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Indicative Planning Decision Using Life Cycle Costs Considerations for Green Building Development Projects

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Abstract: In the current critical economy, demands have exceeded the mere creation and construction of green buildings. The primary obstacle to expansion in the green building business is the impression of elevated costs linked to these structures. It has been commonly recognised that evaluating project costs based on initial expenditures is inadequate. Consequently, life cycle costs (LCC) aids owners and clients in making informed decisions on building materials during the project's design phase. The criteria or components of LCC should ideally be established before the decision to advance with the project. Nevertheless, LCC components for sustainable projects are disjointed and the pieces are not organised into an appropriate system. This scenario, exacerbated by the lack of adequate information on LCC components for sustainable projects, poses difficulties for project stakeholders in implementing LCC. Hence, the purpose of this study was to ascertain LCC components and their respective significance in the context of a green building project, in order to inform planning decisions. The primary tool for data collection was a questionnaire survey. A purposive sampling strategy was employed to disseminate the questionnaire to 84 stakeholders engaged in Green Building Index (GBI)-rated office projects in Kuala Lumpur. The survey indicated that the respondents concurred with the 23 elements of LCC as guiding planning criteria for green construction initiatives. The analysis using the relative importance index revealed that, out of the total 23 components, the 10 most important LCC components were materials costs, initial costs, management costs, installation costs, labour costs, green building certification costs, insurance, safety management costs, design and professional costs and equipment costs. The findings are useful in helping green project stakeholders make planning decisions before moving forward with the development of green projects.

Keywords: Life cycle costs, Cost component, Green building projects, Green office, Sustainability

INTRODUCTION

The construction sector is advancing swiftly and has emerged as a fundamental pillar of the nation. Concerns about environmental degradation have led to the recognition of green buildings as a key tool for sustainable

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construction development. Since the United Nations conference on the Human Environment in 1972, Malaysia has consistently tackled environmental issues through numerous national plans, policies and legislation. The recent *Twelfth Malaysia Plan 2021–2025* emphasises the construction sector's commitment to sustainability by promoting the use of green building design to enhance resources, energy and water efficiency (Economic Planning Unit, 2021). The construction industry accounts for 40% of global energy consumption and contributes to one-third of GHG emissions due to energy performance standards. The Ministry of Energy, Technology, Science, Climate Change and Environment (Kementerian Tenaga, Teknologi Hijau dan Air [KeTTHA]), currently referred to as the Ministry of Environment and Water, formulated the Low Carbon City 2020 policy to fulfil the Sustainable Development and Climate Change Agenda and to improve energy efficiency in low-carbon cities (Mustafa, 2012). The Low Carbon Cities Framework 2017 (KeTTHA, 2017) incorporated green building as an element of the green neighbourhood planning guideline, which seeks to motivate developers to assess development applications for planning permits and to design their development ideas (as shown in Figure 1).

Figure 1. Components of design criteria in the Green Neighbourhood Planning Guideline, Federal Department of Town and Country Planning

The government has institutionalised measures to bolster the economy and foster a healthy environment, while concurrently formulating policies to further sustainable development. The government has recognised policy guidelines, green rating schemes and materials labelling such as the MyHIJAU mark, SIRIM Eco-label, Green Building Index (GBI), Penarafan Hijau JKR, GreenRE, MyCREST, Sustainable INFRASTAR and Government Green Procurement (GGP) guidelines to support green initiatives. Among the evaluation criteria issued in the GGP guidelines is addressing life cycle costs (LCC) in procuring green products and construction materials (De Giacomo et al., 2019; Khalil et al., 2021; Adham, Siwar and Aziz, 2015). LCC functions as an essential instrument to aid clients, developers and other stakeholders in making investments that optimise value for money. Consequently, LCC is crucial in enabling owners and clients to make educated decisions on building materials that promote sustainability.

Client expectations have gone beyond the mere design and construction of green buildings in the current crucial economy. However, the primary obstacle to expansion in the green building industry is the impression of elevated initial costs linked to these structures (Wimala, Akmalah and Sururi, 2016; Weerasinghe and Ramachandra, 2018). It has long been acknowledged that evaluating project costs exclusively based on early expenditures is inadequate. In the asset life cycle, evaluating economic performance is crucial for decision-makers to analyse and allocate discernible value from original capital and operating expenses to relevant stakeholders. Effective cost planning necessitates the consideration of both initial and future expenses alongside various initiatives (Ahmad, 2011). Khalil et al. (2021) presented a life cycle perspective, employing LCC tools to inform judgements on the initial and prospective worth of building ownership. During the design stage, LCC computed the entire ownership costs, encompassing operational and maintenance expenses for construction elements, to yield a more precise estimation. This research sought to identify the LCC components and their significance to the green building project, functioning as an essential decision-making instrument before project initiation.

