



Research paper

Improving the cost performance of green buildings based on soft system methodology and value engineering

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Abstract: The rising demand for sustainable construction practices has prompted a focus on optimizing the cost performance of green buildings. This study investigates enhancing green cost performance by employing the Soft Systems Methodology (SSM), Value Engineering (VE), and Lifecycle Cost Analysis (LCCA) within the framework of the GREENSHIP concept. By utilizing Structural Equation Modeling through Smart PLS, this research constructs a robust structural model that provides insights into cost dynamics over the building's lifecycle. Implementing the GREENSHIP concept entails evaluating initial and long-term lifecycle costs associated with green buildings. The initial investment required to convert conventional buildings to green standards is relatively modest and tends to decrease operational costs significantly over time. This research highlights that, over eight years, operational costs constitute the largest proportion of total expenses. Through the integrated approach of SSM and VE, the study captures diverse stakeholder perspectives and identifies key cost drivers and savings opportunities. The LCCA method further substantiates the financial viability of green buildings by quantifying cost savings over their operational lifespan. The findings indicate that a comprehensive understanding of lifecycle costs, coupled with targeted value engineering, can substantially improve the cost efficiency of green buildings. The results emphasize the necessity for developers and property owners to prioritize lifecycle costs over initial expenditures. By adopting this holistic approach, stakeholders can achieve significant long-term savings while promoting environmental sustainability. This study demonstrates that integrating SSM, VE, and LCCA within a structural model effectively enhances the cost performance of green buildings, thereby supporting their broader adoption in the construction industry.

Keywords: GREENSHIP, lifecycle cost analysis, SEM-PLS, soft system methodology, value engineering

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1. Introduction

Regulation Number 21 of 2021, issued by the Minister of Public Works and Public Housing of Indonesia (PUPR RI), emphasizes the Performance Assessment of Green Buildings. According to this regulation, the following new buildings qualify as Green Buildings: a) Class 4 and 5 buildings with more than 4 floors and a minimum area of 50,000 m²; b) Class 6, 7, and 8 buildings with more than 4 floors and a minimum area of 5,000 m²; c) Class 9a buildings with an area exceeding 20,000 m²; and d) Class 9b buildings with an area exceeding 10,000 m² [1].

The Building Approval (PBG) is a permit from the government allowing the owner or their representative to start construction, renovation, maintenance, or alteration of a building according to the planned specifications. The Certificate of Fitness for Occupancy (SLF) is required for newly completed buildings. Without SLF, a building cannot be operated for any purpose, and extending the SLF is necessary to meet green building standards.

The GREENSHIP certification, developed by the Green Building Council Indonesia (GBCI) and part of the World Green Building Council, is based on the GREENSHIP Rating Tools created in 2009. The primary goals of Sustainable Development, according to the World Green Building Council, are environmental (planet), social (people), and economic (profit) [2].

According to the Green Building Council Indonesia Version 1.2 in 2014, the GREENSHIP framework includes six categories: Appropriate Site Development, Energy Efficiency & Conservation, Water Conservation, Material Resources and Cycle, Indoor Health and Comfort, and Building Environment and Management. Each category has three types of assessments: a) Prerequisite criteria: Mandatory criteria that must be met before further assessment. Examples include Basic Green Area, Electrical Submetering, OTTV Calculation, Water Metering, Water Calculation, Fundamental Refrigerant, Outdoor Air Introduction, and Basic Waste Management. b) Credit criteria: Optional criteria that contribute to the overall assessment. Examples include Site Selection, Community Accessibility, Public Transportation, Bicycle Facility, Site Landscaping, Micro Climate, Stormwater Management, Energy Efficiency Measures, Natural Lighting, Ventilation, Climate Change Impact, Water Use Reduction, Water Fixtures, Water Recycling, Alternative Water Resources, Rainwater Harvesting, Water Efficiency Landscaping, Building and Material Reuse, Environmentally Friendly Material, Non-ODP Usage, Certified Wood, Prefab Material, Regional Material, CO₂ Monitoring, Environmental Tobacco Smoke Control, Chemical Pollutant, Outside View, Visual Comfort, Thermal Comfort, Acoustic Level, Basic Waste Management, GP as a Member of Project Team, Pollution of Construction Activity, Advanced Waste Management, Proper Commissioning, Green Building Submission Data, Fit Out Agreement, and Occupant Survey. c) Bonus criteria: Optional criteria that provide additional points. An example is On-Site Renewable Energy. GREENSHIP certification is categorized into four levels: Platinum, Gold, Silver, and Bronze [3].

