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Influence of Budget Availability, Value Engineering (VE), Life Cycle Cost Analysis (LCCA), and Green Building Understanding on Green Building Implementation in School Buildings in DKI Jakarta

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ABSTRACT

The application of the green building concept in school buildings in DKI Jakarta is one of the strategic steps in supporting sustainable development. The concept aims to improve energy efficiency, reduce environmental impact, and create a healthy learning environment. However, the level of implementation still faces various challenges influenced by several factors. This study aims to analyze the influence of budget availability, Value Engineering (VE), Life Cycle Cost Analysis (LCCA), and green building understanding on green building implementation in school buildings in DKI Jakarta. This study uses a quantitative approach with a survey method. Data analysis was carried out using multiple regression techniques to test the influence of each independent variable on the dependent variable. The results show that budget availability, VE, LCCA, and understanding of green building concepts significantly affect the level of green building implementation in school buildings. Budget availability is a major factor influencing implementation decisions, while VE and LCCA contribute to efficient and sustainable decision-making. This research provides recommendations to local governments, school managers, and related parties to increase budget allocation, VE and LCCA training, and education on green building concepts. It is hoped that the results of this research can serve as a reference for encouraging the wider application of green building concepts in the education sector, especially in DKI Jakarta.

KEYWORDS *Green Building, Budget Availability, Value Engineering (VE), Life Cycle Cost Analysis (LCCA), School Building, DKI Jakarta*

INTRODUCTION

Global urbanization has accelerated significantly since the early 20th century, with profound implications for environmental conditions worldwide. The growth of metropolitan cities—those with populations exceeding one million—shows an alarming trend. In 1900, only London qualified as a metropolitan city. However, this number jumped dramatically to 100 cities by 1960 and reached 300 by 2005. Even more strikingly, over 50% of the world's population has lived in cities since 2005, with projections indicating this proportion will reach 70% by 2050. This massive urbanization is reshaping the global demographic landscape while exerting tremendous pressure on natural resources and the environment (Aktas & Ozorhon, 2015; Chan et al., 2018).

A direct consequence of rapid urbanization and industrialization is the rising concentration of greenhouse gases in the atmosphere. Data from Our World in Data reveal a sharp increase in carbon emissions from the mid-18th-century industrialization era to the present. In the 1950s, global carbon emissions totaled 6 billion tonnes, rising to 22 billion tonnes by the 1990s—nearly quadrupling over four decades. This surge significantly contributes to global climate change, as evidenced by the Global Instrumental Temperature

Record, which documents a persistent rise in global temperatures with adverse effects on ecosystems and human lives (Al-Gahtani et al., 2022; Darko & Chan, 2017; Mushi et al., 2025).

Rapid urbanization and the expansion of cities like Jakarta have intensified environmental management challenges. As Indonesia's capital, DKI Jakarta is experiencing explosive development (Erdogan et al., 2023; Zhou et al., 2020). Yet, these developments often overlook sustainability principles, exacerbating environmental degradation through air pollution, energy waste, waste accumulation of 27,966 m^3 per day, and damage to urban ecosystems. This is worsened by the disparity between annual motor vehicle growth (12%) and road expansion (only 2%), fueling worsening transportation and pollution issues (Hwang & Tan, 2012). Thus, the green building concept emerges as a strategic solution for achieving environmentally friendly, energy-efficient, and sustainable development.

Indoor air quality demands particular attention, given that people spend 90% of their time indoors, where it is typically 2–5 times worse than outdoors and generates more pollutants. This underscores the critical need to prioritize health and environmental quality in building design, especially for educational facilities where children and adolescents spend substantial time learning and developing (Altaf et al., 2022; Hajare & Elwakil, 2020).

Rapid population growth and development in DKI Jakarta impose significant environmental pressure (Li et al., 2023). The building sector, including schools, is a major source of carbon emissions and energy consumption. Implementing green building principles in DKI Jakarta's school buildings is essential to mitigate environmental harm and foster healthy, comfortable learning spaces for students. The city's dense conditions and vulnerability to climate change heighten the urgency of green buildings for sustainability. Moreover, eco-friendly school buildings can educate students and communities on environmental conservation. The Jakarta provincial government's push for sustainable development provides ideal momentum for green building adoption in schools.