In order for decision-makers to evaluate and allocate identifiable value from original capital and operational expenditures to the right shareholders throughout the asset's life cycle, economic performance monitoring is essential. Value for money should be considered in various forms apart from design and construction expenses when evaluating building products and facilities. In Malaysia, the short-term action plans of GGP on goods and services emphasise the policy and legal framework surrounding the use of LCCs (Kahlenborn, Mansor and Adham, 2014). The Public Works Department (PWD), the primary facilitator of the government building project, released the standard LCC guideline known as “Garis Panduan Kos Kitaran Hayat” (PWD, 2023). Every stage of the project must discuss an important cost component outlined in the guideline.

According to Zainol et al. (2014), the maintainability of sustainable buildings affects economic, environmental and social factors because implementing sustainable operations and maintenance can be expensive, impractical and challenging. Therefore, it is important to identify LCC components for green buildings, as these costs significantly impact the building’s operation. Furthermore, the selection of sustainable or low-carbon materials utilised in green buildings must also be taken into account. However, it remains unclear which components lead to high operational and maintenance costs in these buildings.

Shabrin and Kashem (2017) further supported this viewpoint by noting that lower operational costs associated with green buildings reduce the payback period. Nonetheless, Dwaikat and Ali (2018) believed that it is crucial to focus on reducing energy costs throughout the entire life cycle of the building to achieve optimal energy performance in buildings. Understanding how to calculate energy consumption is crucial, as it primarily stems from the operation of various systems like air conditioning and lighting. Gopanagoni and Velpula (2020) asserted that energy expenses constitute a substantial 67% of the whole LCC cost, exceeding the initial construction expenditures of the structure. Moreover, the design and orientation of the building can greatly influence its energy consumption. A well-designed building can take advantage of natural light and ventilation, reducing its dependence on energy-intensive systems. However, despite the importance of these factors, there is a noticeable gap in the available research. Previous studies have shown that information regarding LCC components specific to green buildings is often fragmented and lacking in detail. This highlights the need for a more comprehensive understanding of which components are most effective in minimising total ownership costs in the context of green building development. Identifying these optimal components is essential for ensuring that green buildings not only meet sustainability goals but also remain economically viable over their entire life span.

LITERATURE REVIEW

Determinants of Life Cycle Costs Components for Green Projects

LCC are defined as the costs of the product or system throughout its complete life or functional period duration. The International Organisation for Standardisation (2017) defines LCC as the comprehensive costs of an asset or its components throughout their life cycle while adhering to the performance criteria established in ISO 15686-5:2017 (International Organization for Standardization, 2017). Dwaikat and Ali (2018) define LCC as the total expenses associated with building design and construction, operational activities, maintenance and eventual disposal at the end of a building's life cycle. Consequently, the implementation of an LCC analysis may result in an enhancement in the initial value. Nonetheless, LCC, according to its mechanics, represents a compromise for reduced future financial obligations; for instance, maintenance and operational expenses. The study by Gopanagoni and Velpula (2020) demonstrates that operational, maintenance and disposal expenses of a structure exceed its initial costs. The LCC of a green building is comparable to that of traditional structures. However, there is a lack of clarity in defining its components, which is why research should be conducted to examine the LCC components specific to green buildings.

The literature review found that an initial list of LCC components for the green office buildings was compiled and divided according to the project phases: (1) planning phase, (2) conceptual and design phase, (3) procurement and tendering phase, (4) construction phase and (5) operation and maintenance phase. The phases are aligned to the RIBA Plan of Work 2020 (RIBA [Royal Institute of British Architects], 2020), which describes the overall life cycle of a project from the preliminary planning phase until the end of the operation phase. The planning phase is the process of creating a development plan for a construction project. This comprises a project description, feasibility analysis, costs estimation, location details, project schedule and project delivery schedule. In the design phase, the client's requirements, translated into an acceptable design, are formulated (Bohari et al., 2020; De Giacomo et al., 2019; Ahmad, 2011). The procurement process encompasses contract preparation, contractor selection, pricing determination and consideration of economic aspects to fulfil the client's requirements.