From 2013 to 2018, Indonesia had only 20 GREENSHIP-certified buildings, a small number compared to the total building stock, especially those with more than 12 floors, which numbered 1,329. This highlights the challenge of converting conventional buildings into green ones and maintaining the sustainability of existing green buildings. As of 2023, only 57 buildings in Indonesia have obtained GREENSHIP certification, largely due to a lack of awareness of the benefits of green buildings [4]. Most building owners perceive investments in green buildings as costly [4], and they also deem the operational and maintenance costs of such buildings to be high [5].

The construction industry and building sector face significant challenges, accounting for 36% of global energy consumption and 39% of CO₂ emissions [6]. However, green buildings with sustainable designs can offer significant benefits, including 15% energy savings, 22.3% water savings, and 21% carbon reduction compared to conventional buildings [7]. Green buildings also typically command rental premiums of 5% to 10% and have cost performance ranging from 4.5% to 7% [8]. For instance, a case study in Poland showed a 26% annual profit increase for buildings meeting Green Building standards [9]. Optimizing building envelopes through Value Engineering (VE) has demonstrated energy savings and improved lifecycle performance [10]. VE enhances a building's performance relative to the resources required to achieve it [11]. Lifecycle Cost Analysis (LCCA) selects solutions offering the most financial benefits over their lifetime or the lowest lifecycle cost, which is the main goal of technical and economic analyses [12].

This study aims to address these challenges by exploring how to enhance the cost performance of green buildings through the combined use of Soft Systems Methodology (SSM), Value Engineering (VE), and Lifecycle Cost Analysis (LCCA) within the GREENSHIP framework. Using Structural Equation Modeling (SEM) with Smart PLS, the research constructs a robust structural model to provide insights into cost dynamics over a building's lifecycle.

The primary research question is: How can the integration of SSM, VE, and LCCA improve the cost performance of green buildings within the GREENSHIP framework? By answering this question, the study aims to contribute to the existing literature and support the broader adoption of green buildings in the construction industry. This comprehensive approach captures diverse stakeholder perspectives, identifies key cost drivers and savings opportunities, and demonstrates the financial viability of green buildings through targeted value engineering [12].

2. Green building assessment

Green Building refers to a structure that adheres to technical standards for buildings and demonstrates significant performance in conserving energy, water, and resources. This is accomplished by implementing green building principles throughout the design, construction, and operational stages [13].

Green Building Assessments are conducted by assessment agencies affiliated with the World Green Building Council (WGBC), headquartered in Toronto, Canada. Notable assessment bodies include the United States' Leadership in Energy and Environmental Design (LEED), the United Kingdom's BRE Environmental Assessment Method (BREEAM), Australia's Green Building Council of Australia Green Star (GBCA), and Singapore's Green Mark Scheme. These agencies employ different ranking systems and assessment criteria but share the common goal of evaluating a building's sustainability standards [14].

In Indonesia, the Green Building Council Indonesia (GBCI) is responsible for green building assessments. GBCI uses the GREENSHIP rating system, which is tailored to Indonesia's local climate and conditions, to certify environmentally friendly buildings. The GREENSHIP assessment covers six categories: Appropriate Land Use, Energy Efficiency and Conservation, Water Conservation, Material Sources and Cycles, Health and Indoor Comfort, and Building Environmental Management. Each category includes prerequisite criteria and credit criteria, with certification levels of Platinum, Gold, Silver, and Bronze [3].

Green building involves planning, construction, and operation, each playing a crucial role. During the planning phase, the focus is on conserving energy and water by selecting effective and efficient materials and systems. In the construction and operation phases, attention is given to waste management and disposal, aiming to recycle and reuse materials, as shown in Figure 1.