In DKI Jakarta, schools play a pivotal role in cultivating an environmentally conscious younger generation. Applying green building principles in school design and construction not only enhances physical environments but also educates students on sustainability and conservation. Green building refers to the design, construction, and operation of structures that maximize energy and resource efficiency while minimizing environmental impacts. This encompasses eco-friendly materials, water management, indoor air quality, carbon reduction, and renewable energy use. Globally, green building implementation supports sustainable development goals, including in Indonesia's major cities like Jakarta.

Nationally, green building is gaining traction through Ministry of Public Works and Public Housing (PUPR) regulations. Minister of PUPR Regulation No. 21 of 2021 on Green Buildings underscores the government's commitment to promoting these principles across Indonesia, including DKI Jakarta. It outlines technical standards and criteria for sustainable, eco-friendly buildings, featuring seven core assessment components totaling 165 points. This framework aims to foster efficient, environmentally sound building management that counters climate change.

At the provincial level, Jakarta Governor's Regulation No. 60 of 2022 on Green Buildings establishes a legal foundation for implementation in the region. It mandates that new buildings and those undergoing major renovations—including educational facilities—meet green standards. The regulation also offers incentives for compliant developers and strengthens enforcement.

Nevertheless, green building adoption in DKI Jakarta's school buildings remains minimal. Of 4,048 public school buildings, only four have implemented the concept. This stark disparity highlights the gap between policy and practice. Despite robust regulatory frameworks, on-the-ground realization faces unaddressed constraints in the school context (Alsanad, 2015; Love et al., 2012).

Budget availability is a primary barrier. Green building demands higher upfront investments for energy-efficient systems, water management, and sustainable materials. Public schools often rely on constrained, priority-driven government funds, sidelining sustainability in construction. High operational costs—around 200 kWh/m²/year—further strain resources tied to external utilities like electricity and water. Yet, research indicates green schools with efficient technologies can cut electricity use by up to 45%, as noted in "The Role of Green Building in Education: Case Study of Schools in Southeast Asia" (Journal of Cleaner Production, 2020). The US Green Building Council reports average green building savings: 24–50% in energy, 33–39% in carbon, and up to 40% in water.

Another key factor is Value Engineering (VE), a systematic method to maximize project value by balancing functions and costs. In school buildings, VE enables cost-effective green solutions. However, it is rarely applied in school projects due to limited technical expertise and training among managers.

Life Cycle Cost Analysis (LCCA) evaluates a building's total ownership costs over its lifespan, including operations, maintenance, and replacements. For green buildings, LCCA highlights long-term savings despite higher initial costs. Yet, many school plans prioritize upfront expenses over lifecycle approaches, undermining sustainability.

Despite extensive global literature on green building, gaps persist in contextual factors for developing countries, especially education. Prior studies emphasize commercial, office, and hospital buildings in developed nations (Darko & Chan, 2017; Hwang & Tan, 2012), with scant focus on public schools in urbanizing cities like Jakarta.

While research has addressed budget constraints (Chan et al., 2018), Value Engineering applications (Dell'Isola, 2019), or LCCA methods (Sterner, 2020) separately, integrated analyses—including stakeholder understanding—in educational green building contexts are absent. Indonesian studies rely on qualitative or case-based methods (Achmadi & Okita, 2023; Christophorus & Sutandi, 2023), lacking quantitative validation of factor importance.

This study fills these gaps by: 1) Delivering the first quantitative analysis of green building in DKI Jakarta's public school buildings; 2) Integrating four factors (budget availability, VE, LCCA, and green building understanding) in a unified model; 3) Assessing their relative importance and interrelationships via multiple regression; 4) Providing empirical insights from a developing-country context with unique socio-economic and institutional hurdles.

This research's novelty stems from its comprehensive quantitative lens on barriers and enablers in education, offering theoretical advances in sustainable construction and practical guidance for policymakers, school administrators, and practitioners in emerging economies.

Thus, this study analyzes green building implementation in the Jakarta Provincial Government area—focusing on school buildings—through the lens of Minister of PUPR Regulation No. 21 of 2021 and Jakarta Governor's Regulation No. 60 of 2022. The findings aim to refine green building policies for Jakarta schools, promoting sustainable, eco-friendly development.

METHOD

This study used a quantitative method with the Multiple Linear Regression Analysis approach to analyze the influence of independent variables on dependent variables, both simultaneously and partially. The research aims to answer four research questions: (RQ-1) Do the factors of Budget Availability, Value Engineering (VE), Life Cycle Cost Analysis (LCCA), and Understanding of Green Building Concepts affect the implementation of Green Building in school buildings?; (RQ-2) What is the most dominant influencing factor?; (RQ-3) How to manage these factors so that implementation increases?; and (RQ-4) How does it compare to previous research?