Project-specific contractual agreements are essential for ensuring consistency and clarity about the information required and the timing of its extraction from the design process for procurement or stakeholder engagement, as outlined in the RIBA Plan of Work 2020 (RIBA, 2020). Figure 2 provides an initial list of 23 LCC components associated with the green buildings project. These elements were synthesised from diverse literature and prior studies pertinent to economic studies, development and life cycle expenses.

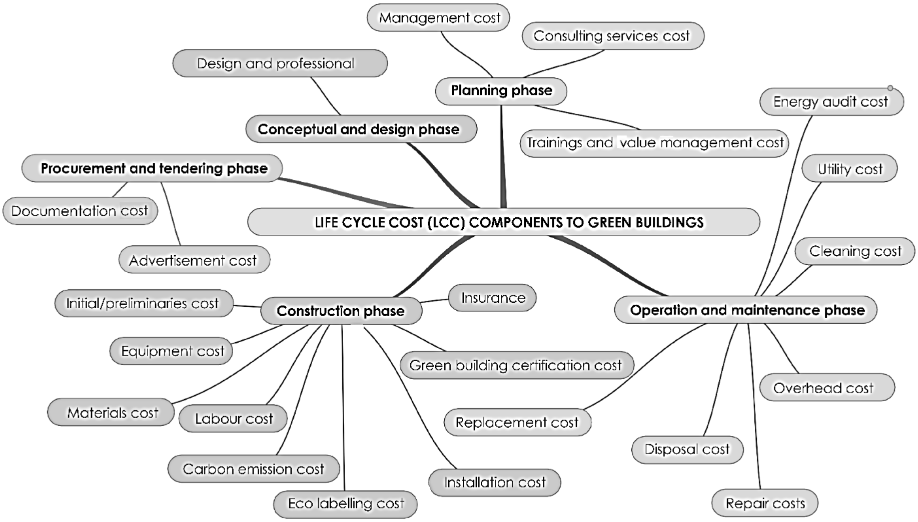

Figure 2. Components of LCC

In the planning phase, the costs elements associated with the green building projects are consulting service costs (PWD, 2023; Shabrin and Kashem, 2017; Tsai et al., 2014), management costs that involve training and value management (VM) costs (PWD, 2023; Khalil et al., 2021; Putro, 2019) and administrative costs (Putro, 2019). Meanwhile, design and professional costs in the design phase was mentioned by several authors (PWD, 2023; Abidin and Azizi, 2021; Gopanagoni and Velpula, 2020; Alshamrani, 2020; Dwaikat and Ali, 2018; Tsai et al., 2014). During the procurement phase, two key components were the costs and advertising costs (PWD, 2023; Khalil et al., 2021; Oduyemi et al., 2018). During the construction phase, the costs elements are materials costs (Khalil et al., 2021; Zhang, Wu and Liu, 2018; Tsai et al., 2014). Other studies indicate that LCC costs include equipment (PWD, 2023; Khalil et al., 2021; Alshamrani, 2020; Dwaikat and Ali, 2018; Oduyemi et al., 2018; Tsai et al., 2014) and labour costs (Dwaikat and Ali, 2018; Tsai et al., 2014). Under the construction phase, there are carbon emissions (Tsai et al., 2014) and safety management costs (PWD, 2023; Putro, 2019). Abidin and Azizi (2021) and Zhang, Wu and Liu (2018) highlight that green building certification costs need to be considered as LCC components for green buildings, while Hajare and Elwakil (2019), Weerasinghe and Ramachandra (2018) and Dwaikat (2016) highlight the importance of insurance in LCC calculation. Other than that, eco-labelling costs are also associated with the green building projects during the construction phase (Khalil et al., 2021). Lastly, in the operation phase, utility costs are among the most mentioned in related studies (PWD, 2023; Khalil et al., 2021; Putro, 2019; Tsai et al., 2014; Zhang, Wu and Liu, 2018; Shabrin and Kashem, 2017; Dwaikat, 2016), including cleaning costs (as highlighted by PWD, 2023; Hajare and Elwakil, 2019; Putro, 2019; Oduyemi et al., 2018; Dwaikat and Ali, 2018; Zhang, Wu and Liu, 2018; Weerasinghe and Ramachandra, 2018; Shabrin and Kashem, 2017).

