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COST MODEL DEVELOPMENT FOR GREEN BUILDING COMPLIANCE WITH INDONESIA'S REGULATION NO.21 OF 2021

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ABSTRACT:
The Indonesian Ministry of Public Works and Public Housing (PUPR), through Regulation No. 21 of 2021, stipulates that a Green Building Performance Assessment must be conducted as a mandatory criterion for securing both the Building Approval (PBG) and the Certificate of Feasibility for Function (SLF). Nevertheless, many actors within the construction industry continue to perceive green building initiatives as financially burdensome due to their perceived high initial costs. To better understand and address these concerns, this study utilized the Soft Systems Methodology (SSM), incorporating expert panel evaluations supported by the Content Validity Index (CVI) method and structured survey instruments. Through this process, five key variables were established: traditional construction methods, sustainable building design, value engineering strategies, lifecycle cost evaluation, and overall cost efficiency. These variables were further detailed into 26 distinct dimensions and 92 measurable indicators. A comprehensive cost modeling approach was then constructed and tested using Structural Equation Modeling (SEM) via the Smart-PLS platform. The analysis revealed significant interdependencies among the identified variables, with the resulting model expressed as $Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4 + \beta$. This equation highlighted that lifecycle cost analysis had the most substantial impact on overall cost-effectiveness. Although green buildings may initially entail higher capital expenditures, the findings suggest that they offer superior economic efficiency over time compared to conventional structures. Furthermore, the proportion of green-related construction expenses relative to total project costs was shown to be relatively small. Overall, the research validates the intent behind Regulation No. 21 of 2021 and promotes the widespread implementation of green building concepts among developers and property industry stakeholders. In addition to demonstrating long-term financial benefits, the study also highlights the educational, environmental, and operational advantages—such as improved resource efficiency and enhanced occupant productivity—that green construction practices can offer to both the professional and academic communities.
KEYWORDS: Cost Model, GREENSHIP, Green Building Investment, Lifecycle Cost, PUPR 21 of 2021, Soft System Methodology, Value Engineering.

1. INTRODUCTION

In 2006, the Indonesian government introduced green building requirements through the issuance of Minister of Public Works Regulation No. 30/PRT/M/2006. Subsequently, on September 11, 2009, the Green Building Council Indonesia (GBCI), a non-governmental organization, was established to oversee GREENSHIP, the country's official green building certification system. Nevertheless, as of 2023, only 57 buildings had achieved GREENSHIP certification, according to GBCI. This limited adoption is primarily due to the low level of awareness about the benefits of green buildings. [1]. Many property owners remain hesitant to invest in green building development, primarily due to perceptions of high initial investment costs [1], and concerns over potentially increased operational and maintenance expenses [2].

To address this, the Ministry of Public Works and Public Housing (PUPR) enacted Regulation No. 21 of 2021, which mandates the completion of a Green Building Performance Assessment as a prerequisite for securing Building Approval (PBG) and the Certificate of Functional Worthiness (SLF). This regulation seeks to accelerate the adoption of certified green buildings across Indonesia. [3]

The Main Building of the Ministry of PUPR serves as a precedent, having obtained GREENSHIP certification in 2012. As a government facility with stable occupancy and operational hours, it experiences minimal fluctuations in electricity, water, and labor usage.

To encourage developers and building owners to comply with PUPR Regulation No. 21 of 2021, understand the long-term benefits of green buildings, and accept the associated transitional costs from conventional to sustainable building practices, it is essential to assess the full lifecycle costs, from design to post-construction operations. This includes evaluating long-term expenditures and identifying potential cost-saving strategies.[4]

Previous research on green building costs and performance reveals important insights: a) A study in Singapore analyzing 242 conventional buildings and 121 green buildings from 30 companies found that green buildings commanded a 5%–10% rental premium, though their cost performance often exceeded budgets by 4.5%–7% [5] ; b) A cost analysis of Green MICE buildings targeting gold-level certification using value engineering indicated an additional investment of 4.689% compared to conventional buildings, which could be recovered in approximately 3 years and 10 months [6]; c) Empirical research using discounted cash flow (DCF) methods has shown that green certifications can increase rental income, reduce operational expenses and vacancy rates, and mitigate property-related risks for professional investors [2] ; d) In Poland, by the end of 2017, approximately 62% of 9.7 million m² of modern office space was certified, an increase of 5% from prior years. Lifecycle cost simulations comparing conventional and certified buildings indicated that certified structures achieved higher Net Present Value (NPV) with lower upfront investment, and shorter payback periods, depending on rental levels. [7] ; e) According to the United Nations Environment Program, the implementation of green building standards in Poland has led to annual profit increases of 26% and energy savings of 30% to 80% due to the adoption of green technologies.

Recent literature highlights the significant potential of green buildings to reduce total lifecycle costs by improving energy and water efficiency, enhancing operational performance, and increasing occupant productivity [8]. Nonetheless, comprehensive cost models that align initial investments with long-term financial benefits remain underdeveloped. This study addresses that gap by constructing a cost model tailored to the Indonesian construction context, integrating five critical variables: conventional buildings, green buildings, value engineering, lifecycle cost analysis, and cost performance, further structured into 26 dimensions and 92 measurable indicators.