The research used one bound variable (Y), namely the Application of the Green Building Concept, and four independent variables (X), namely Budget Availability (X1), Value Engineering (X2), LCCA (X3), and Green Building Understanding (X4). Budget availability includes budgets for green technology and contingency funds (Zuo & Zhao, 2014; Love et al., 2012). Value Engineering includes five stages: informational, functional, creative, evaluation, and implementation (Husin & Kurniawan, 2023; Karolina et al., 2021). LCCA consists of initial costs, operational and maintenance costs, replacement costs, energy-saving technology costs, and the impact on property values (Husin, 2023; Hou et al., 2024; Pass, 2016; Elwakil, 2019; Pratama, 2024). The understanding of Green Building includes basic principles, certifications, technology, environmentally friendly materials, and regulations (Kibert, 2016; Zhou et al., 2020;; Hasan et al., 2021). The implementation of Green Building is measured through the setting of minimum targets, gradual assessments, implementation indices, and integration in public policies (Bappenas, 2021; GBCI, 2013; UN Environment Programme, 2020; PUPR Ministerial Regulation No. 21, 2021). The object of the research is the building of public schools in DKI Jakarta at various stages of development, one of which is SD Negeri Duren Sawit 14.

The research population is all construction or renovation projects of public school buildings in DKI Jakarta in the last 5 years related to the principle of green building. Of the total 4,048 public school buildings in DKI Jakarta, only 4 schools have formally implemented the Green Building concept. The research uses a purposive sampling method with the criteria of schools that have construction/renovation documentation, access to technical data (budget, VE, LCCA), and projects implemented in the last 5 years.

The minimum number of samples was determined using the Slovin formula: $n = N / (1 + N(e)^2)$, with e = 10% as the margin of error tolerance. The threshold of 30 respondents was established based on two criteria: (1) statistical requirement for multiple regression analysis which recommends $n \geq 5 \times$ number of variables (in this case, $5 \times 5 = 25$ minimum), and (2) the central limit theorem which suggests that samples of 30 or more approximate normal distribution, enhancing the robustness of statistical inferences. This sample size determination follows established practices in construction management research (Fellows & Liu, 2015) and ensures adequate statistical power for detecting significant relationships among variables.

Respondents consisted of school principals, project implementing contractors, project supervisory consultants, and related technical agencies in DKI Jakarta such as the Education Office and the Cipta Karya Office. It should be noted that potential limitations in data collection include possible response bias due to self-reported perceptions, limited accessibility to certain high-level decision-makers, and the challenge of obtaining complete technical documentation from all sampled projects. These limitations were mitigated through data triangulation, multiple respondent types per project, and careful validation of responses during the interview process.

The research uses secondary data collected from various related agencies. Data collection was carried out through three methods: field observation, interviews, and questionnaires. Field observation aims to survey project conditions, collect documentation, verify the physical condition of the building, and identify the application of existing green building principles. Interviews were conducted to ensure respondents' suitability with the criteria, dig up in-depth information, and understand implementation barriers.

The main instrument was a closed questionnaire with a Likert scale of 1-5 (1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree). The questionnaire was compiled based on green building literature, GBCI guidelines, Jakarta Governor Regulation No. 60 of 2022, PUPR Regulation No. 21 of 2021, as well as Value Engineering and LCCA theory. The questionnaire is addressed to school principals, implementing contractors, supervisory consultants, and related technical offices to obtain comprehensive data on the implementation of the green building concept.

Data analysis using IBM SPSS Statistics version 30 went through several stages of testing. The data quality test included a validity test using Pearson Correlation (r calculated > r table with N=30, $\alpha=0.05$, r table ± 0.361) and a reliability test using Cronbach's Alpha ($\alpha \geq 0.7$ was declared reliable). Classical assumption tests include normality tests (Sig > 0.05 using Kolmogorov-Smirnov), multicollinearity tests (Tolerance > 0.10 and VIF < 10), and heteroscedasticity tests (random patterns on scatterplots or Sig > 0.05 on Glejser tests).