The costs significantly contribute to the overall LCC of green buildings. Although energy costs are calculated via consumption, the breakdown of energy costs differs according to construction materials and products. It is next followed by energy audit costs (Dall'O', 2013) and overhead costs (Abidin and Azizi, 2021; Oduyemi et al., 2018). In terms of maintenance costs (PWD, 2023; Putro, 2019; Oduyemi et al., 2018; Dwaikat, 2016; Khalil et al., 2021; Hajare and Elwakil, 2019), repair and replacement costs account for the majority of LCC components. The majority of demolition costs include disposal costs (Khalil et al., 2021; Hajare and Elwakil, 2019; Dwaikat and Ali, 2018; Zhang, Wu and Liu, 2018; Tsai et al., 2014; Shabrin and Kashem, 2017).

From the analysis of the review, it can be seen that there is a plethora of LCC components for green buildings. However, detailed items and breakdowns of each element should be further investigated in more stages. The review showed that the green building's LCC components have similarities with conventional buildings, such as acquisition costs, installation, operation and maintenance costs. However, the review revealed that green buildings also incur additional costs, including energy consumption, building energy audits and eco labelling. This corresponds with the conclusions of Hajare and Elwakil (2019) and Kale, Joshi and Menon (2016), who identified energy consumption costs as the primary aspect in minimising the LCC and the substantial yearly budget.

MATERIALS AND METHODS

A questionnaire survey was employed as a data gathering technique and sent to the targeted respondents. The respondents consisted of stakeholders associated with a 22 GBI-rated office building in Kuala Lumpur. GBI was chosen because it is the pioneer of green building tools in Malaysia and most of the buildings are certified by it compared to other instruments. Besides, the green buildings certified by GBI in Kuala Lumpur are plentiful compared to other locations. The targeted population, i.e., the project stakeholders, comprised architects, civil and structural engineers, mechanical and electrical engineers, quantity surveyors and facility managers. According to the filtering standards and purposive sampling procedure, the targeted population comprised 113 project stakeholders associated with the 22 GBI-rated office buildings. Hence, the questionnaire was disseminated to all stakeholders via email and provided an online survey link. The researcher opted to administer the questionnaire online as a means of achieving the research target. A total of 84 respondents responded and the response rate was therefore 74.3%. Creswell (2012) stated that data are considered valid when the sample achieves a response rate of more than 50%. Given that the survey had reached the stated minimum sample size, the data were deemed valid and sufficient.

The questionnaire assessed the level of importance of LCC components in the development of green office buildings. Descriptive statistics, including frequency, mean, standard deviations and relative significance index) (RII), were employed to examine the data. Prior to conducting the survey, a pilot study was executed to verify the reliability of the questionnaire questions and their measurability. Sutrisna et al. (2019) believe that a reliability test is adequate when it encompasses a minimum of 10% of the total survey respondents. Since this survey targeted 110 samples of respondents, the pilot study was disseminated to 11 respondents, or 10% of the targeted sample population. A Cronbach's alpha test was conducted on the pilot study data. Creswell (2012) employed Cronbach's alpha to assess internal consistency. An alpha value beyond 0.70 signifies that the instrument possesses enough reliability or internal consistency (Hair et al., 2010).

Table 1. Result of reliability test using Cronbach's alpha

Section	No. of Items	Cronbach's Alpha
Section A and Section B	32	0.975

Table 1 indicates that the alpha value was 0.975. This indicated that all items attained coefficient alpha values over 0.7, signifying exceptional dependability. As a result, the reliability findings indicated that all variables demonstrate internal consistency, permitting the primary survey to be conducted with all respondents.

ANALYSIS OF RESULTS

The survey analysis was organised based on the sections of the questionnaire items: (1) demographic background and (2) the significance of LCC to energy performance and active design in green office buildings.

Demographic Result

The respondents were requested to provide comprehensive information on their designations, total years of working experience and their participation in any green projects. Table 2 summarises respondents' demographic background. The result showed that the majority, with 64.29% of the respondents, were quantity surveyors, followed by mechanical engineers (17.86%), electrical engineers (7.14%), facility managers (7.14%) and architects (3.57%). This result showed that the questionnaire was predominantly circulated among quantity surveying firms compared to other firms.

The data indicated that a significant majority of respondents had less than five years of experience in green building construction projects (89.3%). It was followed by respondents with 5 to 10 years (8.30%), respondents with 11 to 15 years (2.4%) and no respondents had more than 15 years of experience. The findings indicate that the adoption of green building construction remains limited within the construction industry, which correlates with the respondents' participation in green construction projects for a duration of less than five years.

