern highlighted by the respondents, with a mean score of 3.77. This indicates that a substantial number of individuals perceive a risk associated with wild animals in these areas. Such a situation poses physical dangers and contributes to the overall sense of insecurity within the society.

On the other hand, the survey data also sheds light on the potential attraction of abandoned housing projects to children, with a mean score of 2.49 for "Attract Children to Play There (Danger for children)." While this score is lower compared to the previous two categories, it suggests that a significant proportion of respondent’s express concerns about the safety of children who may be drawn to these locations for play. This underscores the need for improved safety measures in the vicinity.

Lastly, the data reveals relatively low mean scores for issues like homelessness, vandalism, sexual assault/rape, and drug use. Based on the respondents' perceptions, this suggests that these problems are less prominent than the psychological and safety concerns associated with abandoned housing projects. However, it is essential to consider

that these issues may still be significant, even if they are perceived as less pressing by the respondents.

Table 6. Impact of Abandoned Housing Projects on The Society in Klang, Selangor

	Question	Answer					Mean Rank
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
1	Causing fear in the surrounding people (Horror)	11	7	4	39	59	3.83
2	Wild Animals Roam	2	16	12	42	48	3.77
3	Attract Children to Play There (Danger for children)	28	27	16	16	33	2.49
4	Homelessness	47	42	26	4	1	1.63
5	Vandalism	63	48	7	2	0	1.17
6	Sexual Assault/Rape	79	32	9	0	0	1.05
7	Drug Use	79	31	10	0	0	1.02

Impact of Abandoned Housing Projects on The Environment in Klang, Selangor

Firstly, it is evident that most respondents strongly agree that abandoned housing projects significantly spoil the view in the region. With a mean rank of 4.52, this indicates a strong consensus among participants that these projects have a visual impact on the environment, potentially diminishing the area's aesthetic appeal.

Secondly, mosquito breeding sites are a notable concern among respondents as they rated it with a mean rank of 4.31. This suggests that many respondents agree that abandoned housing projects contribute to the creation of mosquito breeding sites which can have implications for public health in terms of disease transmission.

Thirdly, the perception that abandoned housing projects affect the value of surrounding properties is polarised with a mean rank of 4.02. While some respondents strongly agree with this statement, others strongly disagree, indicating a lack of consensus.

Lastly, respondents appear to be less concerned about specific environmental impacts of abandoned housing projects such as landslides, affecting air and water quality, and floods as these factors received relatively lower mean rank values. This could imply that the community may perceive these issues as something other than immediate threats or may be less aware of their potential consequences.

In summary, the data from the questionnaire indicates that abandoned housing projects in Klang, Selangor have a significant negative impact on the environment in terms of spoiling the view and creating mosquito breeding sites which are top concerns for the community. However, there needs to be more agreement regarding the effects on property values and some environmental concerns such as landslides and air/water quality are perceived as less pressing by the respondents. These findings can be valuable for policymakers and local authorities to prioritise and address the most pressing environmental issues associated with abandoned housing projects in the area.

Table 7. Impact of Abandoned Housing Projects on The Environment in Klang, Selangor

		Answer					
	Question	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	
1	Spoil the view	3	0	9	30	78	4.52
2	Mosquito Breeding Sites	0	8	6	32	74	4.31
3	Affect the value of surrounding properties	26	7	5	13	69	4.02
4	Wild Animal Breeding Ground	19	5	13	28	55	3.62
5	Become a garbage dump	14	23	17	26	40	3.50
6	Destruction of the natural habitat of animals	20	13	17	37	33	3.25
7	Destruction of vegetation	21	23	11	32	33	3.08

8	The occurrence of floods	40	13	11	26	30	2.75
9	Affecting air and water quality	55	24	24	15	2	2.25
10	Landslide	69	31	17	2	1	1.74

Potential Solution to Be Taken to Prevent or Address Abandoned Housing Projects in Klang, Selangor

These results reveal the various strategies that could be employed to tackle this problem. The highest-rated suggestion with 43.33% support and a mean rank of 7.43 is giving the project to rescue developers. This indicates a strong preference among respondents for involving experienced developers to revive and complete these projects likely due to their expertise and resources in the field.

The second most favoured option with 29.17% support and a mean rank of 5 is strengthening regulations and oversight. This suggests that a significant portion of respondents believe that stricter regulations and more effective oversight mechanisms could prevent housing projects from being abandoned in the first place. This approach aligns with the idea of proactive prevention.

With 20% support and a mean rank of 3.43 developing subsidy programs emerges as the third most favoured strategy. This suggests that some respondents see financial assistance as a viable solution to incentivise developers to complete abandoned projects making housing more accessible to potential buyers.

The low support for collaboration with stakeholders establishing a recovery fund and government takeover (all at 3.33% or lower) indicates that respondents may perceive these strategies as less effective or feasible in addressing the issue.

In summary, the findings from the questionnaire underscore the importance of involving experienced developers, strengthening regulations and providing subsidies to address abandoned housing projects effectively. These insights can serve as a valuable basis for policymakers and stakeholders in Klang, Selangor as they work towards finding practical solutions to this pressing problem. Considering these preferences and perspectives is essential when devising a comprehensive strategy for dealing with abandoned housing projects to ensure it resonates with the community and maximises effectiveness.

Table 8. Potential Solution to Be Taken to Prevent or Address Abandoned Housing Projects in Klang, Selangor

	Suggestion Answer	Percentage	Mean Rank
1	Give the project to the rescue developer	43.33%	7.43
2	Strengthen regulations and oversight.	29.17%	5
3	Develop subsidy programs	20%	3.43
4	Collaborate with stakeholders	3.33%	0.57
5	Establish a recovery fund	2.5%	0.43
6	The government took over the project	0%	0
7	Enhance coordination among relevant institutions	0%	0

Conclusion

In conclusion, the data findings and analysis shed light on the main causes, impacts, and potential solutions for abandoned housing projects in Klang, Selangor. The study revealed that the primary reasons for housing project abandonment in the area are attributed to developer-related issues and poor financial management. Internal problems in developers' financial mismanagement and lack of resources were highlighted as significant contributing factors aligning with real-world case studies.

When examining the impacts of abandoned housing projects on society, the data indicated a mixed range of perceptions. While some concerns such as fear among residents and potential risks to children and wildlife were acknowledged by many respondents. Other concerns like drug use, sexual assault and vandalism were generally perceived as less significant. The study underscored the complexity of how abandoned housing projects affect the community, with varying degrees of concern depending on the specific aspect.

The environmental impacts of abandoned housing projects were also explored. Respondents expressed notable concerns about the potential for these projects to contribute to waste accumulation, vegetation destruction, flooding, habitat disruption, and mosquito breeding.

Regarding addressing the challenge of abandoned housing projects, the data revealed that respondents favoured measures like involving rescue developers, government intervention and subsidy programs. The significance of capable developers, governmental oversight and financial support was evident in the responses, showcasing the multifaceted approach required to prevent and address abandoned housing projects effectively.

Overall, the study emphasises the critical role of developers' actions and financial management in the success or abandonment of housing projects. Additionally, it highlights the complex interplay between abandoned projects and their impact on society and the environment. Moving forward, the insights from this study can serve as valuable guidance for policymakers, stakeholders, and communities in addressing the challenges associated with abandoned housing projects in Klang, Selangor and similar contexts.

References

Abdul Shukor Lim (2018), The Study on Cause and Effect of Abandoned Housing Project in Selangor, Materials Science and Engineering, https://doi.org/10.1088/1757-899X/431/8/082013

Ahmad, S. (2021, October 5), Isu rumah terbengkalai 15 tahun, Menteri "turun padang." Metro, https://www.hmetro.com.my/mutakhir/2021/10/762910/isu-rumah-terbengkalai-15-tahun-menteri-turun-padang

Alaloul, W., Musarat, M., Rabbani, M., Iqbal, Q., Maqsoom, A., & Farooq, W. (2021), Construction Sector Contribution to Economic Stability: Malaysian GDP Distribution. Sustainability, 13, 5012, https://doi.org/10.3390/SU13095012.