The hypothesis test uses a multiple linear regression model: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + e$, where Y is the Green Building Implementation Rate, X_1-X_4 is an independent variable, a is constant, b_1-b_4 is the regression coefficient, and e is the error term. The Statistical Test F tests simultaneous influences (Sig F < 0.05 means significant), the Statistical Test t identifies the dominant variable (Sig t < 0.05 means significant), and the R^2 Test shows the percentage of ability of independent variables to explain variations in the implementation of green building. RQ-1 and RQ-2 were answered through questionnaire analysis and regression equations, RQ-3 was answered through factor analysis in the case study to produce implementation recommendations, and RQ-4 was answered through comparison of results with previous studies for validation of findings.

RESULT AND DISCUSSION

Hypothesis Results

Table 1. Hypothetical Results

Variable	Coefficient B	Sig. (t-test)	Test Result	R Square (Individual)
X1: Budget Availability	0.296	0.111	Not Significant	0.635
X2: Value Engineering	-0.019	0.86	Not Significant	0.709
X3: LCCA	0.185	0.26	Not Significant	0.747
X4: Level of Understanding	0.422	0	Significant	0.803

a. X1 Budget Availability

Based on the results of multiple linear regression analysis, the variable X1 (Budget Availability) showed a regression coefficient value of 0.296 with a significance value (Sig.) of 0.111. This significance value is greater than the significance level of 0.05, so it can be concluded that partially (t-test), X1 does not have a significant effect on the implementation of green building. Thus, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected for the variable X1.

However, in the simultaneous significance test (F test) involving all independent variables (X1, X2, X3, and X4), a significance value of < 0.001 was obtained, which means that together the four variables have a significant effect on the implementation of green building. This suggests that although individually X1 is insignificant, its presence in the model still contributes to the model as a whole.

Furthermore, based on the results of the determination coefficient (R Square) in a simple regression model involving only the variable X1, an R^2 value of 0.635 was obtained. This means that 63.5% of the variation in the implementation of green building can be explained by budget availability, while the remaining 36.5% is explained by other variables that are not included in this model.

The variable of budget availability has a positive relationship with the implementation of green building, but it is not statistically significant partially. However, its contribution is still visible in the simultaneous model, and the high determination value suggests that X1 is a factor that remains relevant to consider in the context of the application of the green building concept, especially when combined with other variables.

b. X2 Value Engineering

The results of multiple linear regression showed that the variable X2 (Value Engineering) had a regression coefficient value of -0.019 with a significance value (Sig.) of 0.860. This value is far above the significance limit of 0.05, so it can be concluded that partially (t-test), the Value Engineering variable does not have a significant effect on the implementation of green building. Thus, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected for this variable.

Although the results of the partial test showed no significant effect, the simultaneous significance test (F test) on the entire model involving X1–X4 resulted in a significance value of < 0.001, which means that simultaneously, the four variables including Value Engineering had a significant effect on the implementation of green building. This signifies that Value Engineering still has a contribution to the model as a whole, although it is not individually dominant.

Based on the results of the determination coefficient (R Square) test on the simple regression model between Value Engineering and Green Building Implementation, an R^2 value of 0.709 was obtained. This means that statistically, around 70.9% of variations in the implementation of green building can be explained by the Value Engineering variable, while 29.1% can be explained by other factors outside the model (Anzagira et al., 2022; Lee et al., 2023).

However, although the R^2 value is quite high, the absence of significance in the ttest suggests that the relationship is not yet strong enough to be statistically significant (Shazmin et al., 2016; Shen et al., 2017). This may be due to the existence of multicollinearity, indirect influences, or the non-optimal implementation of value engineering principles in supporting the green building approach.

The Value Engineering variable shows a considerable contribution numerically to the implementation of green building based on the R^2 value. However, it is statistically not partially significant, indicated by a very high p-value. Therefore, it can be concluded that value engineering has not been a direct determining factor in the implementation of green building in the context of this research, and requires an integrative approach or strengthening in its implementation practice.

c. LCCA

From the results of multiple linear regression analysis, the variable X3 (LCCA) has a regression coefficient value of 0.185 and a significance value (Sig.) of 0.260. Because this significance value is greater than 0.05, the LCCA partially (based on the t-test) has no significant effect on the implementation of green building. Thus, the null (H_0) hypothesis is accepted, and the alternative hypothesis (H_1) is rejected for the X3 variable.

Although individually insignificant, in the context of simultaneous tests (F-tests) against the entire model (X1, X2, X3, and X4), the results still showed the significance of the model as a whole (Sig. < 0.001). This indicates that although LCCA is not partially significant, its presence in the model contributes to the overall significance of the regression, in relation to other variables.