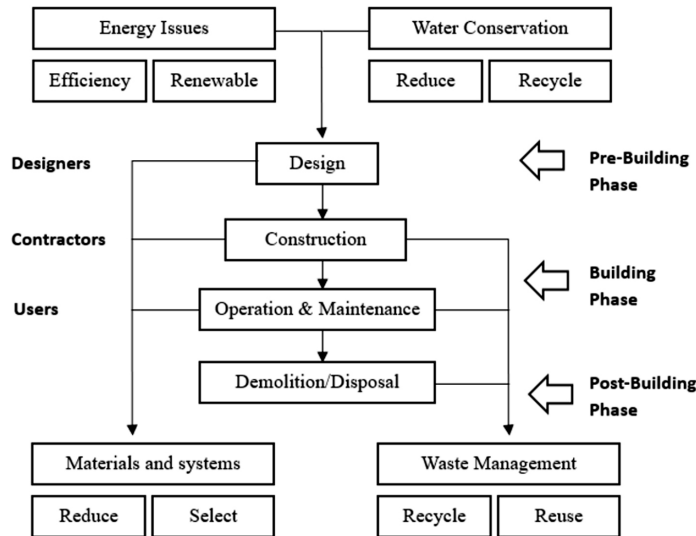


Fig. 1. Green building concept framework

3. Soft system methodology

Soft Systems Methodology (SSM) aims to address diverse perspectives by creating conceptual models of human activity systems. These models are then used to identify interventions that can resolve or improve the situation. SSM is particularly effective for dealing with unstructured or poorly structured problems where stakeholders may not agree on the nature of the issue.

SSM offers significant advantages in managing expectations, identifying practice requirements, modeling potential changes, and proposing improvements that align with the organizational context. It can also uncover a comprehensive set of weaknesses in requirements practices. While not all suggested changes may be necessary, the implemented ones often contribute positively to enhancing the organization's requirements for engineering [15].

The methodology comprises several stages as follows:

- Description of the Problem Situation: Outlining the problem as an ongoing process.
- Rich Pictures: Providing a comprehensive view of the problem, incorporating factual and cultural analysis. This includes examining the intervention, the social system (interaction of roles, norms, and values within the organization), and the political system (power structures and activities aimed at accommodating different interests).

- Root Definition: Articulating the core purpose of the activity system as a transformation process, detailed using the mnemonic CATWOE (Customers, Actors, Transformation, Worldview, Owner, and Environmental constraints).
- Conceptual Model of Root Definition: Constructing a model that includes monitoring and control activities to ensure alignment with the system idea, assessing Efficacy (effectiveness of the means), Efficiency (output relative to resources used), and Effectiveness (whether the transformation meets long-term objectives).
- Comparison: Comparing the model with the real world to assess alignment between the real situation sketches and the created models.
- Possible Changes and Actions: Proposing enhancements to the problem situation and recommending improvements to the existing system.

In this stage of SSM-Based Action Research, the Root Definition at the organizational level focuses on ensuring compliance with regulations and proposing guidelines for implementing green building design and construction concepts. The concept emphasizes "Low Cost, Low Technology, Low Negative Impact Development," aiming to expedite the planning and construction of environmentally friendly and high-quality green buildings. Utilizing the SSM-based action research method, the accuracy of the Root Definition was evaluated through CATWOE Analysis, as illustrated in Figure 2.