Employing Structural Equation Modeling (SEM) with Smart-PLS, the study examines the interrelationships among these variables. The Soft Systems Methodology (SSM) was used to identify key systemic issues, and the model was validated through expert panel assessments and a Content Validity Index (CVI) analysis. By addressing financial concerns and demonstrating long-term economic advantages, this research reinforces the objectives of PUPR Regulation No. 21 of 2021. It promotes the broader implementation of sustainable construction practices across Indonesia [9].

2. LITERATURE REVIEW

PUPR 21 of 2021

The Regulation of the Minister of Public Works and Public Housing (PUPR) No. 21 of 2021 marks a significant step in advancing sustainable construction in Indonesia. It requires integrating green building principles into Building Approval (PBG) and Functional Worthiness Certificates (SLF), with a focus on energy efficiency, water conservation, indoor air quality, and material sustainability. These criteria are essential for compliance and aligning construction practices with environmental, economic, and social sustainability goals while addressing Indonesia's unique regulatory and ecological needs.[10]

Despite its transformative potential, challenges such as high initial costs, limited expertise, and the need for integration with existing codes hinder its implementation. However, the regulation opens opportunities for market transformation, environmental preservation, and long-term economic savings through life-cycle cost optimization. By supporting Sustainable Development Goals (SDGs), particularly Goals 11 and 13, and Indonesia's net-zero emissions target, PUPR No. 21 of 2021 lays a strong foundation for sustainable urban development.[11]

GREENSHIP Certification System

GREENSHIP, developed by the Green Building Council Indonesia (GBCI), is Indonesia's primary green building certification system, designed to promote sustainable construction and environmental stewardship. It evaluates buildings across six categories: energy efficiency, water conservation, indoor air quality, material resources, site development, and building management. Certification is awarded at Certified, Silver, Gold, and Platinum levels, reflecting a building's compliance with these sustainability criteria. Tailored to Indonesia's unique climatic and regulatory contexts, GREENSHIP also aligns with global standards, such as LEED and BREEAM, while prioritizing local needs like managing tropical climate challenges.[4]

Despite its benefits, including reduced carbon emissions, resource efficiency, and market differentiation, GREENSHIP faces challenges such as high perceived costs, limited stakeholder expertise, and the complexity of aligning with existing building codes. However, it supports Indonesia's commitment to the Sustainable Development Goals (SDGs) and complements national regulations like PUPR No. 21 of 2021. By addressing these obstacles through training, cost optimization, and policy integration, GREENSHIP can become a cornerstone for sustainable development in Indonesia.[12]

Conventional Building

Conventional building practices rely on traditional construction methods and materials, emphasizing cost efficiency, structural stability, and quick project completion. These methods typically use readily available resources like concrete, steel, and brick, focusing on functionality and simplicity. However, they often neglect sustainability, resulting in high energy consumption, significant waste generation, and substantial environmental

impact. While upfront costs are relatively low, conventional buildings usually incur higher operational and maintenance expenses over their lifecycle due to inefficient systems and outdated techniques.[13]
Despite widespread use in developing nations like Indonesia, conventional practices face growing criticism for failing to meet modern environmental and regulatory standards. The push toward sustainability, supported by policies like PUPR No. 21 of 2021, highlights the need to shift to greener alternatives. While conventional methods dominate due to affordability and accessibility, integrating sustainable practices can reduce lifecycle costs, environmental impact, and resource waste. [14]

Soft System Methodology

Soft Systems Methodology (SSM), developed by Peter Checkland, is a qualitative problem-solving approach commonly used to analyze complex, human-centered systems. Unlike traditional systems approaches, which focus on well-defined technical problems, SSM tackles ill-structured, ambiguous issues involving diverse stakeholders with varying perspectives. It offers a structured yet adaptable framework for understanding organizational challenges, supporting decision-making, and enhancing processes..[15]
SSM follows an iterative learning cycle, typically involving seven key stages: identifying problematic situations, exploring stakeholder perspectives, developing conceptual models, comparing models with real-world situations, and implementing feasible changes. This methodology is particularly relevant in fields like project management, policy development, and sustainable construction, where diverse interests and uncertainties must be managed. SSM can help navigate regulatory, economic, and technical challenges in green building implementation by incorporating stakeholder input and refining strategies.[16]

Lifecycle Cost

Lifecycle Cost Analysis (LCCA) is a financial assessment method that evaluates the total cost of owning a building or infrastructure throughout its lifespan. Unlike traditional cost assessments, which focus solely on initial construction expenses, LCCA accounts for long-term costs such as operation, maintenance, energy use, repairs, and disposal. By considering these factors, LCCA helps stakeholders make informed investment decisions by identifying cost-effective solutions that maximize performance and sustainability. It is widely used in construction, transportation, and energy-efficient building design sectors to reduce overall expenditure while improving durability and efficiency..[17]
Research highlights the growing importance of LCCA in green building projects, where long-term savings in energy and maintenance often offset higher initial costs. Studies comparing conventional and green buildings indicate that despite their upfront expenses, sustainable construction methods lead to significant cost reductions over time. LCCA also plays a crucial role in regulatory frameworks like PUPR No. 21 of 2021, which promotes sustainable building practices in Indonesia.[18]