To find out how much X3 contributes in explaining the variation in green building implementation quantitatively, a determination coefficient test (R Square) was used. From a simple regression model between X3 and Y, an R^2 value of 0.747 was obtained, which means that 74.7% of the variation in green building implementation can be explained by Life Cycle Cost Analysis, and the remaining 25.3% by other factors.

However, high R^2 values do not necessarily show a statistically significant relationship. The significance value (p-value) remains the main determinant in stating whether the relationship actually occurs in a population. In this case, a p-value of 0.260 indicates that the correlation is not strong enough to be considered significant.

The Life Cycle Cost Analysis (LCCA) variable has a positive regression coefficient and a fairly high R-square value, which shows that LCCA contributes to explaining the variation in the implementation of green building. However, the t-test results show that the effect is not statistically significant partially, so the hypothesis regarding the direct influence of LCCA on the implementation of green building is unacceptable.

Nonetheless, LCCA remains an important element in the green building approach, especially in the context of long-term decision-making. Therefore, strengthening the implementation and in-depth understanding of LCCA is still needed so that this variable can have a more real influence in the context of sustainable development.

d. Level of Comprehension

The results of multiple linear regression showed that the variable X4 (Level of Comprehension) had a regression coefficient value of 0.422 with a significance value (Sig.) of 0.000. Because this significance value is less than 0.05, it can be partially concluded (based on the t-test), that X4 has a significant effect on the implementation of green building. Thus, the zero hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted, which means that the level of understanding of the individual or project implementer significantly affects the successful implementation of the green building concept (Dell'Isola, 2019; Hwang, Zhu, & Ming, 2017).

In simultaneous testing (F-test) of models consisting of X1, X2, X3, and X4, significant results were obtained (Sig. < 0.001), which strengthens the evidence that collectively, these four variables, including X4, exert a significant influence on the dependent variables (the implementation of green building).

In addition, based on the results of the determination coefficient (R Square) test for the simple regression model between X4 and Y, an R^2 value of 0.803 was obtained, which is the highest value compared to other variables. This shows that 80.3% of the variation in the implementation of green building can be explained by a level of understanding variable, and only 19.7% can be explained by other variables that are not studied.

The positive regression coefficient value (0.422) also strengthens the finding that the higher the level of understanding of the green building concept of the parties, the greater the likelihood of the successful application of environmentally friendly development principles in a construction project.

The Comprehension Level variable has the most dominant and statistically significant influence on the implementation of green building, both in the t-test (partial), the F test (simultaneous), and in the determination coefficient test. With a very small significance value

(0.000) and an R Square of 0.803, this variable can be considered as a key driver in the successful implementation of green building.

Therefore, increased understanding, education, and training on the concept and benefits of green building to stakeholders in the project is highly recommended to strengthen the commitment and effectiveness of its implementation.

Variable Indicator Ranking

According to Ghozali (2018), the dominance variable test is used to find out how much the influence of independent variables affects dependent variables. Use the beta coefficient to determine which independent variable has the greatest influence (dominating) on the value of the dependent variable.

Beta Coefficient is also called Standardized Coefficient, which is an independent variable that can be stated to have a dominant influence on the dependent variable (Y) if it has a Standardized Coefficient value based on the results of the analysis in this study can be seen as follows:

Table 2. Variable Indicator Ranking

No	Variable	Standardized Beta	Zero Order	Dominant Values	% Dominant
1	Budget Availability	0.160	0.797	0.127	12.7
2	Value Engineering	-0.033	0.842	-0.028	-2.8
3	LCCA	0.225	0.865	0.195	19.5
4	Level of Comprehension	0.593	0.896	0.531	53.1

Standardized Beta & Zero Order Table Analysis

1. Budget Availability (Beta = 0.160 | Zero Order = 0.797)
   a) It has a fairly strong positive relationship in terms of initial correlation (Zero Order = 0.797).
   b) However, after controlling for other variables in the model, the contribution decreased (Beta was only 0.160).
   c) This means that the influence of the budget on the implementation of Green Building is more mediated or influenced by other variables, especially the Level of Understanding.
2. Value Engineering (Beta = -0,033 | Zero Order = 0,842)
   a) Zero Order is quite high (0.842), indicating that the initial relationship is strong.
   b) After being controlled, the coefficient turned negative and small (-0.033).
   c) This shows that VE's contribution to Green Building becomes very low or even reversed when other factors such as LCCA and Understanding are also taken into account.
   d) There may be overlap with other variables or a lack of integration of VE with green building principles in the field.
   e) VE is often focused on initial cost efficiency. In Green Building projects, solutions chosen through VE may tend to come at the expense of eco-friendly specifications because green materials or technologies typically have a higher starting price. As a result, even though VE saves on the initial budget, the application of green building principles can be reduced.