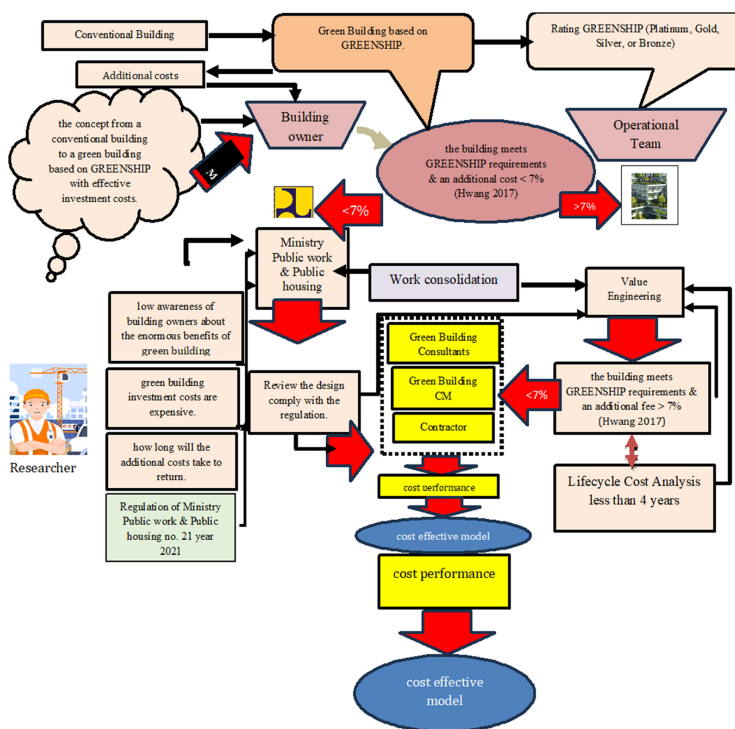


Fig. 2. Rich Picture of Challenges in Achieving Cost-Effective Green Building

This paper explores the concept of green building design by addressing the fundamental causes of inefficiency and ineffectiveness in green building design and construction. A major issue highlighted is the absence of technical guidelines for managing green buildings that integrate the principles of sustainable design. Without incorporating these sustainability principles during the planning and design phases, maintenance and operational costs can escalate significantly once the building is operational.

4. Structural equation modeling (SEM) SMART-PLS (Partial least square)

Structural Equation Modeling (SEM) relies on covariance analysis, which allows for a more precise covariance matrix compared to linear regression analysis. SEM can be viewed as a blend of regression analysis and factor analysis. It is effective for handling equation models with multiple dependent variables and recursive effects. SEM-Partial Least Squares (SEM-PLS) is a statistical method used to simultaneously solve multilevel models that cannot be addressed with linear regression equations [16].

The research model established the minimum sample size based on a path coefficient value of 0.25 and an 80% statistical strength test at the 5% significance level, resulting in a minimum sample size of 69. Questionnaires were distributed to 115 selected respondents, who had between 5 to 30 years of experience in green building and educational backgrounds ranging from undergraduate to doctoral level. Of the distributed questionnaires, 102 were returned, with 88% completed by men and 14% by women, resulting in a questionnaire return rate of 88.69%. Questionnaire results are grouped according to the variables reviewed in this study. Various references that support the research variables are shown in Table 1.

The first outside measurement model is concerned with measuring convergent validity with individual item reliability (> 0.700), aggregated reliability (> 0.700), and mean extracted variance ($AVE > 0.500$). In addition, in this model discriminatory reliability is measured in terms of cross-loading, and the variable correlation is evaluated [16]. The inner structure of the two models relates to the coefficient of determination (R^2), goodness of fit of the model, and hypothesis testing [17].

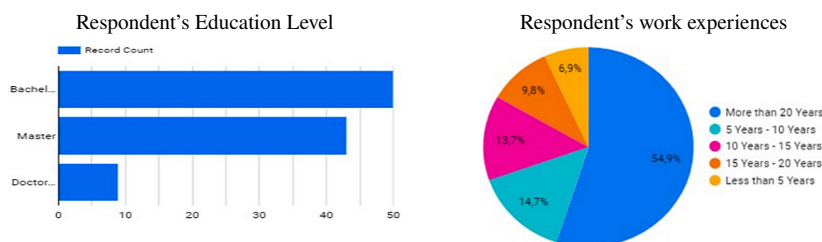


Table 1. Indicators, Category and Variable

Code	Variable/category/indicator	References
GK	Conventional Building	
KP	1.1. Project Management	[18, 19]
KC	1.2. Contract Management	[20, 22]
GB	Green Building	
GS	2.1. Green Building Certification	[3, 6, 23]
GC	2.2. Green Building Construction Costs	[2, 3, 8, 24, 25]
GM	2.3. Green building operational and maintenance costs	[2, 3, 8, 24–26]
GT	2.4. Appropriate Site Development	[3, 27]
GE	2.5. Energy Efficiency and Conversation	[3, 27]
GA	2.6. Water Conservation	[3, 27]
GS	2.7. Material Resources and Cycle	[3, 27]
GK	2.8. Indoor Health and Comfort	[3, 27]
GL	2.9. Building Environment and Management	[3, 27]
VE	Value Engineering	
VI	Information, Function, Creativity, Evaluation, Development, Presentation Implementation,	[20, 28–30]
LA	Lifecycle Cost Analysis	
LC	4.1. Cost Breakdown Structure	[23, 25, 31, 32]
LL	4.2. LCCA	[23, 31, 32]
LR	4.3. Risks	[33, 34]
LP	4.4. Decision	[35]
KB	Cost Performance	
CP	Cost Performance	[9, 31]