Value Engineering

Value Engineering (VE) is a structured, analytical process to maximize a project's value by optimizing functionality and minimizing costs. Initially developed in manufacturing, VE has been widely adopted in construction, infrastructure, and sustainable building projects. This methodology involves analyzing design alternatives, materials, and processes to achieve cost efficiency without compromising quality, performance, or sustainability. By focusing on function-driven decision-making, VE helps identify unnecessary expenditures and provides innovative solutions to improve project efficiency.[19]
Research highlights the effectiveness of VE in balancing initial investment costs with long-term operational savings, particularly in green building projects. Studies show that integrating VE with Lifecycle Cost Analysis (LCCA) can enhance cost-effectiveness by ensuring savings extend beyond construction to energy efficiency and maintenance. In Indonesia, VE aligns with regulations such as PUPR No. 21 of 2021, which promotes sustainable construction practices.[20]

Structural Equation Modeling (SEM) with Smart-PLS

Structural Equation Modeling (SEM) with Smart-PLS is increasingly utilized in construction and sustainability studies to examine the relationships between variables and predict outcomes in complex systems. Its flexibility in handling small sample sizes, non-normal data, and latent constructs makes it suitable for integrating value engineering (VE) and lifecycle cost analysis (LCCA) into sustainable construction frameworks. VE focuses on optimizing project functionality while minimizing costs, whereas LCCA evaluates the total cost of ownership, including design, construction, operation, and disposal phases. Combining these methods within a PLS-SEM framework enables a comprehensive analysis of cost-performance relationships in green building projects.[21]
Recent studies highlight how SEM with Smart-PLS can identify critical factors influencing cost efficiency, stakeholder decision-making, and sustainability outcomes. For example, it has been used to model the impact of VE strategies on reducing initial costs while ensuring compliance with LCCA principles, which emphasize long-term savings. This approach is particularly relevant in aligning with regulations such as PUPR No. 21 of 2021, which mandates the adoption of sustainable practices in construction. This research integrates VE, LCCA, and SEM to develop predictive models that optimize cost management and sustainability, leveraging Smart-PLS's ability to analyze interdependencies between economic, environmental, and regulatory variables.[22]

Green Building Investment

Green building investment refers to allocating financial resources towards constructing buildings designed to be environmentally sustainable, energy-efficient, and resource-conserving throughout their lifecycle. These investments often involve higher initial costs due to the use of advanced technologies, sustainable materials, and

energy-efficient designs. However, numerous studies suggest that significant long-term benefits, including reduced energy and water consumption, lower maintenance costs, and improved occupant health and productivity, offset these upfront expenses. Green buildings also have higher market value and demand, leading to greater investor returns.[23]
Research on green building investments highlights the growing trend of integrating environmental, social, and governance (ESG) factors into decision-making as companies and governments increasingly recognize the importance of sustainability. While the financial viability of green buildings has been questioned due to higher initial costs, studies show that they are often more resilient in the market, demonstrating superior operational efficiency and better long-term financial performance. In countries like Indonesia, regulations such as PUPR No. 21 of 2021 support the growth of green building investment by mandating sustainable construction practices, thereby making green buildings an increasingly viable investment option.[24]

Cost Model in Construction

A cost model in construction is a mathematical representation used to estimate and manage the expenses associated with building projects. It helps stakeholders forecast and control costs throughout a project's lifecycle, from planning and design to construction and operation. The cost model typically incorporates material costs, labor, energy consumption, maintenance, and operational expenses, allowing for a comprehensive understanding of the total cost of ownership. These models are essential for making informed financial decisions and ensuring that construction projects stay within budget while meeting quality and performance standards.[25]
In recent years, the development of advanced cost models has focused on integrating sustainability and environmental factors into cost assessments. Green building initiatives, such as Lifecycle Cost Analysis (LCCA) and Value Engineering (VE), have become crucial components of modern cost models to address the long-term financial viability of sustainable construction. These models consider initial costs and ongoing expenses related to energy efficiency, maintenance, and environmental impact. Research suggests that integrating regulatory frameworks, such as PUPR No. 21 of 2021 in Indonesia, with robust cost models can provide a more accurate picture of the financial benefits of green buildings.[26]

Systematic risk

Systematic risk, also known as systemic risk or market risk, affects the entire market or industry and cannot be avoided through portfolio diversification. This risk is caused by macroeconomic factors that influence the entire market, such as changes in interest rates, inflation rates, monetary and fiscal policies, global economic crises, political changes, and natural disasters. Examples of systematic risk include the 2008 global financial crisis that affected stock markets worldwide, increases in interest rates that impacted bond and stock prices, and changes in monetary policy that influenced currency exchange rates.[27]

3. RESEARCH METHOD

The research process follows a structured sequence of stages to ensure a systematic approach to investigation. It begins with Problem Identification, where the research problem is clearly defined. Once the problem is established, the next stage is Conceptual Framework Development, which involves constructing a conceptual framework or model to better understand the issue. Soft System Methodology (SSM) can be employed at this stage to analyze complex systems and develop conceptual models that provide a structured perspective on the problem.[28]
Following this, the Research Instrument Development phase focuses on designing tools such as questionnaires for data collection, ensuring their validity through Content Validity Index (CVI) assessment. Once the instruments are ready, Data Collection is conducted using these tools, primarily through questionnaires. Finally, in the Data Analysis stage, the collected data is examined to derive meaningful insights. Smart PLS (Partial Least Squares) can be used to model relationships between the studied variables. As summarized in **Fig. 1**, these stages provide a comprehensive roadmap for conducting research effectively.[29]

