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LIFE CYCLE COST (LCC) OF UNIVERSITY BUILDING MAINTENANCE: A SYSTEMATISED REVIEW

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Abstract

An effective maintenance management is predominantly important for university building, but commentators advocated it is more important for the maintenance strategies to be designed based on the efficient use of capital and resources. Commentators pointed out there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works. To overcome this, the life cycle cost (LCC) economic assessment technique has been recommended as an ideal solution that can facilitate the university agencies in the decision making to determine the most optimum building maintenance cost and financial capability over the anticipated study life. However, there is a need to identify any establishment link between the LCC with university building maintenance. Therefore, this paper is prepared with the objective to present the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance. A comprehensive review was conducted by searching databases, titles and abstracts screen, full-text analysis and data extraction on the targeted articles that have discussed the university building maintenance or indicated any form of building maintenance management elements with specific reference to LCC. The articles were identified from Google Scholar, Emerald, SAGE Scopus, My Cite, SpringerLink, as well as other databases. The findings indicate that many studies focused on building maintenance, however, there has been no specified guidelines concentrated on the LCC analysis of university building maintenance, which can be deliberated for practical guidance of maintenance management by the university agencies to attain value for money and making the university buildings and teaching and learning facilities economically wise use over the long term.

Keywords: University building, Life cycle cost, Maintenance

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INTRODUCTION

Education is a critical component in the Malaysian Strategic Thrust to drive the country to become a high-income and developed nation. The government is keen to improve Malaysian education sector to become a hub of education excellence that provides quality education throughout the learning life cycle, beginning from pre-school to university (Olanrewaju et al., 2010; Olanrewaju & Abdul-Rashid, 2015). Since independence, the Malaysia's economy has been guided by five-year economic development plans, and each economy plan shows that the education sector was given prioritize on development budget in terms of value and policy for education improvement. The education buildings in the universities are like any other buildings, that require various maintenance services for implementation to meet the intended purposes throughout the anticipated building life (Kim et al., 2016). The university buildings are designed and built for diverse faculties that have different specialisations with the objective to provide venue for favourable academic-related functions that include teaching, research, consultancy, and other related academic activities (Buys, 2009; Khalil et al., 2016; Kim et al., 2016; Palis, 2019; Odemakin and Abiodun, 2019). An effective maintenance management is predominantly important for university building, but commentators advocated it is more important for the maintenance strategies to be designed based on the efficient use of capital and resources (Abdul Lateef et.al., 2010; Zulkarnain et al., 2011; Kevin Chuks et.al., 2012; Campbell, Reyes-Picknell, et al., 2015; Kim et al., 2016; Puķīte & Geipele, 2017; Akomolafe, 2018; Afifah, 2019; Palis, 2019). Commentators pointed out there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works. To overcome this, the life cycle cost (LCC) economic assessment technique has been recommended as an ideal solution that can facilitate the university agencies in their decision making to determine the most optimum building maintenance cost and financial capability over an anticipated study life (Ayob et al., 2011, 2016a; PWD, 2023). However, there is a need to review and identify any establishment link between the LCC with university building maintenance, including how the LCC has been thought and discussed by scholars and researchers for university building maintenance practice. Therefore, this paper is prepared with the objective to present the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance.

OVERVIEW OF LIFE CYCLE COST (LCC) IN UNIVERSITY BUILDING MAINTENANCE

Maintenance is defined as a sequence of events that involves the implementation of various technical and administrative actions to take maintain the building