Ariffin, N. F., Ali, M. I., Ramli, N. I., Md Jaafar, M. F., Wan Ahmad, S., Abdul Shukor Lim, N. H., & Abd Khalid, N. H. (2018), The Study on Cause and Effect of Abandoned Housing Project in Selangor, Materials Science and Engineering, https://doi.org/10.1088/1757-899X/431/8/082013

Braun, V., & Clarke, V. (2006), Using thematic analysis in psychology, Qualitative Research in Psychology, 3(2), 77- 101, https://www.researchgate.net/publication/235356393_Using_thematic_analysis_in_psychology

Collins Dictionary. (2021), Meaning of Housing, https://www.collinsdictionary.com/dictionary/english/housing

Construction To You (2022), METHODOLOGY: A Comprehensive Guide to Research Procedures, https://sites.google.com/view/effective-risk-assessment/a-comprehensive-guide-to-research-procedures

Husain, H., & Hairom, H. (2021), 79 projek perumahan bernilai RM5.57 bilion terbengkalai, Sinar Harian Online, https://www.sinarharian.com.my/article/165625/berita/nasional/79-projek-perumahan-bernilai-rm557-bilion-terbengkalai

Md. Dahlan, N. H. (2008), The Need to Define 'Abandoned Housing Project' In Peninsular Malaysia: An Analysis. IIUMLJ, https://journals.iium.edu.my/iiumlj/index.php/iiumlj/article/viewFile/45/44

Selangor State Assembly (2015), PROJEK PERUMAHAN TERBENGKALAI, Selangor State Council Official Portal, http://dewan.selangor.gov.my/question/projek-perumahan-terbengkalai-9/

Selangor State Assembly (2016), 75 RUMAH TERBENGKALAI, The Official Portal of the Selangor State Council, http://dewan.selangor.gov.my/question/rumah-terbengkalai/#:~:text=Selain%20itu%2C%20strategi%20pemasaran%20yang,bridging%20loan'%20yang%20membebankan%20pemaju.

Zhuji (2023), Klang, Malaysia — perangkaan 2023, zhujiworld.com. https://ms.zhujiworld.com/my/971260-klang/

INTRODUCING VIRTUAL REALITY (VR) IN RETROFITTING OF THE EXISTING BUILDING: A LITERATURE REVIEW

Mashanim Mahazir, Tan Hong Kin & Diyana Syafiqah Abd. Razak

Abstract

Retrofitting of existing buildings provides the opportunities for upgrading the capacity of the existing buildings. However, with the continuous advancement and increasing accessibility of technology, certain barriers may lessen, hence facilitating a wider acceptance and utilisation of VR in the process of retrofitting pre-existing structures. Currently, these factors are contributing to the relatively poor adoption of virtual reality (VR) technology within this specific domain. The study aimed to apply VR in retrofitting work to raise the awareness about the importance of retrofitting existing buildings in daily life. A total of twenty (20) papers have been reviewed in order to establish a comprehensive review. The results were subsequently gathered in tabular form for evaluating the practical implementation and importance of applying the findings to the pre-existing structure. The significant contribution using VR was, the technology greatly increases the retrofitting process for existing buildings by creating an immersive, interactive, and realistic environment. Further research is needed in looking at the potential benefits of this technology throughout the various stages of construction, including planning, design, implementation, and evaluation that will significantly improve the performance of existing buildings.

Keywords : Retrofitting, Virtual Reality, Construction Technology, Refurbishment, Restoration

Introduction

Virtual Reality (VR) is the combination of the words ``Virtual " and"Reality ","Virtual " is the environment generated using software to simulate the situation in which the humans are experiencing. While “Reality” is the thing that is actually existing, whether it’s being experienced or seen (Moghimi et al., 2016). In general, humans use VR to place themselves into the generated environment to experience and interact with the 3D’s environment. Nowadays, VR is commonly used in different sectors such as entertainment applications, robotics, social sciences and medicines to generate the simulated environment. This will mainly let the consumer experience the “almost real” situation for pleasant, training and education purposes or even occupational safety and health purposes (Woo & Menassa, 2014) for the users to develop their skill within the created environment. This is believed to be helpful in enhancing the required skills for the application of the skill in the existing reality.

Currently, the construction industry is looking at the application of VR for retrofitting to the existing buildings to enhance the buildings performance. Retrofit is defined as an act to add (a component or accessory) to something that did not have it when manufactured. Retrofitting in existing buildings is the components or accessories added to an existing building (Hestnes & Kofoed, 2002) to strengthen the building, improve the building performance or even change the use of building. However, retrofitting existing buildings is complex and high risk. Therefore, the application of VR is used to generate the environment which is to simulate the works during retrofit (Khairi et al., 2017) in reducing the complexity as well as to reduce the risk. This is to aid the onsite construction worker in advance and thus to increase the efficiency of retrofitting work. In addition, the use of VR in retrofitting could reduce the wastage of project resources and provide greater benefits to construction stakeholders.

Retrofitting existing buildings is one of the construction innovations within the Malaysian construction industry. Although there is a wide range of retrofitting technologies available (Gonzalez-Caceres et al., 2019) the use of retrofitting in Malaysia is still at its infancy. Research is needed to look at the methods to identify the most cost-effective measures within the different buildings in Malaysia. Currently, there are many potential retrofitting buildings in Malaysia such as abandoned buildings or occupied buildings that need critical improvement. As a developing country, the Malaysian government and construction industry is currently looking at advance efforts on improving the existing building within the most developed area. Thus, the use of VR in retrofitting to the existing building should be explored in aiding the need of retrofitting. It is acknowledged that there are many barriers related to knowledge and

technical expertise within the different professions of the construction industry in the retrofitting process. Thus, the use of VR may be an initial step as a basis of retrofitting and can be used during the different stages of construction (Dinis et al., 2020) creating a suitable interface for different users to introduce information in the Building Information Modelling (BIM) model. This is needed to ensure effective communication between all the acting parties as many will face the absence of knowledge regarding the building as - is conditions.

Despite the urgency related to these goals, multiple challenges persist within the retro - fitting process shall be acknowledged. Research is thus needed to ensure the applicability of VR in aiding retrofitting of existing buildings as it influences the project decision making. Thus, the study aims to enhance the application of Virtual Reality in the retrofitting projects to promote and propose the retrofitting to existing buildings within Malaysia construction projects. Retrofitting existing buildings will offer significant opportunities to reduce global energy use and greenhouse gas emissions. It is thus considered as one of the main approaches to achieve sustainability in the built environment at a relatively low cost that is in line with Malaysia construction innovation requirements.

Literature Review

Definition of Virtual Reality (VR)

Virtual Reality was typically portrayed as a medium to transfer the information or experiences (Steuer, 1992) and it had been defined in the terms of technological hardware. The applications of VR have shown greater results within the construction industry as it provides solutions for communications and collaborations between different parties. The use of VR required a collection of hardware such as a PC or mobile, headphone, head-mounted displays and other necessary accessories (Hussein & Nätterdal, 2015) to ensure its effectiveness. Virtual Reality (VR) is a technological innovation designed to enhance user experiences and facilitate skill development and training. It offers users the opportunity to repeatedly attempt tasks in a simulated environment (Dinis et al., 2020), minimising the negative consequences of failure. However, this iterative process can be time-consuming. The technology is highly ideal for implementation in high-risk activities or any tasks that require risk mitigation measures (Burdea & Coiffet, 2003) as it provides intuitive, interactive and understandable environments to meet the broader range of users. This application necessitates tasks pertaining to existing buildings, specifically retrofitting, refurbishment, and rehabilitation. This shall include the maintenance of existing building structures as a crucial factor in mitigating the risk such as building collapse. Table 1 shows the definition of VR based on the papers reviewed.