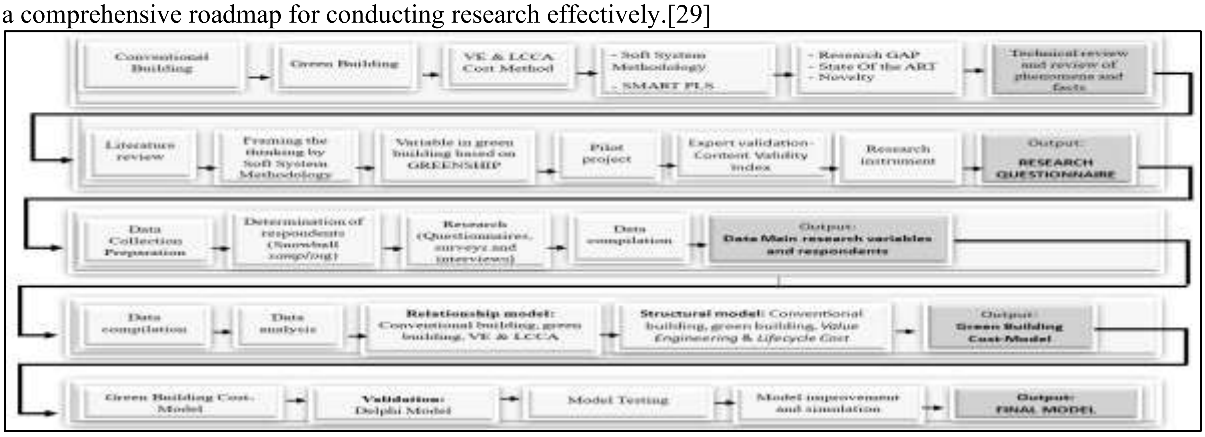

Fig. 1. Comprehensive Research Roadmap

4. RESULT

Soft Systems Methodology (SSM) adopts a systematic framework for examining and resolving complex problem scenarios, as illustrated in Figure 2. The process begins with (1) a Problem Situation Description, which involves continuous exploration and articulation of the underlying issues. This is followed by (2) the development of Rich Pictures, which offer a holistic representation of the situation by integrating factual elements with cultural, social, and political contexts. The artistic dimension probes the nature of the intervention, the social system evaluates roles, values, and norms within the organizational structure, and the political system assesses the distribution of power and strategies used to reconcile conflicting interests. The subsequent step, (3) Root Definition, defines the essential purpose of the system in terms of a transformation process, using the CATWOE framework. This analytical tool identifies six critical components: Customers, Actors, Transformation process, Worldview, Owners, and Environmental constraints, all of which shape the operation and behavior of the system.
Following this, (4) a Conceptual Model is developed, incorporating monitoring and control mechanisms to ensure the system functions as intended. This stage assesses Efficacy (whether the means are effective), Efficiency (the ratio of output to resources used), and Effectiveness (the degree to which long-term goals are met). (5) The model is then compared to real-world situations to identify inconsistencies and areas for improvement. (6&7) Finally, the process concludes with the Implementation of Changes and Actions, where potential modifications are identified, and recommendations are made to enhance the existing system, ensuring a more efficient and effective resolution to the problem.

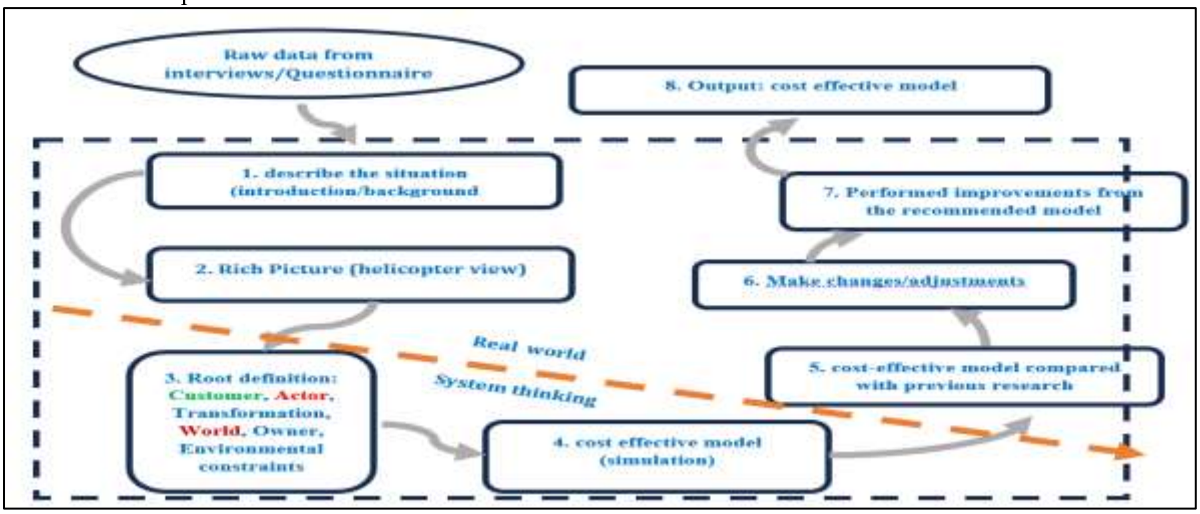

Fig. 2 Steps of Soft System Methodology

The expert panel in this study consisted of five professionals, all certified in green building expertise and holding bachelor's, master's, and doctoral degrees. Aged between 41 and 69, they came from varied professional backgrounds related to green buildings, each with more than five years of experience. Throughout each round of the Delphi method, the experts not only completed questionnaires but also gave feedback to refine the research instruments. The analysis focused on variables such as conventional buildings, green buildings, value engineering, lifecycle cost analysis, and cost performance to ensure validation and interpretation, thereby meeting the established criteria for excellent content validity.