structure, systems and components to the intended functions and performance throughout the anticipated period. (Puķīte & Geipele, 2017). Good maintenance implementation will keep building's value and comfort living environment for building occupants. A well-maintained building requires minimum maintenance repair to remedy defects against deterioration and elongate life span at the optimum cost (Abdul Lateef et.al., 2010; Kim et al., 2016; Akomolafe, 2018; Abdullahi & Chinwendu, 2020; Zulkarnain et al., 2011; Shehu et al., 2020). Effective maintenance management is viewed from the feasibility perspective to ensure the building and its facilities will be operated and maintained in accordance with the consumer expectations and efficient use of capital resources (Afifah, 2019). The performance of building can refer to various meanings depending on the context, but it is commonly used to describe the routine act or regular operation in supporting the execution of tasks or activities in the building. All the maintenance activities of public assets and facilities in Malaysia are administrated by the Ministry of Works (MOW) through its technical agency i.e., Public Works Department (PWD). The PWD oversees the construction and maintenance of public assets and facilities, such as roads, government buildings, schools, hospitals, airports, harbours, piers, and related engineering work (PWD, 2023). Reports show that the Malaysia government has allocated high development fundings from the five-year economic plans to the education sector. However, the capital needed to operate and maintain the whole education buildings nationwide has significantly increased every year (Olanrewaju et al., 2010; Kim et al., 2016; Palis, 2019; Khalisah et.al., 2020). For example, in 2004, the Malaysian government spent RM304 million for the maintenance work of teaching and learning facilities in public universities. But it was reported the maintenance expenditure spent in 2008 had been highly increased double than the amount spent in 2004 to RM600 million (Olanrewaju et al., 2010: Khalisah et.al., 2020). Indeed, the education development budget had been increased by more than 42% over 20 years before 2010 (Olanrewaju, 2010). Nevertheless, the budgets allocation to public universities had been slashed to 70%, with 30% of the budgets were decided to be contributed by the universities from self-generated revenue. The budget cuts were particularly severe in in 2017, where the public universities received a total allocation of RM 6.12 billion, about 19.23 percent decreased from the RM 7.57 billion budget obtained in 2016. (Abdullah, 2017).

According to Khalil et al. (2016), and Odemakin and Abiodun (2019), the university buildings have to be maintained with effective maintenance management strategies by the in-charge agencies during the in-use phase to provide comfort indoor atmosphere for academic-related functions. However, there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works

(Abdul Lateef et.al., 2010; Zulkarnain et.al., 2011; Kim et al., 2016). Life cycle cost (LCC) has been identified as ideal solution that can facilitate the university agencies in their decision making to determine the most optimum building maintenance cost and financial capability over the anticipated study life. However, there is a need to identify any establishment link between the LCC with university building maintenance. LCC is a useful economic assessment technique that can facilitate building owner or investor to estimate and determine the most optimum cost of owning, operating, maintaining, financial and disposing of buildings, facilities, or systems until the end of service life. In addition, LCC can compare the most cost-effectiveness between the competing maintenance methods or alternatives (Akomolafe, 2018; PWD, 2023).

In the Malaysia education sector, LCC economic assessment technique has been programmed as one of important topics in the economic subjects for the quantity surveying bachelor's degree programmes in several universities. Besides, the LCC has been enumerated as a subject matter in the postgraduate teaching courses including postgraduate research. This good development indicates a critical demand of LCC economic assessment technique to be delivered in undergraduate and postgraduate studies of the universities to prepare the students with theory, methodology and practical use of LCC, the benefits, including the LCC data, analysis and output knowledge for assisting them in the future decision making process with regard to economic viability to achieve the best value for money (ASTM International, 2010; BS ISO 15686-5, 2008; BSI, 2008; NATO Research and Technology Organization, 2009; Kelly & Hunter, 2009; Kirk & Dell, 1995, also as cited by Ayob, 2014; PWD, 2023).

Maintenance Management Models

Maintenance management is one of the important aspects in the institutional management of university strategic goals for providing a conducive learning environment that can enhance students' performance (Asiabaka; 2008, Hasbollah et al., 2018; Amaratunga and Baldry, 2000). As advocated by Karamera and Marion (2003), there is a considerable correlation between the students' performance and satisfaction level of educational setting and teaching and learning services they receive in the classes. The maintenance management for university building can be classified into following two categories:

i. Planned Maintenance: it is scheduled at fixed intervals of a certain number of days, months, quarters, seasons, years, or some other predetermined interval. The intervals are based on how much the service part in question has been used (Jenvald, 2020). In planned maintenance, the maintenance work is conducted according to the organization's recommended maintenance procedures. It does not require the consumer's request to preserve and

maintain the facilities. The purpose of planned maintenance is to determine what works need to be completed and how they need to be implemented. It is categorized as planned maintenance when the maintenance works on building and facilities are scheduled in advance to prevent damage and failure (Onawoga, & Akinyemi, 2010).