3. Life Cycle Cost Analysis / LCCA (Beta = 0,225 | Zero Order = 0,865)
   a) The initial correlation was very strong (0.865), indicating that LCCA has great potential to encourage the adoption of Green Building.
   b) Once controlled, the Beta dropped to 0.225 but remained positive.
   c) This signifies LCCA remains relevant in the model despite not being the most dominant, and its role could be stronger when combined with improved understanding of project actors.
4. Comprehension Level (Beta = 0.593 | Zero Order = 0.896)
   a) It has the highest initial correlation value (0.896) and the highest Beta (0.593).
   b) This shows that even after considering all other variables, the Level of Understanding still makes the largest and most significant contribution to the implementation of Green Building.
   c) These variables play a key role as a key factor that affects the effectiveness of budgets, VE, and LCCA in encouraging the application of sustainability principles.

Table 3. Variable Indicator Ranking

Ranking	Variable	Standardized Beta	Conclusion	Information
1	Level of Comprehension	**0,593**	Dominant	Had the largest and significant positive influence ($p < 0.001$). Increasing the understanding of project actors makes them able to direct the budget, Value Engineering, and LCCA to really support the implementation of Green Building.
2	LCCA	**0,225**	Not Dominant	It has a positive effect and is relevant to the Green Building principle through the calculation of life cycle costs. However, it is not partially significant ($p = 0.260$) because the implementation of LCCA in the field is still limited and not yet mandatory.
3	Budget Availability	**0,160**	Not Dominant	It had a positive effect, but it was not partially significant ($p = 0.111$). The existing budget has not been fully directed to the green component because the priorities of using funds vary.
4	Value Engineering	**-0,033**	Not Dominant	The negative coefficient shows a downward trend in the implementation of Green Building when VE is not integrated with sustainability principles. It was insignificant ($p = 0.860$) so the effect was partially very low. VE is often focused on initial cost efficiency. In Green Building projects, solutions chosen through VE may tend to come at the expense of eco-friendly specifications because green materials or technologies typically have a higher initial price

Managing variables/factors so that the Green Building Implementation Rate increases.

1. Level of Understanding (Most Dominant Factor)

Standardized Beta = 0.593 (the highest, significant $p < 0.001$) is the main determinant of the success of the implementation of Green Building.

Management:

a) Training & Certification: Require regular training for architects, engineers, and project managers on Green Building (LEED) standards.
b) Integration into the Curriculum: Incorporate sustainability and Green Building materials into formal civil engineering & architectural education.
c) Workshop & Case Study: Host a forum to share best practices from successful projects.
d) Technical Guidance Documents: Provide a pocket book or practical guide to implementing Green Building for public school projects.

2. Life Cycle Cost Analysis (LCCA)

Standardized Beta = 0.225 (positive, not partially significant). The potential is high because it is in line with the principle of long-term efficiency.

Management:

a) Require LCCA: Make LCCA a public project planning requirement, not an optional option.
b) Cost Data System: Create a database of material lifecycle costs and green technologies in Indonesia.
c) LCCA Technical Training: Teach LCCA calculations to procurement teams and planners.
d) Implementation Oversight: Ensure that the results of the LCCA are used in decision-making, not just a formality.

3. Budget Availability

Standardized Beta = 0.160 (positive, partially insignificant). Its influence is stronger if it is directed correctly by good understanding.

Management:

a) Special Allocation: Set aside a special budget portion for green components (solar panels, energy-efficient HVAC systems, certified materials).
b) Multi-Source Funding: Look for additional funding sources from CSR, environmental grants, or public-private partnerships.
c) Phased Budget Scheme: Implement phased development so that green technology can be installed even though the annual budget is limited.

4. Value Engineering (VE)

Standardized Beta = -0.033 (negative, partially insignificant). Without the integration of sustainability principles, VE has the potential to reduce green features for initial cost efficiency.

Management:

a) Green VE: Implement VE with additional assessment criteria that measure sustainability impact.
b) Collaboration with Environmental Experts: Include sustainability consultants in the VE team.

c) Long-Term Impact Evaluation: Ensure any cost-saving proposals from VE are tested with the LCCA before approval.
d) Documentation & Controls: Keep a record of all VE decisions to avoid the removal of crucial eco-friendly components.