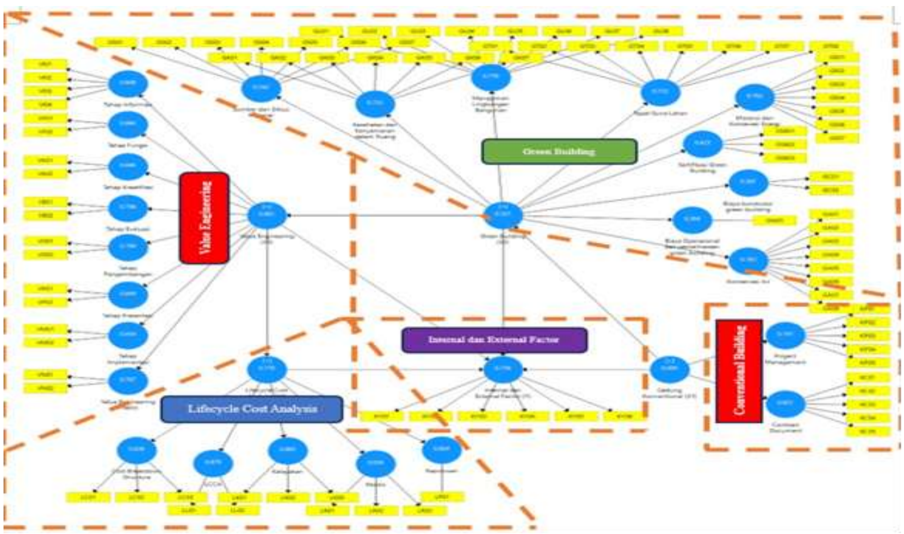

Fig. 3. SEM Smart-PLS Diagram

As illustrated in **Fig. 3**, the schematic distinguishes between conceptual (latent) variables and their associated measurement indicators using distinct colors: blue for the latent constructs and yellow for the observed indicators, all derived from the SEM Smart-PLS analysis. This visualization confirms the validity of the measurement model, showing that each indicator meaningfully aligns with its respective construct. The study categorizes five main variables.

First, Conventional Building (X_1) is structured around two core dimensions: Project Management and Contrct Management. It comprises ten key indicators, which include aspects such as project organizational structure, risk assessment, monitoring and control mechanisms, the effectiveness of project leadership, communication and coordination practices, bill of quantity preparation, technical documentation (drawings and specifications), scheduling, and adherence to regulatory frameworks.

Second, Green Building (X_2) is defined through six thematic dimensions: Site Development, Energy Efficiency, Water Conservation, Material Use and Lifecycle, Indoor Environmental Quality, and Environmental Management. This variable is represented by 58 distinct indicators, covering diverse components such as green open space provision, energy sub-metering, OTTV (Overall Thermal Transfer Value) calculations, water consumption tracking, use of eco-friendly refrigerants, ventilation and air supply standards, solid waste management systems, selection of building sites, access to public transportation, cycling infrastructure, landscaping strategies, microclimate and stormwater controls, natural lighting and airflow, mitigation of climate impacts, efficient plumbing fixtures, recycling initiatives, use of alternative and harvested water, sustainable material sourcing and reuse, non-ozone-depleting substances, certified or local material content, CO_2 monitoring, chemical emissions control, visual, thermal, and acoustic comfort, as well as stakeholder engagement through professional involvement, commissioning protocols, construction pollution mitigation, tenant fit-out guidance, and post-occupancy evaluations. Additionally, the use of on-site renewable energy is considered a bonus indicator to enhance the green performance rating.

Third, Value Engineering (X_3) comprises eight operational dimensions: Information Gathering, Function Identification, Creative Development, Option Evaluation, Design Development, Presentation Techniques, and Practical Application. It includes 17 indicators such as executive-level commitment, data analysis capacity, inter-team communication, policy alignment, enhanced design quality, function-based analysis, construction method optimization, material selection strategies, evaluation frameworks, ideation processes, alternative cost-saving proposals, application of cost-effective materials, strategy implementation, optimal resource deployment, quality improvement, and functional efficiency. This approach plays a significant role in driving cost-effectiveness within the construction sector.

Fourth, Lifecycle Cost Analysis (LCCA) (X_4) consists of five analytical dimensions: Cost Structuring, Assessment Methodology, Contextual Relevance, Risk Appraisal, and Strategic Decision-Making. The 12 corresponding indicators include upfront capital costs, long-term operation and maintenance expenditures, scoring methods, financial return metrics such as payback period, sensitivity testing, internal rate of return (IRR), net present value (NPV), and external economic variables like currency exchange rates, inflation rates, and interest fluctuations. LCCA serves as a pivotal tool for evaluating the financial feasibility of green projects.

Lastly, the Cost Performance (Y) variable is centered on a singular dimension that encapsulates both internal and external financial drivers. It includes six indicators: raw material costs, labor expenses, equipment procurement, transportation charges, price variability in construction materials, and environmental externalities.