ii. Unplanned Maintenance: needed unexpectedly, not scheduled in advance, or based on user's request (Rahman, 2007). The unplanned maintenance is commonly executed when the defect or failure is not expected (Mobley2002, Jenvald and Hovmoller, 2020). The unplanned maintenance is preferred to be conducted when the element or part is damaged or defected that require new replacement (Onawoga, & Akinyemi, 2010). It is more difficult to estimate the unplanned maintenance rather than planned maintenance. This maintenance work is.

According to BS 3811:84, maintenance is the sum of all technical and related administrative actions meant to maintain or restore an object to a state in which it can the required functional performance. The literature study has identified several common models of building maintenance management. The identified models were reviewed and classified according to the two maintenance management categories, as presented in Table 1.

Table 1: Classification of Building Maintenance

Author	**Type of Maintenance**	
	Planned Maintenance	**Unplanned Maintenance**
British Standards Institution BS 8544: (2013)	Corrective maintenance, Preventive maintenance, Proactive maintenance	Reactive maintenance
Olanrewaju and Abdul-Aziz (2015)	Preventive maintenance, predictive maintenance, and proactive maintenance	Corrective maintenance
Salem M.A. Abuznaid (2018)	Preventive maintenance, Predictive maintenance, and Scheduling maintenance	Corrective maintenance
P. Palis (2019)	Planned maintenance, Predictive maintenance, and Preventive maintenance	Corrective maintenance
Nor Hapira Nadia et al. (2020)	Preventive maintenance, Statutory maintenance	Corrective maintenance Backlog maintenance.
N. Sipumelele et al. (2022)	Condition-based Maintenance, Reliability-centred maintenance	Total productive maintenance

Reactive maintenance or corrective maintenance

Reactive maintenance, also known as corrective maintenance or breakdown maintenance, is a maintenance approach in which repairs and maintenance works are carried out in response to the equipment failure or malfunction. According to GWilliam, (2022). reactive maintenance is the world's oldest method of maintenance. Reactive maintenance, sometimes known as "run-to-failure," is the process of performing maintenance chores after an asset has failed. The goal of reactive maintenance implementation is to restore the assets to operational status as soon as possible. Reactive maintenance, as opposed to planned maintenance, happens in response to unforeseen breakdowns or failures. Reactive maintenance is frequently utilized when the preventative maintenance resources are limited, or equipment failure is unpredictable. However, it is often seen as less efficient than proactive maintenance procedures, as it can result in higher expenditures, increased downtime, and lower overall equipment reliability. Corrective maintenance involves performing maintenance after a component or system has failed (Servio, 2015). Corrective maintenance involves finding, isolating, and fixing defects to ensure equipment, machines, or systems function properly (TWI, 2021).

Backlog maintenance

Backlog maintenance is the process of managing and updating a prioritized list of tasks, issues, or requirements that need to be addressed in the project or system (Department of Health Guideline, Queensland Health, 2017). Effective backlog maintenance management is essential for analysing maintenance demand, guiding maintenance programs, and identifying and managing hazards. For example, in road infrastructure, the is backlog maintenance defined as the cost of bringing the existing condition to a predetermined level, and hence has a monetary value. In the oil and gas industry, the backlog maintenance encompasses of a work package perspective that examines which work orders are not completed by the due date (Harald Rødseth and Per Schjølberg ,2017). This maintenance entails assessing, revising, and reprioritizing backlog items on a regular basis in response to shifting priorities, new information, feedback, and changing project objectives. By keeping the backlog maintenance current and relevant, greater focus can be given to the most important activities that can deliver value efficiently. This strategy is often employed in agile and iterative development methodologies.