Frequently, Virtual Reality is being defined in a terms of technological hardware (Steuer, 1992) that includes a collection of hardware such as core, either it is a PC or a mobile, head mounted display (HMDs), headphones, motion-sensing gloves or controller and also a software which can deliver the immersive experience (Steuer, 1992) (Hussein & Nätterdal, 2015). Virtual Reality is a medium that applied the specialised technology enabling the users to experience the virtual world (Steuer, 1992) (Schultheis & Rizzo, 2001) (Burdea & Coiffet, 2003) (Sherman & Craig, 2018) and to portray a continuously changing of the real built environment, whose in - formation is often difficult to acquire (Dinis et al., 2020). In addition, the use of Virtual Reality helps to generates the immersive environment which allows the users to have a real-time interaction with the virtual world (Bell & Fogler, 1995) (Burdea & Coiffet, 2003) (Khor, et al., 2016), this will aid the complex work of retrofitting and ensure full benefits is achieved.

Table 1. The definition of Virtual Reality

Author	Definition
Steuer (1992)	VR has been portrayed as a medium, such as telephone or television. VR is defined in terms of particular collections of technological hardware such as computers, head mounted displays, headphones and motion sensing gloves.
Bell & Fogler (1995)	VR is a modernly emerging computer interface categorised by high degrees of immersion, credibility and interaction, with the goal of making the user believe that the user is actually immersing in the computer generated environment.
Burdea & Coiffet (2003)	VR is a simulation in which a computer image is used to create a realistic looking environment.
Hussein & Natterdal (2015)	VR is a collection of hardware, including PC or mobile, head mounted displays, tracking sensor and software to deliver an immersive experience.
Khor, Et. Al (2016)	VR generates an immersive, entirely man-made computer simulated environment with real-time interaction.

A. The Application of Retrofitting Work.

Table 2 presents the various applications of retrofitting in construction projects that have been defined. According to Dubois et al. (2015), the retrofitting of pre-existing buildings is a method that can be employed to attain energy-efficient and sustainable lighting solutions of superior quality. Others such as Ma, Cooper, Daly, and Ledo (2012) suggested the implementation of retrofitting techniques in pre-existing buildings has the potential to effectively diminish energy consumption and mitigate the release of greenhouse gas emissions thus avoiding the deteriorated buildings. By doing so, it is believed that the implementation of retrofitting technology has the potential to enhance the capacity of pre-existing structures(Wu and Li,2017; Ferraioli and Mandara,2017; Yoshimura and Meguro,2004; and Mahdi and Mahdi ,2013) and further providing opportunities to improve the environment. Nevertheless, retrofitting measures can be implemented as a means of enhancing the longevity of existing buildings (Yoshimura and Meguro, 2004) and has become one of the critical needs in promoting innovation for safe construction development.

Table 2. Retrofitting work in construction projects.

Author	Definition
Dubois Et. Al (2015)	Appropriate retrofitting enables the achievement of high quality lighting in energy-efficient and sustainable ways.
Ma Cooper, Daly& Ledo (2012)	The retrofitting of existing buildings can reduce global energy consumption and greenhouse gas emissions.
Wu, & Li (2017)	Retrofitting technology is explored to increase the structural ductility and robustness under extreme conditions.
Ferraioli & Mandara (2017)	Common retrofitting methods are to increase the ductility, stiffness, and the strength of existing buildings.
Yoshimura & Meguro (2004)	Seismic retrofitting reduces the damages to existing buildings during earthquakes.

Mahdi & Mahdi (2013)	Seismic retrofitting is the cost of rescue for rubble removal of temporary buildings and also permanent residence reconstruction. Retrofitting provides the opportunities for upgrading the buildings to withstand different conditions.

B. The importance of Virtual Reality (VR) for retrofitting existing buildings.

According to the data presented in Table 3, it is evident that every task within the construction industry carries a significant level of risk, as even a minor error can result in financial insolvency for one or more parties involved, as well as potential loss of life. Therefore, it is of utmost importance to effectively control and manage on-site risks (Ma et al., 2012) to ensure risk can be mitigated. The responsibility of a project manager encompasses the anticipation, estimation, and mitigation of these risks that need to be supported through innovation in construction. It is believed that the utilisation of virtual reality (VR) technology in the context of retrofitting existing buildings can aid project managers in predicting potential risks that may arise during the retrofitting process. This enables the development of comprehensive solutions that increase the likelihood of project success, while simultaneously reducing the occurrence of construction worker errors. By minimising defects, project profitability can be enhanced.

The utilisation of virtual reality (VR) technology by project managers can be advantageous in the anticipation and mitigation of risks associated with upgrading old structures. By employing VR, project managers can effectively forecast potential risks and implement appropriate measures to optimise project profitability while minimising resource loss. In contrast to traditional paper-based communication, the utilisation of virtual reality (VR) in retrofitting existing buildings offers project managers the opportunity to enhance risk management on site. The primary objective of VR is to enhance user experience by creating a virtual environment that closely resembles the real-world setting. By employing VR technology, project managers can effectively present critical events and conduct reviews based on the generated blueprint (Steuer, 1992). As an illustration, a labourer sustains an injury as a result of an unforeseen wall collapse, which can be attributed to the building's antiquity and inadequate maintenance practices.

Table 3. The importance of application of VR in retrofitting to existing buildings

Author	The importance of VR in retrofitting
Steuer (1992) **Barot, Lourdeaux, Burkhardt, Amokrane & Lenne (2013). Akintoye, & MacLeod(1997). Zou, Kiviniemi, Jones (2017).**	To facilitate risk management of retrofitting works for existing buildings.
Khor Et. Al (2016). Chong & Mohamad Zin R. (2012). Marini, Folgieri, Gadia & Rizzi (2012).	To improve communication between the parties involved in the project.
Khairi M. Jaapar, & Yahya (2017) **Rachel Novotny (2018). Whyte (2003).**	To shorten the retrofit project's duration.
Nagaraju & Reddy (2012).	To improve the resources management of project managers, no matter effectiveness, accuracy
Bell, Fogler (1995, June). **Messner, Yerrapathruni, Baratta, & Whisker (2003, June) Selaru (2012)**	To generate certain experiences and viewpoints that can only be provided by VR

The project manager is responsible for assessing and mitigating risks at the construction site. By employing effective risk management practises, the occurrence of injuries can be minimised. Virtual reality (VR) technology is a valuable tool for project managers as it allows them to gain a comprehensive understanding of the site conditions and anticipate potential risks (Barot et al., 2013). Prior to commencing the project, the project manager can utilise a simulated environment that closely resembles the actual construction site. This enables them to simulate various risk scenarios and devise appropriate precautionary measures to address these situations. Consequently, the risk management plan can be continuously refined to prevent severe injuries during retrofit activities, particularly when VR is employed in retrofitting existing buildings.

Disputes frequently arise within the construction business, constituting a prevalent occurrence that the various stakeholders involved in construction projects must confront. There exist many

methods for resolving conflicts, including arbitration, mediation, the Construction Industry Payment and Adjudication Act (CIPAA), and resorting to litigation in court. Nevertheless, the resolution of these conflicts incurs significant financial expenses, as the stakeholders participating in the project are primarily motivated by profit maximisation rather than expenditure (Chong & Mohamad Zin, 2012). The principle of prevention surpasses that of remediation, as it is of utmost significance to possess a mechanism aimed at mitigating disputes between parties, rather than solely addressing them after they have arisen.