Discriminant validity testing is performed to ensure that indicators within a construct have the highest loading factor on that specific construct, rather than on other constructs. Validity testing results are shown in Table 2.

Table 2. Composite Reliability, Cronbach's Alpha, and AVE Values

Construct / Variable	Average Variance Extracted (AVE) (>0.5)	Composite Reliability (>0.7)	Cronbach Alpha (>0.7)
Conventional Building (X1)	0.979	0.976	0.979
Green Building (X2)	0.971	0.992	0.992
Value Engineering (X3)	0.979	0.989	0.988
Lifecycle Cost Analysis (X4)	0.992	0.986	0.987
Internal dan External Factor (Y)	0.987	0.971	0.964

R -square and Q -square testing are methods used to refine the Goodness of Fit criteria for each structural model. R -square (R^2) assesses the extent to which a specific independent latent variable influences a dependent latent variable, with R^2 values ranging from 0 to 1. R^2 values of 0.75, 0.50, and 0.25 typically indicate strong, moderate, and weak models [20]. Chin classifies the R^2 criteria as strong, medium, and weak with values of 0.67, 0.33, and 0.19. The R -square and Q -square test results for each variable are shown in Table 3.

Table 3. R -square & Q -square values

Variable	R -square	Q -square
Green Building (X2)	0.757	0.527
Internal dan External Factor (Y)	0.908	0.756
Lifecycle Cost Analysis (X4)	0.906	0.770
Value Engineering (X3)	0.807	0.661

The R -squared value indicates the extent to which an independent variable explains the variance in the dependent variable. For instance, an R -squared value of 0.908 for $Y = \text{cost}$ means that the latent variables and the median account for 90.8% of the variance in the cost.

To assess the significance and strength of relationships between constructs and to test hypotheses, path coefficients between constructs are measured. These coefficients range from -1 to $+1$, with values closer to $+1$ indicating a stronger relationship between the constructs. Values below -1 signify a negative relationship [16]. To evaluate the value of structural models (inner loading) or the relationships between constructs (latent variables), the Bootstrapping procedure is used for further analysis. The interpretation of coefficient paths is derived from the bootstrapping results, path analysis, or structural models. A path is considered significant if the statistical T -value exceeds 1.96 and the P -value is below 0.05. Table 4 indicates that the analysis results are significant, as evidenced by T -statistic values greater than 1.96 (T -statistic > 1.96) and P -values less than 0.05 (P -value < 0.05).

Table 4. Path Coefficient Values

Correlations	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T -statistics (O/STDEV)	P -values
Conventional Building (X1) – Green Building (X2)	0.870	0.865	0.041	21.187	0.000
Conventional Building (X1) – Internal and External Factor (Y)	0.756	0.751	0.066	11.383	0.000
Conventional Building (X1) – Lifecycle Cost Analysis (X4)	0.744	0.738	0.066	11.239	0.000

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Table 4 – Continued from previous page

Correlations	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T-statistics (O/STDEV)	P-values
Conventional Building (X1) – Value Engineering (X3)	0.782	0.776	0.061	12.818	0.000
Green Building (X2) – Internal and External Factor (Y)	0.850	0.845	0.078	10.904	0.000
Green Building (X2) – Lifecycle Cost Analysis (X4)	0.855	0.851	0.042	20.139	0.000
Green Building (X2) – Value Engineering (X3)	0.899	0.896	0.035	25.556	0.000
Lifecycle Cost Analysis (X4) – Internal and External Factor (Y)	0.683	0.692	0.105	6.489	0.000
Value Engineering (X3) – Internal and External Factor (Y)	0.743	0.747	0.098	7.611	0.000
Value Engineering (X3) – Lifecycle Cost Analysis (X4)	0.952	0.949	0.016	59.212	0.000

To evaluate the significance of the prediction model in testing the structural model, refer to the *T*-statistic values for the relationship between the independent and dependent variables in the Path Coefficient table provided in the Smart-PLS output shown at Table 5.