Preventive maintenance

Preventive maintenance is a proactive approach that is often planned and scheduled in advance to minimize disruption or prevent failure to operations that can trigger unplanned downtime. Normally, the preventive maintenance is scheduled and then executed after a defined amount of time, or when a specific

system has been used to lower the probability of its failure (Basri et al., 2017). According to Tabikh and Khattab (2011), the preventative maintenance is a broad notion that encompasses all operations conducted on a machine to reduce unplanned downtime. According to Alhourani et al. (2021), the preventive maintenance was established in the 1950s to prevent unexpected failures of machines and equipment. It was designed and executed to prevent system breakdowns after prolonged use (Kimura, 1997). Such failures can create substantial delays and interruptions in the manufacturing lines, that had significantly increased costs and customer discontent (Al-Hourani et al., 2018). The preventive maintenance involves scheduled inspections, repairs, and upkeep of machinery, systems, or infrastructure to identify and address potential issues that can cause breakdown or failure. According to Olanrewaju and Abdul-Aziz, (2015), the preventive maintenance helps to identify any malfunctions and prevent failures or breakdowns before they occur. It may include routine inspections, replacement of components according to a predetermined schedule or based on usage metrics.

Proactive maintenance

According to Muganyi and Mbohwa (2018), proactive maintenance has been identified as a very useful method that can help to improve equipment reliability and performance. It prioritizes reliability and safety by reducing, automating, or simplifying maintenance tasks. It is also a preventative maintenance technique that focuses on finding and resolving possible issues before the occurrence of equipment failure or downtime Voisin et al. (2010). It entails methodical planning, scheduling, and execution of maintenance tasks to ensure equipment reliability and performance. The proactive maintenance solutions seek to increase equipment reliability, reduce downtime, and optimize maintenance costs by preventing problems rather than reacting to them after they occur.

Scheduling maintenance

According to Hasanuddin et. al., (2024), implementing scheduled maintenance practices within building facility management significantly mitigates risks, minimizes unplanned maintenance expenditures, and enhances overall building performance. The scheduling maintenance entails planning and coordinating maintenance tasks to ensure that they are completed at the proper times to minimize operational disruptions and increase maintenance efficiency. It includes the process of determining when the maintenance work should be completed, assigning resources, and coordinating activities to make the best and efficient use of time and resources. An effective maintenance scheduling is critical for guaranteeing the equipment reliability, availability, and performance while reducing downtime, costs, and operational disturbances.

Predictive maintenance

Predictive maintenance is an advanced maintenance plan that employs data analytics, sensor technologies, and machine learning algorithms to forecast when the equipment may fail, allowing repair to be performed proactively before the breakdown happens. According to Servio, (2015), the predictive maintenance anticipates damage/damages in future. The predictive maintenance can be periodic with fixed time intervals or predictive with forecasted failure times. Zhu et al., (2024) stated that the predictive maintenance, is also known as condition-based maintenance, that is implemented to prevent unexpected breakdowns that can increase building maintenance expenses. Almost all project management programs are time-based, and maintenance activities rely on elapsed time. The equipment's failure behaviour can be predictable. According to Fiix, (2021), the predictive maintenance uses data analysis to discover irregularities and potential problems of the equipment and its related process, allowing for early correction to prevent failure. Instead of following a set timetable or waiting for indicators of breakdown, the predictive maintenance uses real-time data and predictive analytics to uncover patterns and trends that indicate approaching equipment failure or degradation. The predictive maintenance is frequently used in the industries like manufacturing, energy, transportation, and utilities, where the equipment downtime can provide serious financial adverse effects. However, the predictive maintenance devices are more expensive to install, making them ideal for specialist building features, particularly in the manufacturing industry (Olanrewaju and Abdul-Aziz, 2015).

Condition-based maintenance (CBM)

Markus (2003) stated that the condition-based maintenance involves measuring an asset's condition and using the data to estimate necessary maintenance. The goal of CBM is to prevent breakdowns and extend preventive maintenance periods. This will boost the performance of the asset. The CBM analyses equipment status in real-time and uses diagnostics and prognostics to predict mechanical system failures. Telford et al., (2011). Condition-based maintenance is a maintenance method that involves the monitoring of equipment status in real time to decide when the repair work should be conducted. The condition-based maintenance assesses the health and performance of equipment using sensors, data analysis, and prediction algorithms, rather than following a fixed maintenance timetables or waiting for faults to occur. The condition-based maintenance helps to improve maintenance operations, increase equipment reliability, and maximize operational performance by leveraging real-time data analytics.