The process of retrofitting necessitates a substantial allocation of resources, encompassing financial capital, human labour, and material inputs. It is an often observed phenomenon that consumers often fail to comprehend the rationale for the substantial financial investment required for retrofitting old structures, given that the fundamental structure of these buildings remains intact. The occurrence of conflict associated with retrofitting is undeniably influenced by this particular element, necessitating the relevant parties to engage in resolution efforts. This paper presents the utilisation of virtual reality (VR) technology in the context of retrofitting existing buildings. The objective is to mitigate client misunderstandings and proactively avert conflicts and disagreements. An illustrative instance involves a conflict that arises between a client and the main contractor as a result of the exorbitant expense associated with adapting an existing structure. In this particular scenario, the contractor has the option to employ a traditional approach, wherein they utilise the "papers" (referring to drawings and reports) throughout the meeting presentation to elucidate to the client the pricey occurrences.

Nevertheless, a critical aspect is in the client's comprehension of the professional explanations and scholarly articles. The conflict will persist if the client fails to comprehend the explanations provided by the main contractor, as a significant portion of clients are hesitant to invest in unfamiliar areas without proper persuasion. The implementation of virtual reality (VR) in this particular context is expected to enhance the efficacy of the main contractor's persuasive efforts, hence increasing the likelihood of success in influencing the client's decision. The client has the ability to access the virtualized environment in order to observe and identify the specific occurrences inside the project that incur significant costs. The client can gain an understanding of resource allocation and associated expenses through the explanation provided by the principal contractor, alleviating any concerns or anxieties. The utilisation of Virtual Reality (VR) technology in the retrofitting process of pre-existing buildings has proven to be highly advantageous in enhancing communication between clients and contractors (Marini, Folgieri, Gadia, & Rizzi, 2012).

Construction activities are known for their significant time requirements, since a typical construction project often spans over several years until its completion. Retrofitting is a form of construction activity that, while less time-consuming than the construction of new buildings, nonetheless requires a significant amount of time to complete the job. The retrofitting of existing buildings is a time-saving process as it involves the reuse of old structures such as walls, doors, slabs, and ceilings. Nevertheless, it is imperative for the surveyors to physically visit the site and assess the structural integrity and appropriateness of such constructions in relation to their compatibility with the proposed design and the incorporation of supplementary components (Khairi, Jaapar, & Yahya, 2017). Upon completion of data collection, the surveyors are required to undertake an analysis of the gathered information. Subsequently, the findings are forwarded to the architect for the purpose of designing the retrofit project. Following this, the design is returned to the client for evaluation, with the aim of determining its alignment with the client's specific scope. The process of collecting information and confirming the design can be time-consuming. In the event that the client is not pleased with the first design, the architect must undertake the task of re-designing the project. This revised design is then sent back to the client, and the architect must await acceptance.

In addition, the duration of the retrofit can be reduced by addressing engineering challenges and uncertainties at the site. This would enable the on-site workers to consistently adhere to the retrofit schedule, thereby minimising the likelihood of clients requesting variation orders. Consequently, the project can be completed within the designated timeframe or potentially ahead of schedule. While retrofitting existing structures is generally less time-consuming than traditional construction projects, it is nevertheless advisable to minimise the project duration due to the significant resource requirements associated with each day of work. There are numerous applications of virtual reality within the construction sector, which serve to visually represent and address issues, hence mitigating uncertainties encountered on site. The implementation of virtual reality (VR) technology in the retrofitting process of pre-existing structures has the potential to reduce project timelines. This is primarily due to the ability of VR to accurately anticipate and manage risks and uncertainties encountered on-site, particularly in the context of large-scale projects. One example of the utilisation of virtual reality (VR) in retrofitting existing buildings is its ability to enhance precision and minimise the need for rework.

Contractors can effectively get precise instructions and objectives by utilising virtual reality technology, which can subsequently be communicated to executive staff. Clear and concise

instruction and information dissemination from contractors to lower-level executive staff is of utmost importance in order to minimise the occurrence of defects resulting from misunderstandings. The occurrence of defect reduction signifies a decrease in the time required to rectify flaws, hence extending the overall duration of the project. In addition, it is worth noting that if the client expresses complete satisfaction with the design at the initial stages of the project, the likelihood of necessitating variation orders would be diminished. Consequently, this reduction in variation orders would also result in a decrease in the contractor's need to request an extension of time. Therefore, the utilisation of virtual reality (VR) technology in the retrofitting process of preexisting structures proves to be highly advantageous in reducing the overall duration of the project.

The availability of resources serves as the foundation for a retrofitting project. The resources encompass several elements such as financial capital, physical materials, human labour, machinery, and tools and equipment. The proficiency and aptitude of a project manager in resource allocation are crucial as they contribute to the mitigation of resource wastage. In the event of any errors occurring in resource allocation, the project manager is liable to incur significant damages. In addition to this, inadequate management of resources can lead to the financial inability of the project manager and even result in the termination of the contract. A competent project manager possesses the ability to proficiently manage resources and assign them in a manner that optimises both effectiveness and efficiency, ultimately leading to the successful completion of the defined scope of work. The temporal and financial aspects of a project are intricately linked to the accessibility of resources (Nagaraju, Reddy, & Chaudhuri, 2012).

The distribution of resources will have a direct impact on the duration of the retrofit project, thus influencing the overall project cost. In the event that a retrofit project entails the completion of a specific task, it is estimated that a workforce of ten individuals will be required to accomplish this task within a timeframe of ten days. If the project manager were to assign only five workers to the activity, it would be challenging for them to successfully do the task within the given timeframe of ten days. Insufficient allocation of resources will result in project delays, as previously indicated by the researcher. Furthermore, it is important to note that the duration of the project directly correlates with the quantity of resources needed. This example illustrates the significance of project managers' precision in resource allocation. Inadequate allocation of resources can lead to project delays, while excessive allocation can result in resource wastage.

The utilisation of virtual reality in the retrofitting process of pre-existing buildings has the potential to enhance the efficacy and efficiency of project managers in resource allocation. The utilisation of virtual reality (VR) technology enables project managers to visually represent the distribution of resources. For instance, project managers can employ virtual reality to observe the impact of various resource allocations on retrofit projects. Through the utilisation of virtual reality technology, the project manager is able to make an estimation of the duration of the project. This enables the manager to assign resources with a higher degree of accuracy, hence facilitating the completion of the project within the designated timeframe while minimising resource wastage. In some cases, this approach may even result in the attainment of a state where there is no wastage of resources, denoted as "0% wastage of resources." Moreover, the utilisation of virtual reality (VR) in the retrofitting process of preexisting structures has the potential to enhance the efficiency of project managers in resource allocation. This is primarily due to the virtualization of all resources, eliminating the need for quantity surveyors to manually generate bills of quantities for various components such as tiles or finishes based on the dimensions of walls, floors, and ceilings. Instead, within the simulated environment, all specifications including types, shapes, and sizes are virtually represented.

The promotion of retrofit projects in Malaysia is rather limited due to the country's status as a developing nation. The prevailing trend among construction companies is to prioritise the development of underdeveloped areas, resulting in a reduced demand for and limited experience in adapting existing buildings. The prioritisation of retrofitting activities on existing structures is mostly influenced by this particular condition. Furthermore, in the event that a retrofit project is proposed, a significant portion of construction businesses allocate substantial resources towards the research and development of retrofitting techniques for pre-existing structures. The implementation of virtual reality in the retrofitting process of pre-existing structures offers a potential solution to these challenges. According to Messner, Yerrapathruni, Baratta, and Whisker (2003), the utilisation of advanced graphical models can facilitate the acquisition of knowledge and experience by experts in a more efficient manner. Through the utilisation of virtual reality technology, specialists are able to repeatedly engage in retrofitting exercises, hence generating diverse sets of data and experiences. This iterative process aids in the advancement of research endeavours. The utilisation of virtual reality yields data that is more precise and reliable in contrast to conventional research and development methods. This is due to the fact that virtual reality applications offer a platform for experts to conduct experiments that closely simulate real-life conditions at construction sites.