Table 2. Demographics of the respondents

Demographic Category	Items	%
Designation background	Architect	3.57
	Mechanical engineer	17.86
	Quantity surveyor	64.29
	Facility manager	7.14
	Electrical engineer	7.14
Years of experience in green building projects	Less than 5 years	89.30
	5 years to 10 years	8.30
	11 years to 15 years	2.40
	More than 15 years	–

Relative Importance Index on the Life Cycle Costs Components Associated with the Planning Phase of Green Building Projects

LCC components were specified for the energy performance of active design in green office buildings. The components were retrieved through the synthesis and meta-analysis of literature studies relating to life-cycle costs in green buildings. To guarantee the feasibility of green office initiatives, the appropriateness of the components was categorised into five project phases: (1) planning phase, (2) conceptual and design phase, (3) procurement and tendering phase, (4) construction phase and (5) operation and maintenance phase. The data were then analysed to determine the level of importance of the components using an inference statistic, the relative importance index (RII). Murugan and Marisamynathan (2022) utilised the RII method to find out how important different factors are based on what consumers prefer. This method has been widely used to determine and rank certain factors over others. In this study, the respondents rated the importance of each factor on a scale of one to five, ranging from 1 = Very Unimportant to 5 = Very Important. The collected data were then transformed to RII for each factor, following Equation 1.

$$RII = \Sigma W / (A*N) \qquad \text{Eq. 1}$$

where W was the weighting given to each factor by the respondents (ranging from 1 to 5), A was the highest weight (i.e., 5) and N was the total number of respondents.

RII scores provided a clear view of the level of importance of LCC components, providing insights into components that should be given the highest priority when implementing LCC calculations. A greater RII value indicates a higher significance of the components (Tholibon et al., 2021). In addition, the results tabulation included a presentation of descriptive statistics, featuring mean scores and standard deviations for each component. The mean score presents the average value of a given variable, while the standard deviation describes how the observations in a data set are spread around the mean value (Darussalam and Hussin, 2021). The results were tabulated and the components were ranked accordingly (as shown in Table 3).

Table 3. The result of mean, standard deviation, RII and rank of LCC components

Phases	Components	Mean ($\bar{x}$)	Standard Deviation	RII	Rank in Each Phase (Based on RII)	Overall Rank
Planning phase	Management costs	4.440	0.717	0.888	1	3
	Consulting services costs	4.155	0.814	0.831	2	19
	Training and value management costs	4.048	0.849	0.810	3	22
Conceptual and design phase	Design and professional costs	4.345	0.768	0.869	1	9
Procurement and tendering phase	Documentation costs	4.238	0.786	0.848	1	15
	Advertisement costs	3.917	0.839	0.783	2	23

(Continued on next page)

Table 3. *Continued*

Phases	Components	Mean ($\bar{x}$)	Standard Deviation	RII	Rank in Each Phase (Based on RII)	Overall Rank
Construction phase	Materials costs	4.536	0.648	0.907	1	1
	Initial/ preliminary costs	4.452	0.684	0.890	2	2
	Installation costs	4.429	0.716	0.886	3	4
	Eco labelling costs	4.226	0.734	0.845	2	17
	Labour costs	4.410	0.696	0.881	4	5
	Green building certification costs	4.405	0.679	0.881	5	6
	Insurance	4.369	0.757	0.874	6	7
	Safety management costs	4.357	0.739	0.871	7	8
	Equipment costs	4.333	0.717	0.867	8	10
	Carbon emission costs	4.262	0.838	0.852	9	13
Operation and maintenance phase	Utility and electricity costs	4.310	0.711	0.862	1	11
	Repair costs	4.274	0.734	0.855	2	12
	Overhead costs	4.262	0.793	0.852	3	14
	Energy audit costs	4.238	0.786	0.848	4	16
	Replacement costs	4.214	0.746	0.843	5	18
	Disposal costs	4.143	0.852	0.829	6	20
	Cleaning costs	4.131	0.724	0.826	7	21

Based on the results presented in Table 3, the RII scores for all 23 LCC components ranged from 0.783 to 0.907, which shows that the components hold significant importance as indicative planning decisions for LCC components in green building development projects. In general, the mean score ranged from 3.917 to 4.536, indicating that the components and requirements supported the RII output of significance as LCC components. The data dispersion was likewise less scattered, as indicated by the standard deviation score, which ranged from 0.648 to 0.852. The scattered data's standard deviation value centred around the mean. Hair et al. (2010) state that a higher mean score corresponds with a smaller standard deviation. The derived mean score or mean value for each component in this study was considered acceptable and reliable, given that it was nearly zero and not spread out.