Reliability-centred maintenance

Reliability-centred maintenance is a comprehensive maintenance strategy that aims to increase the dependability, safety, and efficient use of equipment and systems at the optimum maintenance costs. The reliability-centred maintenance has created a decision model that emphasizes the importance of preventative maintenance to minimize costly repairs. Investing huge resources is not cost-effective as it exceeds the cost of errors (Nord et al., 1997; Liedberg, 2021). It is a one-of-a-kind tool used by reliability, safety, and/or maintenance engineers to create optimal maintenance plans that describe the criteria and tasks that must be completed to achieve, restore, or maintain a system's or equipment's operating capacity. (Brauer,1987). It is a systematic approach to ensuring that physical facilities function as intended. Reliability-centred maintenance is a key approach for regular preventative maintenance. (Sajaradj et al., 2019). Unlike traditional maintenance methods that focus on routine or reactive maintenance chores, the reliability-centred maintenance stresses a methodical and data-driven assessment of equipment reliability and maintenance requirements. Overall, the reliability-centred maintenance is a proactive and methodical maintenance management approach that can assist businesses in improving the dependability, safety, and efficient use of business assets, while preventing downtime. This method is adopted when the equipment dependability is crucial for business operations in certain industries, e.g., manufacturing, aviation, transportation, and utilities.

Total productive maintenance (TPM)

According to Liedberg (2021), defined total productive maintenance as an approach to reduce or eliminate downtime that allow maintenance and production operators to perform daily maintenance using autonomous maintenance. It emphasizes the importance of maintenance as a fundamental aspect of work (Liedberg, 2021). When the TPM and Total Quality Management (TQM) can be worked together to improve operational performance. The TPM will help to minimize costs by reducing scrap and producing fewer defective goods (Modgil and Sharma, 2016). The TPM is an improved maintenance strategy that is established to increase equipment efficiency, minimise failures and encourage autonomous maintenance through the involvement of employers and employees in the organisation (Bhadury, 2000; Cheong et al., 2021). It is one of the lean manufacturing approaches that can help to improve equipment performance by increasing the production rate, equipment availability and overall productivity of manufacturing. It helps to achieve zero breakdown, zero defect, zero accident that preserves the building functions (Azid, 2018).

METHODOLOGY OF STUDY

The study targeted articles that discussed on the Life Cycle Cost (LCC) and university building maintenance management. The identified articles for review were searched from Google Scholar, Emerald, SAGE Scopus, ISI Index, My Cite, SpringerLink, ISRA publications, as well as other databases.

Search Strategy

The searching strategy implemented in the study was designed with a systematized analysis of literature that evaluates the internal validity of each article following the advised given by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al., 2009; Booth 2009; Bello, 2021). The study looked for related academic publications covering all years until 15 March 2024 and covered all related studies based on Life Cycle Cost (LCC) and university building maintenance management. A structured approach was designed to categorize potentially important database research that in line with the best practices on the systematic literature review. The database search consisted of three components: (1) the identification of relevant terms relating to LCC (keyword quest), and the subject headings: 'Public Building maintenance,' 'educational or education building maintenance,' or 'university building maintenance. or (2). was identifying Malaysian research using keywords like "world country," and "Malaysia". Then those search strings were put together using Boolean operators such as "or" and "and" for all possible combinations. In addition to the database searches, the reference lists of the academic literature and the relevant papers were also searched (Bello et al., 2021)