In addition, the utilisation of virtual reality (VR) for the presentation and explanation of data and information proves to be more convenient compared to traditional methods such as using papers. This is due to the ease with which partners can comprehend the data and information, enabling them to provide feedback on research and development initiatives. Moreover, experts can engage in the simulation of retrofitting activities in a virtualized environment, employing various management techniques, and subsequently observe the disparities between these approaches. It is worth noting that even within a single organisation, it is uncommon to encounter two similar projects that do not differ significantly in terms of management practices (Selaru, 2012). Consequently, organisations must continually enhance their capabilities through the execution of diverse or similar projects. By employing VR in the retrofitting of existing buildings, experts can acquire knowledge and experience, even in the absence of extensive precedent references within the Malaysian context.

Methodology

A total of twenty (20) papers were referred to in writing an extensive review on the application of VR in retrofitting the existing building. The review commenced by delineating the definition of virtual VR and its associated components. Subsequently, a total of 20 sets of paper were compiled. All scholarly articles were thoroughly reviewed and synthesised in order to examine the practical implementation and significance of utilising VR technology in the process of retrofitting pre-existing buildings (Nakano & Muniz, 2018).

The paper review was conducted meticulously, and the study flow as depicted in Figure 1.

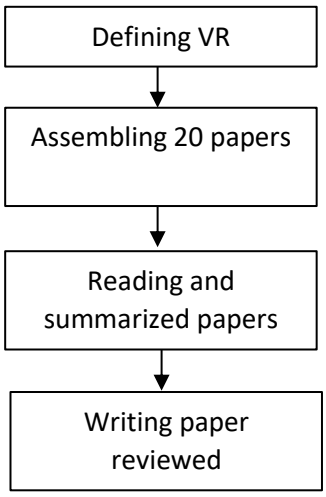

Figure 1. Paper review process

Result And Discussion

Based on the data presented in Table 4, the author has organised the order of significance regarding the implementation of VR for retrofitting existing buildings as follows:

i. In order to enhance the efficacy of risk management in retrofitting projects for pre-existing structures.

ii. To enhance the level of communication among the stakeholders engaged in the project.

iii. VR is capable of generating unique sensations and perspectives that are exclusive to this technology.

iv. In order to reduce the time of the retrofit project, several strategies can be implemented.

v. In order to enhance the management of resources by project managers, it is imperative to focus on improving effectiveness, accuracy, and efficiency.

Result tabulated in Table 4 also shows that, “to convenience risks management of retrofitting works for existing buildings” has become the most significant factor of the importance of application of VR in retrofitting the existing buildings. “To improve resource management of project managers” has become the most unpopular factor in retrofitting existing buildings.

Table 4. Mapping and ranking for the importance of application of Virtual Reality in retrofitting to existing buildings

Factors / **Authors**	**To convenience risks management of retrofitting works for existing building**	**To improve the communication between the parties involved in the project**	**To shortens the retrofit project’s duration**	**To generate certain experience and viewpoints that can be provided by VR**	**To improve resources management of project managers**
Steuer J. (1992)	x				

Akintoye & MacLeod (1997)	x				
Barot Et. Al (2013)	x				
Zou, Kiviniemi, Jones (2017)	x				
Khor Et. Al (2016)		x			
Marini, Folgieri, Gadia, Rizzi (2012)		x			
Chong & Mohamad Zin (2012)		x			
Whyte (2003)			x		
Khairi, Jaapar & Yahya (2017)			x		
Rachel Novotny (2018)			x		
Nagaraju Reddy (2012)					x
Bell & Fogler (1995)				x	

Messner, Yerrapathruni, Baratta, & Whisker, V. E. (2003)				x	
Selaru, (2012)				x	
Frequencie	4	3	3	3	1
Score	1	2	3	4	5

One primary significance is in the facilitation of risk management for retrofitting operations conducted on pre-existing buildings, as evidenced by the presence of four scholarly journal references. The three key importance factors, each supported by three journal articles, are as follows: enhancing communication among project stakeholders, leveraging unique experiences and perspectives offered by VR, and reducing the duration of retrofit projects. Lastly, it is crucial to enhance the resource management capabilities of project managers, encompassing factors such as efficacy, accuracy, and efficiency. Based on the scholarly literature, the use of VR has been identified as a potential means to enhance the risk management process in retrofitting existing structures. The authors assert that Virtual Reality can be instrumental in anticipating and predicting project risks. The authors have identified a second significant benefit of VR namely its potential to enhance communication among project stakeholders. VR can serve as an effective medium for transmitting messages and information, offering a superior platform for conveying information and enabling users to gain a more comprehensive understanding of the content being communicated.

According to the authors, the utilisation of VR in retrofitting projects offers unique experiences and perspectives that are exclusive to this technology. VR has the capability to create a simulated environment in which users can engage in real-time interactions and experiments without any negative consequences. This enables users to gather essential information and knowledge that can be utilised to enhance the retrofitting project. The researcher concluded that the utilisation of VR has the potential to decrease the duration of retrofit projects. This assertion is supported by findings from various scholarly journals, where authors have reported that the implementation of VR technology in projects has proven highly effective in minimising errors and discrepancies. Consequently, this can lead to a reduction in the time

required to rectify defects or mistakes made by contractors. Nagaraju & Reddy(2012) asserts that the utilisation of Virtual Reality inside a project has the potential to enhance the project manager's ability to optimise resource allocation and resource management.

The propose application of VR for retrofitting to the existing building

Firstly, the rationale for suggesting the utilisation of VR in the process of retrofitting old buildings is to aid the complexity of retrofitting to the existing building. In addition to its aforementioned significance, the utilisation of VR in retrofitting existing buildings is a cost-effective approach. The produced environment has the potential to be repurposed, since the construction corporation may choose to sell it to institutions for instructional use. Generating a conducive environment within a university setting might pose challenges, despite the presence of an IT department and IT professionals. This can be attributed to two key factors: restricted availability of materials, such as drawings and specifications, and the time-intensive nature of the process. According to Hussein and Nätterdal (2015), construction companies possess the necessary resources to create a virtual environment that can effectively engage students in learning about retrofitting works. This virtual environment is believed to be more appealing and comprehensible to students compared to traditional classroom instruction. In addition, the construction industry can utilise the generated projects as a means of providing training opportunities for interns, recent graduates, and workers. This practice facilitates a better comprehension of their respective responsibilities and tasks (Barot, Lourdeaux, Burkhardt, Amokrane, & Lenne, 2013).

The utilisation of VR in the retrofitting process of pre-existing buildings proves advantageous in facilitating the generation of design and construction plans for conceptual structures. As an illustration, the Kuala Lumpur Performance Art Centre (KLPac) in Malaysia serves as a pertinent example. This theatre was meticulously transformed from a preexisting railway warehouse, entailing a financial investment of RM30 million and a construction period of 15 months (Khairi, Jaapar, & Yahya, 2017). The integration of VR technology in retrofitting projects has the potential to maintain costs at their current levels while simultaneously reducing construction duration. This is achieved through the ability of virtual reality to predict and mitigate risks and uncertainties, resulting in the development of effective solutions outlined in detailed blueprints. Construction organisations have the ability to utilise virtual reality technology in order to produce conceptual designs and assess their feasibility in terms of constructability (Novotny, 2018).