Based on research, the Level of Understanding is a top priority to be improved because it is able to reinforce the positive effects of the other three variables.

The best approach is a synergy of four factors:

1. A high understanding → directs the use of the budget appropriately.
2. LCCA → ensure green investments are profitable in the long run.
3. The budget → provide special funding for environmentally friendly technologies.
4. VE → adapted to be "Green VE" so that cost efficiency is aligned with sustainability.

Comparison of Research Results Against Previous Research

The results of previous research show various findings that are the basis for the development of research in this field. Some studies have also highlighted that there are differences in results based on variables such as location, method, or sample used. However, there are some limitations in previous research, such as limitations in methods, samples, or research scope. Therefore, this study aims to enrich the previous results with a more comprehensive approach and more in-depth analysis. The following is a comparison table of previous research can be seen in the table.

The findings of the research that have been carried out state that the research variables, namely (X2, X2, X3 and X4), can affect the Level of Implementation of the Green Building Concept in School Buildings in DKI Jakarta.

Table of Comparison of Research Results Against Previous Research

Table 4. Comparison of Research Results Against Previous Research

No	Title /author /year	Research Results	Information
1	Green building research–current status and future agenda: A review. Renewable and Sustainable Energy Reviews (Zuo, J., & Zhao, Z. Y., 2014) Strategies for Implementing Green Buildings in DKI Jakarta (Iswan Achmadi & Indrastuty R. Okita, 2023) Identification of Challenges in the Implementation of Green Buildings in DKI Jakarta (Johannes Christophorus & Arianti Sutandi, 2023) Green Building Management Plans with a Building Environment Management (BEM) Approach (Regina, Liong Ju Tjung, Priyendiswara A.B.3, 2019) Incentives and Barriers to Green Building Implementation: The Case of Jakarta. (Sigid Prasetyawan, Rossy Armyn Machfudiyanto, Titi Sari Nurul Rachmawati, 2023) Empirical Examination of Factors Influencing the Adoption of Green Building	In previous research, the budget was the main obstacle, both in terms of initial construction costs and long-term operational costs. Financing and maintenance of Green Buildings are felt to be expensive by project owners. Financial risks are considered too great. ***Budget availability*** is influenced by economic conditions, Research states that high initial costs are an obstacle so policy support (subsidies, fiscal incentives, soft financing is needed). Adequate budget planning is an important requirement to maintain certification and improve the implementation of the Green Building concept. Government support, social demand, and management leadership play a crucial role in motivating developers to adopt green building technologies. This is in accordance with and supports the variable **Budget Availability** in this study, that Budget	Supports Budget ***Availability implementation Variable (X1)***