Inclusion and exclusion criteria

All the publications of life cycle cost of university building maintenance that were found from the search activities, have been added to the list of articles in this paper. The search process is in line with the PRISMA as illustrated in Figure 2. A set of inclusion and exclusion criteria was established to select papers that eligible to be included in the systematized review, which includes as follows: 1. Identification of relevant studies by searching the databases; 2. Screening and removal of duplicate records; 3. Eligibility checks; and 4. Inclusion of articles that are most suitable in this systematized review (Bello et al, 2021). Based on the outcome of PRISMA assessment as presented in Figure 1, a total of 530 records were found by the research and other sources, 227 duplicate records were removed that left 303 records. Following that, 183 records were removed at the title screening stage, and the remaining 120 records were further assessed according to inclusion and exclusion criteria that has withdrawn 78 records. 42 records were found relevant for full text assessment, and therefore, as a result, 33 records were

found not relevant to withdraw, which finally left 9 records that are found eligible for inclusion in the systematized review.

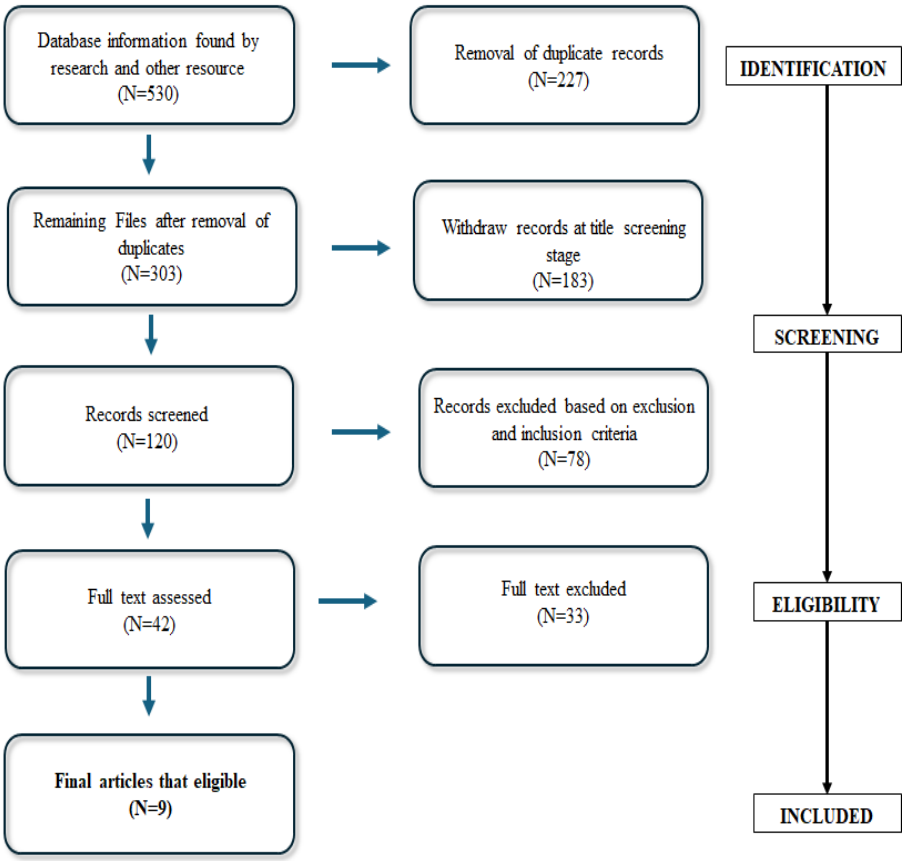

Figure 2: Prisma Flow Diagram (modified from Bello et al., 2021)

Data Extraction

The required data were extracted from each of the nine (9) qualifying papers that include the following details: name of the author(s), the title of the article, date of publication, name of publication journal/conference, research method adopted in the study and a summary of the findings. The details of extracted data from the nine (9) qualified articles are presented in the following section 4.0.