Conclusion

The daily energy consumption showed a consistent upward trend, with a significant proportion of this consumption being attributed to the building sector (Martínez-Molina, Tort-Ausina, Cho, & Vivancos, 2016). The promotion of energy conservation within the building industry is of significant importance. The implementation of energy-saving systems in pre-existing buildings has proven to be beneficial for environmental conservation, as evidenced by studies conducted by Castleton, Stovin, Beck, and Davison (2010) and Pisello, Petrozzi, Castaldo, and Cotana (2016). These systems have effectively reduced the energy consumption of buildings. Numerous green building initiatives are currently available, although a significant oversight by construction businesses lies in their failure to recognise the potential for retrofitting existing buildings into environmentally sustainable structures.

The following approaches outline the proposition for the utilisation of VR in the context of retrofitting existing buildings. The application of VR in retrofitting existing buildings can be effectively promoted through the education sector. This is because students, who often have limited visualisation abilities, are more likely to be inspired and interested in this application. Consequently, they may exhibit greater enthusiasm for virtual reality compared to traditional paper-based study methods (Messner, Yerrapathruni, Baratta, & Whisker, 2003). In addition to this, the construction sector has the potential to offer training programmes focused on the utilisation of virtual reality technology for retrofitting purposes in existing buildings, thereby promoting the participation of workers in these educational courses.

This holds significant utility within the context of Malaysia, a nation currently undergoing developmental processes. Insufficient or poor maintenance of buildings might potentially lead to significant and tragic incidents. It is imperative for the government to enact legislation mandating owners of older buildings to undertake retrofitting measures in order to bring their properties into compliance with established standards. The government have the capacity to employ several methodologies in order to assess and project the durability of historical structures. Concurrently, the government can also facilitate the adoption of virtual reality technology by building owners to visually demonstrate the appearance of retrofitted buildings.

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References

1. Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and management in construction. *International journal of project management*, *15*(1), 31-38.

2. Barot, C., Lourdeaux, D., Burkhardt, J. M., Amokrane, K., & Lenne, D. (2013). V3S: A virtual environment for risk-management training based on human-activity models. Presence, 22(1), 1-19

3. Bell, J. T., & Fogler, H. S. (1995, June). The investigation and application of virtual reality as an educational tool. In Proceedings of the American Society for Engineering Education Annual Conference (pp. 1718-1728)

4. Burdea, G. C., & Coiffet, P. (2003). Virtual reality technology. John Wiley & Sons

5. Castleton, H. F., Stovin, V., Beck, S. B., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. Energy and buildings, 42(10), 1582-1591.

6. Chong, H. Y., & Mohamad Zin, R. (2012). Selection of dispute resolution methods: factor analysis approach. Engineering, Construction and Architectural Management, 19(4), 428-443.

7. Dubois, M. C. et al., (2015). Retrofitting the electric lighting and daylighting systems to reduce energy use in buildings: a literature review. Energy Research Journal, 6(1), 25-41

8. Ferraioli, M., & Mandara, A. (2017). Base isolation for seismic retrofitting of a multiple building structure: design, construction, and assessment. Mathematical Problems in Engineering, 2017

9. Gonzalez-Caceres. A, Rabani. M, & Wegertseder Martínez, P. M. (2019) A systematic review of retrofitting tools for residential buildings IOP Conference Series: Earth and Environmental Science, Volume 294, Sustainable Built Environment Conference 2019 Tokyo (SBE19Tokyo) Built Environment in an era of climate change: how can cities and buildings adapt? 6–7 August 2019, The University of Tokyo, Japan

10. Hestnes, A. G., & Kofoed, N. U. (2002). Effective retrofitting scenarios for energy efficiency and comfort: Results of the design and evaluation activities within the OFFICE project. Building and Environment, 37(6), 569–574. https://doi.org/10.1016/S0360-1323(02)00003-3

11. Hussein, M., & Nätterdal, C. (2015). The benefits of virtual reality in education-A Comparison Study.

12. Khairi, M., Jaapar, A., & Yahya, Z. (2017). The application, benefits and challenges of retrofitting the existing buildings. IOP Conference Series: Materials Science and Engineering, 271(1). https://doi.org/10.1088/1757-899X/271/1/012030

13. Khor, W. S., et al. (2016). Augmented and virtual reality in surgery—the digital surgical environment: applications, limitations and legal pitfalls. Annals of translational medicine, 4(23)

14. Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. Energy and Buildings, 55, 889–902. https://doi.org/10.1016/J.ENBUILD.2012.08.018

15. Mahdi, T., & Mahdi, A. (2013). Reconstruction and retrofitting of buildings after recent earthquakes in Iran. Procedia Engineering, 54, 127-139

16. Marini, D., Folgieri, R., Gadia, D., & Rizzi, A. (2012). Virtual reality as a communication process. Virtual Reality, 16(3), 233-241

17. Martínez-Molina, A., Tort-Ausina, I., Cho, S., & Vivancos, J. L. (2016). Energy efficiency and thermal comfort in historic buildings: A review. Renewable and Sustainable Energy Reviews, 61, 70-85.

18. Messner, J. I., Yerrapathruni, S. C., Baratta, A. J., & Whisker, V. E. (2003, June). Using virtual reality to improve construction engineering education. In American Society for Engineering Education Annual Conference & Exposition.

19. Moghimi, M., Stone, R., Rotshtein, P., & Cooke, N. (2016). The Sense of embodiment in Virtual Reality. Presence: Teleoperators & Virtual Environments, 25(2), 81–107. https://doi.org/10.1162/PRES

20. Nagaraju, S. K., & Reddy, B. S. (2012). Resource Management in Construction Projects–a case study. Resource, 2(4).

21. Nakano, D., & Muniz, J. (2018). Writing the literature review for empirical papers. Production, 28. https://doi.org/10.1590/0103-6513.20170086

22. Pisello, A. L., Petrozzi, A., Castaldo, V. L., & Cotana, F. (2016). On an innovative integrated technique for energy refurbishment of historical buildings: Thermal-energy, economic and environmental analysis of a case study. Applied Energy, 162, 1313-1322.

23. Rachel Novotny (2018). 4 Ways Virtual Reality in Construction Makes an Impact on Commercial Construction.

24. Selaru, C. (2012). Resource allocation in project management. International Journal of Economic Practices and Theories, 2(4), 274-282.

25. Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. Journal of communication, 42(4), 73-93

26. Whyte, J. (2003). Innovation and users: virtual reality in the construction sector. Construction Management and Economics, 21(6), 565-572. Woo, J. H., & Menassa, C.

(2014). Virtual Retrofit Model for aging commercial buildings in a smart grid environment. Energy and Buildings, 80, 424–435. https://doi.org/10.1016/J.ENBUILD.2014.05.004

27. Wu, C., & Li, J. (2017). Structural protective design with innovative concrete material and retrofitting technology. Procedia Engineering, 173, 49-56

28. Yoshimura, M., & Meguro, K. (2004, August). Proposal of retrofitting promotion system for low earthquake-resistant structures in earthquake prone countries. In 13th world conference on earthquake engineering (pp. 1-6)

29. Zou, Y., Kiviniemi, A., & Jones, S. W. (2017). A review of risk management through BIM and BIM-related technologies. Safety science, 97, 88-99

ARE GREEN BUIDINGS ALWAYS GREEN?

Goh Cheng Siew

Introduction

The building and construction industry has long been criticised for its extensive impacts on the environment, regardless of greenhouse gases emission, construction waste, pollution (including noise, air and water pollution), habitat destruction, depletion of natural resources, or destroying the balance of biodiversity. According to GABC (2016), energy consumption in buildings and for building construction takes more than one third of global final energy use and gives rise to nearly 25% of global greenhouse gases emission. The building sector therefore has the biggest potential in mitigating impacts to the natural environment. Being green has evolved as a new trend in the built environment, and it particularly plays a vital role in contributing to environmental sustainability.