The results showed that all respondents agreed that the 23 components of LCC were indicative in the planning decision for green building projects. Based on the overall rank for all cost components, it was found that the most important LCC component was materials costs (RII = 0.907). It was followed by preliminary costs (RII = 0.890), management costs (RII = 0.888), installation costs (RII = 0.886), labour costs (RII = 0.881), green building certification costs (RII = 0.881), insurance (RII = 0.874), safety management costs (RII = 0.871), design and professional costs (RII = 0.869) and equipment costs (RII = 0.869). The ten components were depicted as the most important considerations before commencing the green office construction project. Placed at the next 11th important rank is utility and electricity costs (RII = 0.862), followed by repair costs (RII = 0.855), carbon emission costs (RII = 0.852), overhead costs (RII = 0.852), documentation costs (RII = 0.848), energy audit costs (RII = 0.848), eco-labelling costs (RII = 0.845), replacement costs (RII = 0.843), consulting services costs (RII = 0.831), disposal costs (RII = 0.829), cleaning costs (RI = 0.826), trainings and value management costs (RII = 0.810) and advertisement costs (RII = 0.783).

The following section delves into the discussion on the level of importance of LCC components in green buildings. The discussion, however, was entailed in accordance with the rank attained at each project phase in the green project: (1) planning phase, (2) conceptual and design phase, (3) procurement and tendering phase, (4) construction phase and (5) operation and maintenance phase.

RESULTS AND DISCUSSION

The findings demonstrated the significance of LCC cost components during the planning phase, including management costs, consulting services costs, training costs and VM costs. The planning phase consists of input for all construction projects, where clients' requirements are formulated. The result showed that the important component in the planning phase was management costs. The management costs involve various breakdowns, such as documentation costs, manager costs and team costs, all aimed at ensuring that the estimates meet the project deliverables. Effective project cost management guarantees the completion of a project within its reported scope and budget. Advancing Professional Construction and Programme Management (2022) supported this by stating that management expects a client to manage the project's scope, costs, function, schedule, safety and quality effectively.

The costs of consulting services rank second. The consultants receive payment for their services, which typically include project design, costing, management and administration (Abidin and Azizi, 2021). Activities concerning planning and controlling a project's design, budget and management by the professionals ensure the project works according to its planned scope. The key individuals influencing the project's outcome were architects and engineers, as they bear the most significant responsibilities compared to other consultants. According to Abidin and Azizi (2021), cost structures typically adhered to guidelines established by professional organisations, but they were adjusted based on the complexity of the project. Generally, green building projects preferred a negotiated cost over a fixed rate.

Next, the important LCC component was training and value management costs. To achieve maximum benefit, it is important to carry out training from the early stages of a project, during the planning phase. Rahim et al. (2014) mention that LCC can contribute to sustainable building by offering significant advantages in identifying potential issues early in a project's life cycle. In line with Abidin and Azizi (2021), training and value costs involve determining project viability and direction at the initial stage of the project planning. Based on the Economic Planning Unit (2011), the costs to management tool in the implementation of government programmes and projects that are appropriate for achieving value for money are value costs. Therefore, to maximise returns, the application of this method should be integrated into all planning and execution stages of government projects from the outset. This cost consideration also extends beyond the government sector to the private sector as well.

The conceptual and design phase involves the formulation of the client's requirements and translating these into an acceptable design (Ahmad, 2011). From the survey, the most important LCC component was design and professional costs. Professionals play a crucial part in guiding green projects towards green concepts and sustainable design from the start. Among the key roles of the professionals or consultant team in green building projects are design, costing, specifications, contract documentation and the project's programme (Hallen, 2020). The second-ranked LCC component in this phase was eco-labelling costs. Eco-labelling products obtain independent confirmation that manufactured items meet environmental standards, increasing products' acceptance in the green market, which rewards environmentally friendly products with a premium price and facilitates involvement in green procurement schemes by the corporate sector (SIRIM

QAS International, 2019). Therefore, to ensure that the green projects utilise sustainable materials and green products, the cost component must be considered by the project stakeholders in LCC.