Utilizing a path coefficient of 0.25, with 80% statistical power and a significance threshold of 5%, the SEM analysis conducted via Smart-PLS determined that at least 69 participants were necessary to ensure model validity. To surpass this requirement and enhance the robustness of the study, a total of 115 seasoned professionals. These individuals represented a broad academic spectrum, including bachelor's, master's, and doctoral degree holders (refer to **Fig. 4a**)—each possessing between 5 and 30 years of experience in green building implementation—were approached for participation (see **Fig. 4b**). From the outreach, 102 completed responses were received, yielding a high participation rate of 88.69%, with the gender distribution comprising 88 male and 14 female respondents.

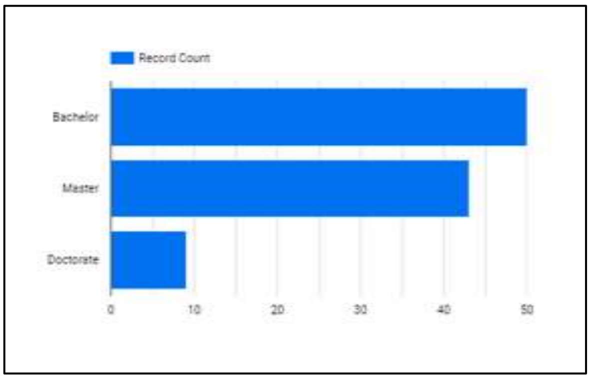

Fig. 4a Respondent's Academic Level

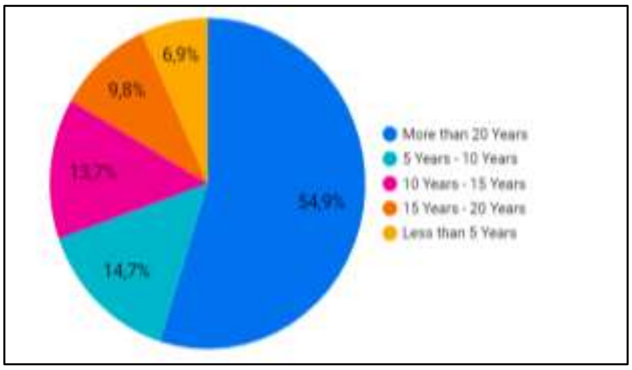

Fig. 4b Respondent's Field Experience

5. DISCUSSION

The conceptual model developed through Soft Systems Methodology (SSM) aligns strategic organizational proposals with Regulation No. 21 of 2021 of the Minister of Public Works and Public Housing of the Republic of Indonesia, as well as with the GREENSHIP standards established by the Indonesian Green Building Council. This model serves as a foundational framework for planning and executing green building design and construction. It strengthens implementation by addressing gaps in various stages of green building management that are often not clearly defined. These stages include: (1) the Planning Stage, which harmonizes sustainable design principles with stakeholder aspirations to inform the development of technical implementation guidelines; (2) the Technical Design Stage, which offers critical reference materials for all parties involved; (3) the Construction Stage, which ensures all prerequisites for a streamlined building process are in place; and (4) the Operation and Maintenance Stage, whose success largely depends on the effective execution of the preceding stages.

The SSM-based action research approach involves interactive dialogues aimed at evaluating how well the conceptual model corresponds with real-world practices. Through this process, researchers identify necessary interventions and transformative actions to address prevailing issues. From a philosophical and practical perspective, several key considerations are essential to promoting the implementation of sustainable building design and construction: (1) the urgent need to accelerate the enforcement of Ministerial Regulation No. 21/2021 concerning green buildings; (2) the importance of raising awareness and understanding of the GREENSHIP green building certification standards issued by the Green Building Council Indonesia; and (3) the need for enhanced coordination among stakeholders to produce integrated and detailed guidelines for green building development.

The action research process culminates in the formulation of contextually relevant and culturally sensitive recommendations for change, aimed at resolving identified problems. These recommendations are organized in a structured manner to support meaningful organizational transformation. The proposed measures are designed to improve both the effectiveness and efficiency of green building management processes, ensuring alignment with the study's original goals. A concise summary of these strategic recommendations is illustrated in **Fig. 5**.