No	Title /author /year	Research Results	Information
	Technologies: The Perspective of Construction Developers in Developing Economies. (Zhou, L., et al., 2020))	Availability has a significant effect on the implementation of the Green Building concept.	
2	Analysis of the Implementation of Green Buiding on the Implementation Cost of Value-Based Industrial Building Projects (Nurhikmah Alam & Agus Suroso, 2024) Improvement of Value Engineeting-based *Cost Performance* in *Green Hospital Projects* (Immron & Husin, 2021) Cost Performance Analysis of Green Concept in the Main Building of the Flour Mill Plant Based on Value Engineering and Life Cycle Cost Analysis / (Kurniawan & Husin, 2023) Analysis of the Implementation of Green Areas in Residential Areas Based on Value Engineering and Life Cycle Cost Analysis / (Amalia, 2023) Improvement of Green-Based Façade Work Cost Performance Building and Value Engineering in High-Rise Hotel Buildings / (Karolina, 2021)	In previous research, the application of **Value Engineering (VE)** was the most dominant variable affecting project cost performance, energy efficiency with the selection of a more environmentally friendly system, VE effectively reducing initial costs. Meanwhile, in this study, the researchers got different results, the solution chosen through VE may tend to sacrifice environmentally friendly specifications because green materials or technologies usually have a higher initial price. As a result, even though VE saves on the initial budget, the application of green building principles can be reduced. For this reason, further research is needed.	Support Varibel ***Value Engineering (X2)***
3	Analysis of Green Zone Implementation in Residential Areas Based on Value Engineering and Life Cycle Cost Analysis / (Amalia, 2023) Identification of Challenges in the Implementation of Green Building in DKI Jakarta (Johannes Christophorus & Arianti Sutandi, 2023) Innovative building technologies and technical equipment towards sustainable construction – a comparative LCA and LCC assessment (Passer, A. 2016) Life Cycle Cost Analysis of Energy Efficient Single Family Residence (Ayushi Hajare & Emad Elwakil, 2019) Sustainable Construction: The Role of Environmental Assessment Tools Case Study of Cost Optimization of Green Building Projects Using Value Engineering Methods (Clarissa & Anondho, 2023) Green Infrastructure Retrofit on Jetty Based on Value Engineering and Life Cycle Cost Analysis to Improve Cost Performance / (Iswidyantara, 2018) Analysis of Energy Efficiency and Conservation Factors for the Application of Near Zero Energy with the Concept of Green Building and Value Engineering in Office Buildings (Fajarika, 2024)	The results of previous research show that sustainability assessments should be carried out from the early stages of project appraisal, so that strategic decisions can be more aligned with sustainability goals. Many LCA studies only take into account the initial costs, even though materials and components have a limited lifespan and require periodic replacement. Replacement costs (the cost of replacing materials such as roofs, windows, mechanical systems) can significantly affect the total lifecycle cost outcome and environmental impact of the building. LCCA (Life Cycle Cost Analysis) calculations that do not include replacement costs will result in less accurate cost estimates. By including replacement costs, design decisions and material selection can be more precise, especially to achieve long-term efficiency in green buildings. This supports the LCCA **(Life Cycle Cost Analysis) variable** in this study, because it has a positive effect and is relevant to the principles of Green Building through the calculation of life cycle costs.	Support Varibel ***Life Cycle Cost Analysis (X3)***
4	*Strengthening green building policies in Indonesia* (Sahid, S., Sumiyati, Y., and Purisari, R., 2021) Strategies for the Implementation of Green Building in DKI Jakarta (Iswan Achmadi & Indrastuty R. Okita, 2023) Study on the Implementation of Green Building in Bank Indonesia Surakarta Building (Taufiq Lilo Adi Sucipto, Jati Utomo Dwi Hatmoko, Sri Sumarni and Jeni Pujiastuti,	The results of previous research show that regulations that support the implementation of green building in Indonesia are still relatively limited, both at the national and regional levels. The incompleteness of this policy has the potential to hinder the effective implementation of green building, including in terms of the quality of its implementation. Lack of contractor knowledge and experience regarding	Support Varibel ***Understanding Green Building (X4)***

No	Title /author /year	Research Results	Information
	2017) Incentives and Barriers to Green Building Implementation: The Case of Jakarta. (Sigid Prasetyawan, Rossy Armyn Machfudiyanto, Titi Sari Nurul Rachmawati, 2023) Empirical Examination of Factors Influencing the Adoption of Green Building Technologies: The Perspective of Construction Developers in Developing Economies. (Zhou, L., et al., 2020) Sustainable Construction: The Role of Environmental Assessment Tools	GB. Lack of knowledge and expertise of consultants. Lack of socialization from the government. Lack of experts in the government related to GB. One such study provides insight into the factors influencing the adoption of GBT in developing countries. It was found that government support, social demand, and management leadership play a crucial role in motivating developers to adopt green building technologies. This supports the Green ***Building Understanding*** variable in this study, which is due to the lack of understanding and awareness of stakeholders on the concept of green building. Lack of financial incentives and policy support. The Level of Understanding variable has the most dominant and statistically significant influence on the implementation of green building.	

CONCLUSION

This study concludes that Budget Availability, Value Engineering (VE), Life Cycle Cost Analysis (LCCA), and Understanding of Green Building Concepts collectively exert a significant influence on green building implementation in DKI Jakarta's school buildings, explaining 86% of implementation variance ($R^2 = 0.86$). Green Building Understanding dominates at 53.1%, followed by LCCA (19.5%), Budget Availability (12.7%), and VE (-2.8%, indicating a counterintuitive negative effect). These findings underscore stakeholders' knowledge and awareness as pivotal drivers, with budgetary and technical tools proving effective only alongside robust understanding—aligning with prior studies on comprehension's primacy while highlighting contextual divergences in VE and LCCA from international research. To boost adoption, enhancing stakeholder capacity on green building principles and benefits, alongside reinforced VE and LCCA application, is essential. Future research should conduct longitudinal studies tracking long-term implementation outcomes post-training interventions, incorporating qualitative insights from school administrators to explore VE's negative effect and refine context-specific models for Indonesian public infrastructure.

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