FINDINGS

Overview of Review Findings

Paper 1 (T. Puvaneswary (2014) focused on activity-based life cycle cost process model of facilities maintenance for public universities authors of corroborated that

to identified high-priority facilities and developed an Activity-Based Life Cycle Cost (AB-LCC) model for public facilities upkeep an effective cost management in building facilities maintenance must provide. On their part, the authors of Paper 2 (Ayob and Abdul Rashid, 2018) found that there is no model, system or guideline has been established in the Malaysian construction industry that can facilitate the LCC estimators to trace, define, collect, and update cost data as inputs into the process of producing reliable LCC outputs. Paper 3 (Huang et al., 2018) presents the outcome of study on reducing the environmental impacts caused by the Chinese university dormitories development. The study has identified two improving opportunities to reduce the said environmental impact: 1) improving building with deep renovation for current dormitories and implementing low energy buildings standards for new built dormitories; and 2) increasing the use of low environmental impacts building material by implementing carbon tax on main building material and timbers as structure material. Paper 4 (Chang-Sian Li and Sy-Jye Guo 2018) presents the outcome of study on life cycle cost analysis of maintenance costs and budgets for the university buildings in Taiwan using the BPN, MR and SLR models. The study outcomes have established that the BPN model is more superior cost prediction model of university buildings maintenance rather than MR and SLR to obtain the optimal life cycle maintenance scenario.

In Paper 5, (Dilawar Husain & Ravi Prakash (2018)), presents the outcome of study on the life cycle ecological footprint assessment of academic building. The study explains the ecological impacts of a building, the methodology used in the estimation of life cycle ecological footprint (LCEF total) of building, life cycle resources consumption (e.g., energy, water, building materials, manpower, etc.) and life cycle waste assimilation. Paper 6 (Bidi and Ayob, 2015) presents the outcome of investigation on the quality of cost data as inputs for LCC analysis of maintenance during the in-use phases of university building. The study has established the quality criteria of data required as inputs for producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building. In the paper 7 the title is to investigation of LCC analysis practice of university mosque maintenance during the in-use phase (Salem, 2018) found that the type of mosque maintenance during the in-use phase are scheduled maintenance, routine maintenance, and preventive maintenance where there is the common maintenance type that can be practiced in mosque maintenance works.

Table 2: The nine (9) qualifying papers included in the systematized review.

No	Author & Year Publish	Title	Key Findings/Conclusion
1	T. Puvaneswary (2014)	Activity-based life cycle cost process model of facilities maintenance for public universities	It presents the Activity-Based Life Cycle Cost (AB-LCC) model for public facilities upkeep.
2	Ayob, Mohd Fairullazi, Abdul Rashid, Khairuddin (2016a)	Protocol of Life Cycle Cost (LCC) data input requirements process	It presents the protocol that can facilitate the LCC estimators to trace, define, collect, and update cost data as inputs into the process of producing reliable LCC outputs.
3	Huang, Lizhen; Liu, Yongping: Krigsvoll, Guri: Johansen, Fred (2018)	Life cycle assessment and life cycle cost of university dormitories in the southeast China: Case study of the university town of Fuzhou	It presents environmental impacts caused by the Chinese university dormitories development and two improving opportunities to mitigate the impacts.
4	Chang-Sian Li & Sy-Jye Guo (2018)	Life Cycle Cost Analysis of Maintenance Costs and Budgets for University Buildings in Taiwan	It presents the LCC of maintenance costs and budgets for the university buildings in Taiwan using the BPN, MR and SLR models.
5	Dilawar Husain & Ravi Prakash (2018)	Life Cycle Ecological Footprint Assessment of an Academic Building	It presents the life cycle ecological footprint assessment (LCEF total) of academic building, resources consumption (e.g., energy, water, building materials, manpower, etc.) and waste assimilation.
6	Bidi, Nor Khalisah and Ayob, Mohd Fairullazi (2015)	Investigation of Quality of Cost Data for Life Cycle Cost Analysis in University Building Maintenance	It presents the quality required for the cost data as inputs for LCC analysis of maintenance during the in-use phases of university building.
7	Salem M.A. Abuznaid (2018)	Investigation of LCC Analysis Practice of University Mosque Maintenance During the In Use Phase	It presents scheduled maintenance, routine maintenance and preventive maintenance that are practiced in mosque maintenance works
8	Mysarah Maisham, Hamimah Adnan, Noor Akmal Adillah Ismail and Noor Aisyah Asyikin Mahat (2019)	Developing a Research Methodology for Life Cycle Costing Framework for Application in Green Projects	It presents the state of LCC in practice in green projects for both public and private sectors