In response to the call for climate change mitigation, an increasing number of green buildings have been built to reduce greenhouse gas emissions. On one side, there are 36,259 certified BREEAM projects, with 22114 BREEAM new construction projects as of 24 November 2023 (BREEAM, 2023). On the other side, U.S. Green Building Council has also recorded a total of 167,854 LEED-certified projects globally as of November 2023 (USGBC, 2023). The exponential increase of green buildings however does not guarantee superior performance of the built environment in creating a greener and more comfortable environment to live and work. Over the past few decades, more studies (Goh, 2022; Newsham et al., 2009; Thatcher and Milner, 2016) revealed that green buildings may not necessarily live up to people's expectations in delivering the sustainable development goals, thus demurring the status quo of green buildings. This paper therefore will review the state-of-the-art of green building performance and debunk the myth of green buildings for meeting net zero carbon goals in a very short term.

Green Buildings and Their Development

Green building is recognised as a flagship for creating a more sustainable built environment, as an effort to transform the carbon intensive construction industry into a more environmentally friendly sector. As defined by U.S. EPA (2016), green building is a practice of creating structures or buildings with the use of environmentally responsible and resource-efficient processes throughout a building life cycle from sitting to design, construction, operation,

maintenance, renovation and deconstruction. This definition regards green buildings as a process of pursuing green standards, instead of an end product. From here, it is clear that green building is a dynamic process that should not rest or end, until it reaches the end of the building life cycle.

In the green movement, several green building assessment schemes have emerged in the market to guide construction stakeholders in the delivery of green buildings. These assessment schemes give measurement indicators to stakeholders in determining how green a building is. Due to geographical and cultural consideration, each of the assessment schemes has different emphases on the criteria for green buildings in. The popular assessment schemes in the market include LEED (US), BREEAM (UK), Green Star (Australia), BEAM Plus (Hong Kong), Green Mark (Singapore) and GBI (Malaysia).

Green buildings need to be designed, constructed and managed in an environmentally friendly manner. Green features are introduced to minimise negative impacts of the built environment on climate, natural environment, biodiversity and surrounding communities. The introduced green features intend to encourage efficient use of resources; adopt renewable energy; reduce carbon emission and pollution; decrease water use; improve indoor environment quality; promote reuse and recycling of materials; and improve biodiversity. Innovation also bears a credit by creating new ways of making the structure and built environment more resilient and flexible in order to accommodate changes of people's needs for building use over time, hence minimising the need to renovate and demolish buildings due to being obsolete.

The performance of green buildings could be examined from different perspectives in terms of building life cycle and stakeholder. Each green building has its own unique design and management characteristics based on regional, cultural, economic, political and institutional factors and this leads to different expectations for the attainment of green building goals. Regardless of the differences, the main purpose of adopting green building approaches is to greatly reduce environmental impacts of the building construction industry. The main criteria of assessing the performance of green buildings include energy, materials, water, waste, indoor environmental quality, health and wellbeing, land use/sites, transportation, management and innovation. In most instances, green buildings are designed to reduce carbon emissions throughout the building life cycle, with improved comfort and wellbeing without compromising the desired functionality and durability.

Overall Positive Performance of Green Buildings

With the incorporation of green design features, green buildings could have performed better than conventional buildings in terms of energy efficiency, environmental impacts, and comfort level. In 2008, the US General Services Administration (GSA) commissioned a post-occupancy evaluation to 12 green buildings to examine environmental performance, financial metrics and occupant satisfaction and found that the studied buildings on average perform better in occupant satisfaction than the national average for US commercial buildings (GSA Public Building Service, 2008). In 2010, the same research team reassessed the green building performance with additional 10 green buildings and the whole building performance are observed as follows: a) aggregate operating costs are 19% lower than the baseline; b) carbon dioxide equivalent emissions are 34% lower than conventional buildings; c) energy use intensity are 10% -25% better than multiple referenced baseline (Fowler et al., 2010).

Similar trends are also observed in other studies. Newsham et al. (2009) found that LEED buildings on average used about 18 -39% less energy per floor area than their conventional counterparts while Thatcher and Milner (2016)'s study shows significant improvements in air quality elements in green buildings. In a more recent study, Liu et al. (2018) also revealed green buildings generally have higher user satisfaction in the areas of cleanliness, lighting, air freshener, visual privacy, acoustic, temperature and the overall satisfaction, regardless of cold zone, hot summer-cold winter zone and hot summer-warm winter zone. Overall, green buildings would have better user comfort and improved environmental impacts if they are properly administered in accordance with the recommended design and operational manual. It is, however, important to note the aforementioned green building performance is examined in aggregate to give the promising results of green performance.

In a recent study conducted by Zhou et al. (2022), green buildings in Beijing were found to have achieved good performance in aspects of land use, energy efficiency, indoor environment quality, and user satisfaction. Green residential buildings in Beijing have an improved performance in air quality, thermal environment, sound environment and overall user satisfaction. The same study also revealed that green buildings achieve good quality of public space and optimal land use, in which the investigated green residential buildings have an average centralised green space area of 1.8m^2 per capita, with an average green space rate exceeding 35%.

Are Green Buildings Always Green?

With the above examples, can we assume that all green buildings always live up to people's expectations towards green or environmental sustainability? Surprisingly, there is no consistent success attained by the green buildings and research demonstrates that green buildings do not necessarily bring positive performance in their life span as anticipated by the project parties and long awaited by the public. The following gives some examples of deviated green building performance with regards to their environmental and social targets.

As for energy and environmental related performance, Newsham et al. (2009) unveiled that 28-35% of LEED buildings used more energy per floor area than their individually matched buildings in the 2003 Commercial Building Energy Consumption Survey database. No statistically significant relationship between LEED certification level and energy use intensity was found, although there are correlations between energy credit and the awarded certification levels (Newsham et al., 2009). On the other hand, Goh (2014) also found several certified green buildings did not achieve their desired green goals in the post occupancy stage. In her study, the wind turbine installed at the rooftop of green buildings experienced some failures in harvesting and converting wind energy, not to mention the closure of the wind turbine system for a period of time due to unexpected malfunctions. Geng et al. (2019) also reported a significant deviation in green building performance in which some buildings perform even poorer than their traditional counterparts, not to mention the baseline performance.

Zhou et al. (2019) conducted a post occupancy investigation in 40 certified green buildings in China and uncovered that most implemented technologies in green buildings are poorly rated, and these include utilisation of renewable energy, non-traditional water source, HVAC automatic monitoring and controlling system, as well as power (cold & heat use) metering and charging. The same study also revealed that the average energy use intensity (EUI) of the studied green shopping mall buildings was higher than the city average baseline, although the average EUI of green residential buildings was almost the same as the city’s average.

At the same time, green buildings may not perform satisfactorily in meeting their social related expectations. Paul and Taylor (2008) found no clear evidence that green buildings are more comfortable than conventional buildings. Thatcher and Milner (2016) also revealed that green buildings demonstrated no significant improvements related to psychological well being, job satisfaction, propensity to stay in the organisations, organisational image and absenteeism.

These indicate that not all green buildings are more successful than others in delivering satisfactory results for environmental or social sustainability.

Why Failed to Deliver the Promised Green Performance?

Green buildings need to be evaluated based on the actual performance, instead of the assumed results or modelled performance. Most people assumed that green buildings would definitely perform greener and better than traditional buildings. However, literature above has suggested a gap for numerous green buildings in delivering their green targets. During the design stage, green building performance is normally simulated with flat assumptions, speculations and extrapolated principles and this simulated result did not turn out in reality. Gaps are therefore resulted from the designed model result and real building performance when the buildings are in use later. Conniff (2017) put the blame on the overly optimistic energy modelling and found it as the root cause of the performance gap of green buildings. As revealed by Conniff (2017), refurbished apartment buildings in Germany missed the predicted energy savings by 5-28% while fifty leading-edge modern buildings in the UK were reported to use up to 3.5 times more energy than the design had allowed for and produce approximately 3.8 times the predicted carbon emission. These again suggest that the promising performance of all green buildings is not fully supported, and sometimes the result could be contradictory.