Table 5. Reflective Loading of Variables Based on Category

Correlations	Original sample estimate	Mean of subsamples	Standard deviation	T-statistic
Conventional Building (X1) – Green Building (X2)	0.870	0.865	0.041	21.187
Conventional Building (X1) – Internal and External Factor (Y)	0.016	0.019	0.080	0.202
Green Building (X2) – Internal and External Factor (Y)	0.182	0.174	0.118	1.551
Green Building (X2) – Value Engineering (X3)	0.899	0.896	0.035	25.556
Lifecycle Cost Analysis (X4) – Internal and External Factor (Y)	0.683	0.692	0.105	6.489
Value Engineering (X3) – Internal and External Factor (Y)	0.093	0.090	0.136	0.689
Value Engineering (X3) – Lifecycle Cost Analysis (X4)	0.952	0.949	0.016	59.212

Obtained model equation: $Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4$

The model is considered a good fit based on the SRMR value of 0.050, which is below the threshold of 0.08. However, it does not meet the fit criteria based on the RMS Theta (Root Mean Square Theta) value of 0.147, which exceeds the threshold of 0.10. Therefore, despite one of the fit criteria being satisfied, the model generally fits the data based on the assessment.

5. Research result

The equation $Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4$ demonstrates that life cycle costs (0.683) have a strong impact on cost performance. This highlights the necessity for property owners and developers to consider not only initial costs but also life-cycle costs, as initial expenditures have a minimal effect on overall life-cycle expenses.

Many property owners and developers focus on upfront costs while often neglecting their significant impact on long-term operational expenses, particularly in high-rise buildings. This presents an opportunity for further research into how the green building concept influences financial decision-making among developers in Indonesia, especially in the context of high-rise construction projects.

6. Value engineering

Value Engineering (VE) is a methodical approach that involves a thorough assessment of projects, products, or processes by a team of experts from various disciplines. Its main objective is to improve performance, quality, and/or life cycle costs. Within the Value Engineering framework, Life Cycle Cost analysis is crucial, as it emphasizes value and identifies alternatives that provide the lowest total cost [31].

VE is recognized as a comprehensive management strategy that involves problem-solving, exploring alternative designs, making cost-driven decisions, and pursuing performance-oriented project goals, all guided by structured selection criteria. Both governmental bodies and private sector entities, especially in construction, value VE for its ability to enhance efficiency and lower project costs. Originating in the 1950s, VE has become a widely embraced practice among government agencies, private engineering firms, and contractors. Its flexible techniques enable the attainment of various objectives, including cost savings, time efficiency, and performance improvement [36].

7. Lifecycle cost analysis (LCCA)

LCCA is a method employed to identify solutions that offer the greatest returns over their lifespan, or more simply, have the lowest life cycle costs. These goals are the central focus of both technical and economic analyses [37].

The concept of life cycle costs covers the total projected expenses incurred from the inception to the disposal of equipment or projects. These costs are calculated through a detailed analysis and evaluation of all expenses accumulated over the item's lifetime. The full life cycle cost of an item encompasses all expenditures from its design phase through to its eventual obsolescence [24, 38]. Based on these principles, the formula for Life Cycle Cost (LCC) is as follows:

$$(7.1) \quad LCC = \text{Initial Cost} + \text{Cost of Usage} + \text{Cost of Care and Replacement}.$$

When considering the life cycle of a green building, the additional costs compared to conventional buildings are very small or insignificant relative to other costs, as depicted in Figure 4.