No	Author & Year Publish	Title	Key Findings/Conclusion
9	Bidi, Nor Khalisah and Ayob, Mohd Fairullazi and Aripin, Srazali and Mat Noor, Noorsidi Aizuddin. (2020)	A study on quality of cost data in life cycle cost analysis of maintenance during the in-use phases of university building	It presents the quality state of cost data as inputs for each of the cost components in producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building

(Maisham 2019 et al.,) in their Paper 8, presents a research methodology for Life cycle costing framework for application in green projects. The study has established that the application of LCC practice is still limited in green projects, although the research trends of LCC are increasingly important in this green project areas. Both the public and private sectors are still wedged to the traditional procurement approach of project development, looking towards more on short term initial cost rather than the optimum long-term cost over the economic life. Lastly, Papers 9 Bidi et al., (2020) presents the outcome of study on the quality of cost data required as inputs for each of the cost components of LCC analysis of maintenance of university building. The study has established that the operation and maintenance cost data of the university building are not readily available, accessible, current and reliable to be used as quality inputs for producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building.

Thematic Areas

The thematic areas of the studies were categorized according to the key discussion points reported by the authors in their papers. According to the mode score in Table 3, the highest mode score in this variable is item 4 (M=3, item 4 – 33.33%, papers 4,6,9) which the authors discussed on the cost data issues and LCC analysis of university building maintenance. The second rank are shared by items 1 and 5, with 2 authors each respectively (M=2, items 1 and 5 – 22.22%, papers 1,2-item 1, papers 5,8-item 5) which the authors discussed on the administration and management of LCC, and framework for LCC analysis in university building maintenance.

Table 3: Thematic Focus of the studies and mode rank

No	Thematic areas	Paper	Mode rank
1	Administration and management of LCC	1,2 (22.22%)	2
2	Public Engagement and involvement in the development of LCC in maintenance	7 (11.11%)	3
3	Analysis of Case studies on LCC of building maintenance	3 (11.11%)	3
4	Cost data issues and LCC analysis of university building maintenance	4,6,9 (33.33%)	1
5	Framework for LCC analysis in university building maintenance	5,8 (22.22%)	2

DISCUSSION

The outcome of the study has proven the established links between the Life Cycle Cost (LCC) with university building maintenance. From the 530 review papers listed, only nine (9) papers met the requirements for inclusion of systematised review. All the 9 papers are research papers, but only two research papers presented framework for LCC analysis in university building maintenance, i.e., Papers 5 and 8 and the thematic areas is ranked second place of highest mode score. Therefore, based on the outcome of systematised review, it is not misconception to state that no specified guidelines or protocol concentrated on the LCC analysis of university building maintenance is currently available, including in Malaysia, which can be deliberated for practical guidance of maintenance management by the university agencies to achieve economic efficiency and value for money decision making in facilitating them to manage the building and teaching and learning facilities economically wise use over the long term. In addition, the findings show many literatures discussed on university building maintenance, but very limited literatures reported on the LCC of university building maintenance, i.e., only 9 papers.

CONCLUSION

This paper has presented the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance. Good maintenance management for education buildings is important to make Malaysia as the hub of education excellence. It prolongs the service life of university buildings to provide conducive learning environment that can enhance students' academic performance. It also helps to keep the university building's value economically wise use and makes staff and students' living comfort and enjoyable. On the contrary, neglecting maintenance will provide various adverse impacts to building owners and occupants. Although LCC has been identified as an ideal and useful economic assessment technique to facilitate the university agencies in their decision making to design and implement maintenance strategies based on the efficient use of capital and resources, it is deemed appropriate for

recommendation of further study to be carried to develop a specified guidelines or protocol concentrated on LCC analysis of university building maintenance that can revolutionize the traditional building maintenance policy based on annual budget availability for preventing unforeseen restriction that can hinder the comprehensive implementation of university building maintenance works.

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