During the procurement and tendering phase, strategies are implemented to meet the client's needs, including choosing contractors, drafting contracts, setting prices and considering economic factors. The results showed that the documentation costs were the most significant LCC component during this phase. This aligns with Dwaikat's (2016) emphasis on the vitality of documentation costs in LCC calculations. This was done to ensure that the construction of the green building adheres to the planned standards and compliance. The second important LCC component was advertising costs. It is essential to allow for project marketing and promotion (Abidin and Azizi, 2021) as clients are entitled to get returns and profits from potential buyers when the buildings are sold.

Construction costs of green buildings refer to all of the expenditures associated with the building process, which include labour costs, material and equipment costs, management costs and other expenses (Fan, Chan and Chau, 2018). However, the discussions for this phase concentrated on the two important components. First was the material costs. According to Shakantu, Tookey and Bowen (2003), materials inquiries contain details on the material specifications, quantities, estimated delivery, and terms and conditions. Buildings are constructed with materials, which is the reason a significant portion of the expenditures associated with green construction initiatives are related to materials. However, materials for construction are not focused on construction materials such as cement, concrete, sand and bricks only. According to Zhang, Wu and Liu (2018), for green buildings, there are costs for green materials such as energy-saving air conditioning and lighting; meanwhile, Firsani and Utomo (2012) highlight the costs for light shelves and dynamic blind systems. The next component was the initial costs. The initial costs pertain to the capital needed for the scheme. To ensure there are no hidden costs in this cost component, the related party must also take into account the costs of delivery and installation (Dwaikat, 2016). This includes site preparation costs such as land acquisition, permits, stamp duty (PWD, 2023) and other authority requirements (Abidin and Azizi, 2021).

The last phase in the green project development is the operation and maintenance phase. Even though this phase involves the occupancy period of green buildings, it is imperative to determine the cost component of LCC. This is because this phase comes before the operation and maintenance phase commences following the completion of the building and its subsequent handover to the client for occupancy. The survey showed that the most important LCC component in this phase was utility and electricity costs. The aim of having green buildings is to reduce energy consumption and carbon emissions during the operational period. Hence, it is crucial to prioritise utility and electricity costs resulting from the energy output of the green buildings. This is aligned with green procurement studies by Khalil et al. (2021), where energy and utility costs ranked first in LCC components in green procurement. Knowing the estimated total yearly building energy consumption, the electricity price tariff and the anticipated rates of inflation can determine the entire LCC electricity costs (Dwaikat, 2016). The second important LCC component is repair costs. The repair costs are also included in the maintenance costs, where the scope is not merely for the building facades but also the building materials, facilities and amenities. A study by Lee and Chu (2016) indicates that green-rated buildings have lower maintenance costs compared to non-green buildings. Even though the repairing and maintenance works may not be highly required for green-rated buildings, it is crucial to consider the component in the LCC exercise as consideration to proceed with the green project during the early planning project commencement.

CONCLUSIONS

This study explored LCC components in green building projects, offering key insights to help stakeholders make informed planning decisions before beginning project development. The findings underscore the significance of LCC components throughout different phases of a project, highlighting that although green buildings may incur higher initial costs, their long-term savings in operational and maintenance costs make them a more cost-efficient and sustainable choice. The theoretical contributions of this research include a thorough analysis of LCC components within the context of green buildings in Malaysia, as well as the introduction of a systematic method for assessing the importance of each LCC component during specific project phases. This approach could serve as a valuable reference for future research and industry practitioners. From a practical standpoint, this study provides useful guidelines for construction industry stakeholders such as quantity surveyors, engineers and facility managers in planning and estimating costs across the life cycle of green buildings. By understanding the relevance of each LCC component, stakeholders can make more informed decisions, ultimately helping to reduce long-term costs in green building development and management. Despite its contributions, the study was limited to 22 GBI-rated buildings in Kuala Lumpur, which may not fully represent the wider green building landscape in Malaysia. As a result, the findings may not be applicable to other regions or countries with different green certification systems. Future research could broaden its scope by including buildings certified under other green rating systems, providing a more complete understanding of LCC in varied green building contexts. Additionally, incorporating social and environmental impacts into LCC calculations could offer a more comprehensive view of LCC of green buildings. In conclusion, this study laid a strong foundation for understanding

LCC in green building projects and offers practical recommendations to guide stakeholders in the development of more sustainable and economically viable green buildings.

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