Geng et al. (2019) pointed out that most of the previous green building studies were in fact design-oriented, in which the studies mainly highlighted what green buildings “should” perform during the operation. The “designed” building performance shall not, in any way, represent the real performance results of green buildings, hence concluding the superior performance of green buildings as a silver bullet to meet the global net zero carbon target.

Researchers also reported conflicts in delivering multiple objectives in green buildings. For instance, air tightness for improved energy performance in green buildings has resulted in poor indoor air quality and overhearing in the transition seasons (Geng et al., 2019). The use of a centralised HVAC system also puts the user's thermal comfort at risk with the loss of personalised control (Goh & Yang, 2022). Privacy in open design, overheating risks from natural ventilation, humidity and occupant wellbeing are amongst the controversial issues reported in literature of green building studies in recent years.

Discussion

The above performance gaps of green buildings could arise from a failure of putting humans at the centre of planning and designing green buildings (Goh, 2022; Goh and Chong, 2023). Green building comprises numerous interconnected systems made up of various technologies, materials, and information systems for creating a resilient and sustainable environment to live and work. Multidimensional socio-technical aspects should be taken into account in the design and operation of green buildings (Goh, 2022). Interplay between humans and the environment in green buildings should not be neglected. Green buildings are often designed based on the desires of designers and developers, while the actual demands, needs and expectations of end users in the operation stage have not been fully considered (Goh, 2022; Zhou et al., 2022). These result in the performance gaps, technology abandonment, and investment waste of green buildings, hence raising doubts in the cost benefit analysis of the green built environment. The interplay between end-users and environment in green buildings is a key factor to determining the success of green buildings. Human behaviour variability is one of the main drivers that may counteract the intended green building outcomes, particularly when end users operate the green buildings in an inappropriate manner.

According to Zhou et al. (2022), most construction organisations are pursuing the publicity value and have insufficient enthusiasm to apply green (with wait-and-see attitudes). In absence of direct immediate economic benefits, there is no urgency and enthusiasm of stakeholders in the construction value chain to vigorously apply green in their buildings. The authors also revealed that there is a lack of people-oriented service consciousness in green buildings. Most of the operation teams have a low expertise level, low green cognition, a low informatisation level, and frequent personnel flow and the traditional property management models, thus leading to the poor implementation of green buildings (Zhou et al., 2022).

A value proposition to shift green buildings from energy-focused or carbon-oriented projects to people-oriented projects has therefore emerged. Engaging and empowering users is of urgent importance to optimise the performance of green buildings. In addition to advance green technologies, interactive information systems shall be incorporated into the building system, hence allowing users to communicate their needs and requirements constantly. Feedback can ensure the building management systems respond to the changing user needs and environmental conditions in a dynamic manner. Human-centric approaches are therefore advocated to make green buildings more adaptive, responsive and resilient based on physical, physiological, and psychological characteristics (Goh, 2022). By deploying human-centric solutions, building functions in green buildings can be improved with more contextualised

operational strategies in accordance with the site, functions and user requirements. Goh (2022) emphasised the integration of two main principles of human-centric solutions in green buildings to leverage green building features for seamless connections between users and environment: i) accessibility and availability, and ii) functionality, serviceability, and flexibility. Additionally, the support of information and communication technologies with sensing, inferring and communication abilities is critical to make green buildings more perceptual and cognitive (Goh and Chong, 2023). With the strengthened green management capacity of end-users, the integration of human-centric solutions provides a measure to make green buildings more engaging and adaptive. This would ultimately help mitigate significant variance of green buildings between the design and the operation and solve the underperforming issues of green buildings.

Conclusion

There is no constant guarantee of success that green buildings will outperform conventional buildings. Although no direct victory can be assured by green buildings, this paper in no way suggests the green building movement should be discontinued. Green building, or a broader term - sustainable building is always the right thing to do and it is critical to do it right, with efforts from all the parties. An aspiration of green buildings can only be fulfilled with the full support and commitment of green users, green facilities managers, green communities, etc. The interactions between users and buildings are of great importance to determine how successful a green building is. An integrated life cycle approach would be a valuable model to reap full benefits of green buildings. Human-centric approaches have therefore been proposed to provide synergies between users and environment in green buildings, hence reducing performance gap issues associated with green building over the past few decades. The move towards green buildings and sustainable cities is no longer a scientific and technological transformation but also a social transition. However, more research is necessary to develop a holistic human centric approach in green buildings to necessitate the delivery of net zero carbon goals by 2050.

References

BREEAM (2023). Explore BREEAM. Retrieved from 24 November 2023, from https://tools.breeam.com/projects/explore/buildings.jsp

Conniff, R. (2017). Why Don't' Green Buildings Live Up to Hype on Energy Efficiency? Yale Environment 360. Retrieved 21 April 2018, from https://e360.yale.edu/features/why-dont-green-buildings-live-up-to-hype-on-energy-efficiency

Fowler, K. M., Rauch, E. M., Henderson, J. W., & Kora, A. R. (2010). *Re-assessing green building performance: A post occupancy evaluation of 22 GSA buildings* (No. PNNL-19369). Pacific Northwest National Lab: Richland, WA (United States).

GABC (2016). Global Status Report 2016: Towards Zero-emission Efficient and Resilient Buildings.

Geng, Y., Ji, W., Wang, Z., Lin, B., & Zhu, Y. (2019). A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction. *Energy and Buildings*, *183*, 500-514.

Goh, C. S. (2014). Development of a capability maturity model for sustainable construction. *HKU Theses Online (HKUTO)*.

Goh, C. S. (2022). Unlocking Human Factors for More Resilient and Sustainable Built Environments: Human Centric Solutions. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1101, No. 7, p. 072011). IOP Publishing.

Goh, C. S., & Chong, H. Y. (2023). Opportunities in the Sustainable Built Environment: Perspectives on Human-Centric Approaches. *Energies*, *16*(3), 1301.

Goh, C. S., & Yang, K. S. (2022). A Key to Make Sustainable Buildings People Centric: User-environment Interactions. In *Proceedings of the PAQS Congress*.

GSA Public Building Service (2008). Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings. Retrieved 22 April 2018, from https://www.usgbc.org/Docs/Archive/General/Docs4308.pdf

Liu, Y., Wang, Z., Lin, B., Hong, J., & Zhu, Y. (2018). Occupant satisfaction in Three-Star-certified office buildings based on comparative study using LEED and BREEAM. *Building and Environment*, Vol 132, pp. 1-10.

Newsham, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but…. *Energy and Buildings*, Vol *41* Issue 8, pp 897-905.

Paul, W. L., & Taylor, P. A. (2008). A comparison of occupant comfort and satisfaction between a green building and a conventional building. Building and Environment, Vol 43 Issue 11, pp 1858-1870. doi: 10.1016/j.buildenv.2007.11.006

Thatcher, A., & Milner, K. (2016). Is a green building really better for building occupants? A longitudinal evaluation. *Building and Environment*, Vol *108*, pp 194-206.

USGBC (2023). LEED Rating System. Retrieved 23 November 2023, from https://www.usgbc.org/projects

US EPA (2016). Green Building. Retrieved from https://archive.epa.gov/greenbuilding/web/html/about.html

Zhou, H., Zhao, Y., Zhang, Z., Geng, Y., Yu, J., & Lin, B. (2022). Post occupancy investigation of 40 certified green buildings in Beijing: Results, lessons and policy suggestions. *Journal of Building Engineering*, *60*, 105153.