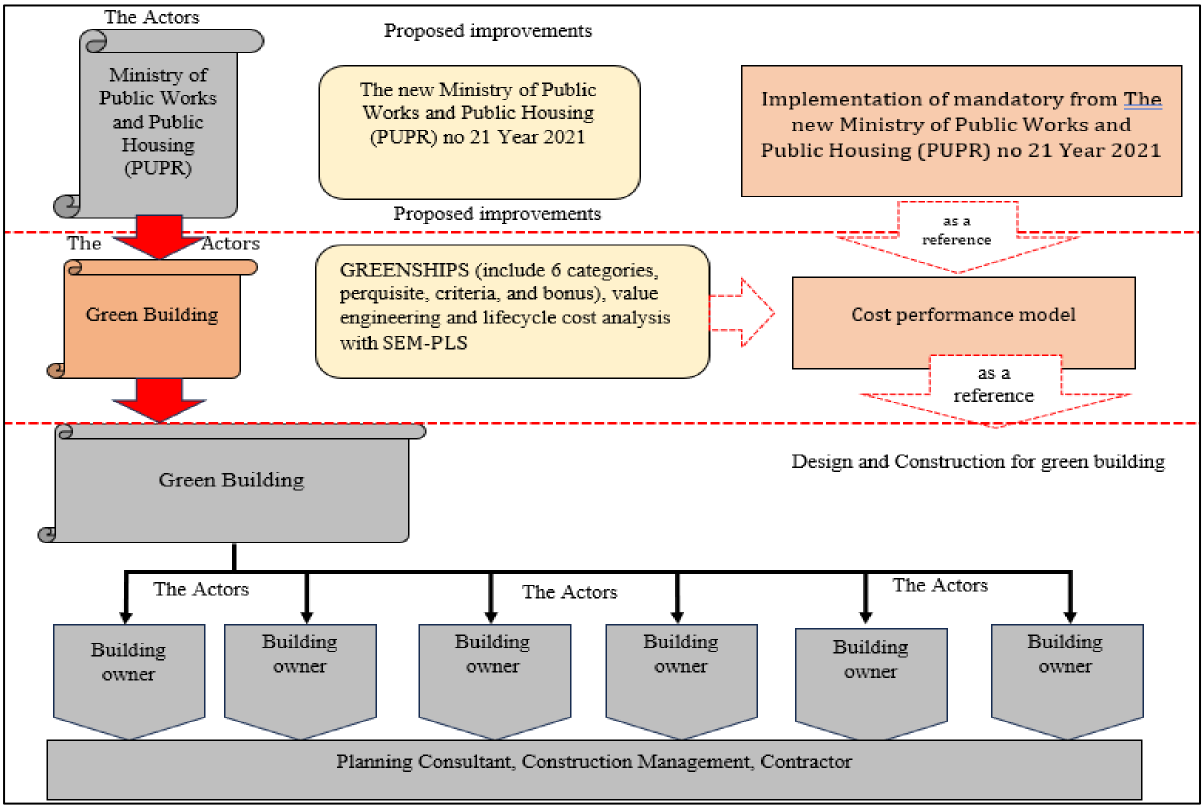

Fig. 5. Organizational Functions Supporting Green Building Implementation

Discriminant validity testing is conducted to confirm that each indicator loads more strongly on its designated construct than on any other constructs. The results of this validity assessment are shown in **Table 1**.

Table 1 Evaluation of Measurement Reliability and Convergent Validity

Construct / Variable	Composite Reliability (> 0.7)	Cronbach Alpha (>0.7)	Average Variance Extracted (AVE) (>0.5)
X_1	0.976	0.979	0.979

X_2	0.992	0.992	0.971
X_3	0.989	0.988	0.979
X_4	0.986	0.987	0.992
Y	0.971	0.964	0.987

R-Square (R^2) and Q-Square (Q^2) tests evaluate the Goodness of Fit in structural models. R^2 measures the impact of an independent latent variable on a dependent latent variable, with values ranging from 0 to 1. Generally, R^2 values of 0.75, 0.50, and 0.25 represent strong, moderate, and weak models, respectively [33]. Chin further categorizes R^2 as strong (0.67), medium (0.33), and weak (0.19). The R^2 and Q^2 test results for each variable are shown in **Table 2**.

Table 2 R^2 and Q^2 Metrics for Model Fit and Predictive Accuracy

Variable	R Square	Q Square
X_2	0.757	0.527
X_3	0.807	0.661
X_4	0.906	0.770
Y	0.908	0.756

The R-squared (R^2) statistic represents the proportion of the variability in the dependent variable that the combined influence of the independent variables can explain. For instance, an R^2 value of 0.908 for the dependent variable cost implies that approximately 90.8% of its variation is attributed to the predictive power of the latent constructs and the median.

To assess the directional strength and statistical relevance of relationships among variables, path coefficients are examined. These coefficients, which range from -1 to +1, serve as indicators of correlation strength: values closer to +1 indicate a strong positive association, while those below zero signal a negative relationship [36].

The bootstrapping technique is applied to evaluate the structural model—particularly the inner model loadings and the interrelations among latent constructs. The significance of each path is interpreted through the outcomes of bootstrapping, supplemented by structural equation modeling (SEM) or structural path analysis. A relationship is considered statistically significant if the T-value exceeds 1.96 and the p-value is less than 0.05. As demonstrated in **Table 3**, all paths meet these criteria, with T-statistics above the threshold and p-values within acceptable limits, thereby confirming the robustness of the proposed model.

Table 3 Path Analysis Results

Correlations	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
X_1 -> X_2	0.870	0.865	0.041	21.187	0.000
X_1 -> X_3	0.782	0.776	0.061	12.818	0.000
X_1 -> X_4	0.744	0.738	0.066	11.239	0.000
X_1 -> Y	0.756	0.751	0.066	11.383	0.000
X_2 -> X_3	0.899	0.896	0.035	25.556	0.000
X_2 -> X_4	0.855	0.851	0.042	20.139	0.000
X_2 -> Y	0.850	0.845	0.078	10.904	0.000
X_3 -> X_4	0.952	0.949	0.016	59.212	0.000
X_3 -> Y	0.743	0.747	0.098	7.611	0.000
X_4 -> Y	0.683	0.692	0.105	6.489	0.000

To assess the predictive relevance and structural validity of the model, refer to the T-statistics presented in Table 4, derived from the Smart-PLS output. These values help determine the strength and significance of the relationships between the exogenous and endogenous constructs.