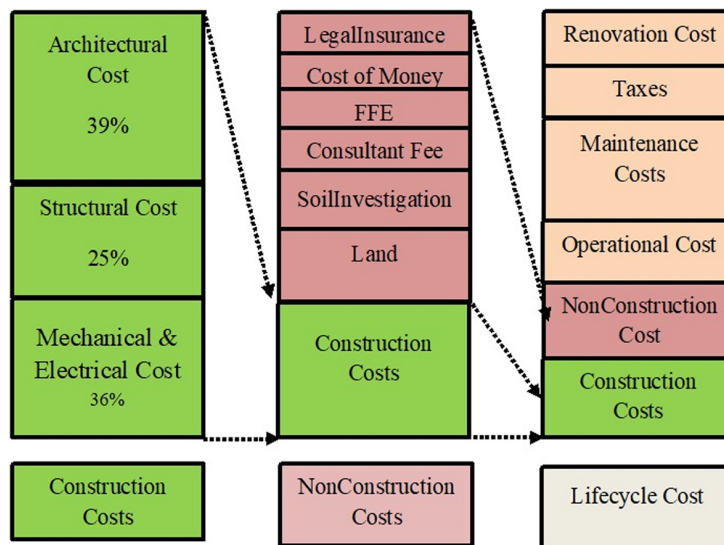


Fig. 4. Life cycle building

8. The Building being examined

The main office of the Ministry of Public Works and Housing Main Building achieved Platinum-level status. In Table 6, the contract costs for building management from 2012 to 2019 totaled USD 3,373,985.50 additional contract costs totaling USD 234,276.17. Therefore, the total operating and maintenance costs over 8 years amounted to USD 3,608,261.67. Regarding electricity costs, Table 7 indicates that the total electricity expenses from 2012 to 2019 were USD 1,423,077.16. Additionally, the total electricity used for water needs during this period was USD 91,640.77. Consequently, the total electricity costs over 8 years amounted to USD 1,514,717.93.

Table 6. Contracts of Building Management

Num	Year	Contract Cost USD	Contract Period
1	2012	175,169.06	5 Months
2	2013	343,565.32	1 year
3	2014	419,175.80	1 year
4	2015	483,117.66	1 year
5	2016	499,312.50	1 year
6	2017	469,187.50	1 year
7	2018	475,435.86	1 year
8	2019	39,619.65	4 Months
		469,402.15	8 Months

Table 7. Power Cost

No.	Year	Total Electricity Consumption kWh	Energy Use Intensity kWh/M ² /year	Annual Cost USD/year
1	2012	1,260,840	118.25	63,995.72
2	2013	3,276,636	128.04	186,922.27
3	2014	2,844,586	111.16	180,225.24
4	2015	3,026,500	118.27	207,745.67
5	2016	3,143,684	122.85	170,702.89
6	2017	3,385,022	132.28	193,225.00
7	2018	3,520,452	137.57	202,458.96
8	2019	3,794,145	148.27	217,801.39
Total (USD / 8 years)				1,439,077.16

Analysis of lifecycle cost

By combining the Initial Costs, Operation & Maintenance Costs, and Energy Costs, the Life Cycle Cost Analysis for the Main Building of the Ministry of Public Works and Public Housing can be calculated over 8 years, from 2012 to 2019. This government facility is projected to be operational for 50 years, maintaining functionality and reliability according to specified standards (Permen PU 45/PRT/M/2007). To determine the 8-year life cycle costs, the Initial Costs need to be adjusted to account for the building's service life. Table 8 presents the results of these calculations.

Table 8. Structure of lifecycle cost

No.	Category	Cost	LCC	Percentage
		USD	USD / 8 years	%
1	Initial Cost	25,101,052.10	4,016,168.34	43.94%
2	O & M Cost	3,608,261.67	3,608,261.64	39.48%
3	Electricity Cost	1,514,717.93	1,514,717.92	16.57%
	Total		9,139,147.90	100.00%

9. Conclusions

The research findings show that in the Validity Test, both the Outer Loading and Average Variance Extracted (AVE) values exceed 0.5, indicating strong construct validity. In the Reliability Test, both Composite Reliability and Cronbach's Alpha values are above 0.7, signifying high internal consistency and reliability. Implementing the GREENSHIP concept in green buildings, utilizing Soft System Methodology, Value Engineering, and Lifecycle Cost Analysis methods, significantly enhances the cost performance of green buildings within a well-fitted structural model. When developing green buildings, developers and property owners must consider not only the initial costs but also the life cycle costs. This approach is crucial because the initial investment required to convert a conventional building into a green one is relatively low and typically decreases further once the building becomes operational.

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