The model exhibits an acceptable level of fit, as indicated by the Standardized Root Mean Square Residual (SRMR), which registers at 0.050, well within the permissible limit of 0.08, suggesting a satisfactory approximation between the observed and predicted correlations. However, the model does not meet the threshold based on the Root Mean Square Theta (RMS Theta), which stands at 0.147, surpassing the 0.10 benchmark. This suggests that while the model achieves a good fit under one criterion, it falls short under another. Nevertheless, the overall assessment indicates that the structural model maintains a generally acceptable level of fit to the observed data.

Table 4 Reflective Loadings of Variables Categorized by Groups

Indicator	original sample estimate	mean of subsamples	Standard deviation	T-Statistic
X_1 -> Y	0.016	0.019	0.080	0.202
X_2 -> Y	0.182	0.174	0.118	1.551
X_3 -> Y	0.093	0.090	0.136	0.689
X_4 -> Y	0.683	0.692	0.105	6.489

The model equation, derived from **Table 4**, is given as $Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4$. Due to Indonesia's high volatility in inflation, interest rates, and currency exchange rates, a beta factor is used as a multiplier so the cost model $Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4 + \beta$

Evaluation of Cost Model Development

By utilizing data on initial costs, operating and maintenance expenses, and energy costs, life cycle cost calculations can be made for the Ministry's main building over the eight years from 2013 to 2020. The building, designed to remain functional and reliable, is expected to have a 50-year service life, as per PUPR Regulation 45/PRT/M/2007, which corresponds to a 2% depreciation rate per year.

Empirical data for the Main Building of the Ministry's main building (2013–2020), presented in **Table 5**, indicates a relatively stable occupancy rate. Tenant working hours do not exceed 10 hours per day, and there is no employee activity on Saturdays, unlike in rented buildings. Consequently, electricity and water usage remain consistent from month to month. Predictive data based on the effective cost model equation is provided in **Table 6**.

Table 5 Cost Model of the Ministry's main building – Actual

Year to	Year	Cost Model	Lifecycle Cost	Initial Cost PUPR Reg.	Cumulative Management Fee	Cumulative Maintenance Fee	Cumulative Water & Electricity Cost
1	2013	25,042,088,877	17,583,370,108	8,032,336,672	5,497,045,076	867,056,800	3,186,931,560
2	2014	37,981,172,220	36,527,855,237	16,064,673,344	12,203,857,903	1,934,114,100	6,325,209,890
3	2015	51,958,323,665	56,992,205,816	24,097,010,016	19,933,740,503	3,120,819,780	9,840,635,517
4	2016	65,991,630,917	77,538,775,731	32,129,346,688	27,922,740,503	4,434,426,580	13,052,261,960
5	2017	80,194,484,141	98,333,582,794	40,161,683,360	35,829,740,503	6,001,483,420	16,340,675,511
6	2018	94,598,485,115	119,422,896,078	48,194,020,032	43,736,714,214	7,741,863,982	19,750,297,851
7	2019	109,349,573,444	141,020,389,971	56,226,356,704	51,881,062,691	9,482,845,212	23,430,125,365
8	2020	124,563,911,892	163,296,141,725	64,258,693,376	60,432,628,592	11,310,875,503	27,293,944,255

Table 6 Cost Model of the Ministry's main building – Predicted

Year to	Year	Predicted	Lifecycle Cost	Initial Cost PUPR Reg.	Cumulative Management Fee	Cumulative Maintenance Fee	Cumulative Electricity & Water Fee
1	2013	25,042,088,877	17,583,370,108	8,032,336,672	5,497,045,076	867,056,800	3,186,931,560
2	2014	37,981,172,220	36,527,855,237	16,064,673,344	12,203,857,903	1,934,114,100	6,325,209,890

Year to	Year	Predicted	Lifecycle Cost	Initial Cost PUPR Reg.	Cumulative Management Fee	Cumulative Maintenance Fee	Cumulative Electricity & Water Fee
3	2015	51,292,905,433	56,017,947,788	24,097,010,016	19,246,011,371	3,054,524,265	9,620,402,137
4	2016	64,894,886,881	75,933,001,153	32,129,346,688	26,640,272,513	4,230,954,938	12,932,427,014
5	2017	78,840,367,570	96,350,981,664	40,161,683,360	34,404,246,712	5,466,207,145	16,318,844,447
6	2018	93,204,148,662	117,381,407,861	48,194,020,032	42,556,419,621	6,763,221,962	19,867,746,246
7	2019	108,068,852,994	139,145,250,220	56,226,356,704	51,116,201,175	8,125,087,521	23,677,604,821
8	2020	123,283,481,564	161,421,426,750	64,258,693,376	60,103,971,807	9,555,046,357	27,503,715,211

6. CONCLUSION

The following formula outlines the optimized cost framework for implementing green construction in multi-story buildings, where cost efficiency is determined by the weighted influence of four key factors:

$Y = 0.016X_1 + 0.182X_2 + 0.093X_3 + 0.683X_4 + \beta$

Where:

X_1 = Conventional building cost

X_2 = Green building cost

X_3 = Value engineering cost savings

X_4 = Lifecycle cost analysis

Y = Effective cost performance

β = Systematic risk = 5%

This structural equation forecasts outcomes with a maximum 5% deviation, accounting for systematic risk, making it a dependable predictive tool. It serves as a valuable reference for developers aiming to build GREENSHIP-rated structures, helping to minimize initial costs while maximizing operational and maintenance efficiencies.

The cost model reveals that the overall expenses are lower compared to the lifecycle costs of the Ministry's main building.

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