



# Value Engineering Analysis on Building Structure Work with the Application of Green Building Concept

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**Abstract.** The construction industry has a significant impact on the environment, particularly in terms of its contribution to global warming, due to high energy consumption. The green building concept serves as a strategic solution to mitigate these negative impacts by applying sustainability principles in building design, construction, and operations. One method that can be used to implement sustainability principles is value engineering analysis. This study examines the application of value engineering in building structural work to optimize costs and enhance efficiency without compromising quality or sustainability principles in the context of green building. The long-term objective of this research is to draft implementation guidelines for structural work by applying green building concepts through value engineering. The specific objectives of this study are to identify alternative material recommendations for structural work based on green building principles and to determine the most cost-effective implementation during the structural work phase. The research method employed is a quantitative descriptive approach, with primary data collection conducted through stakeholder interviews to identify project requirements for value engineering. Secondary data includes cost estimates and standard unit price analyses. The results obtained include material alternative recommendations for the structural work of the Six Palm Villa Type B3-Main House, specifically precast concrete columns, hollow-core slabs, and lightweight steel roof frames. The most economical implementation alternative amounts to Rp 55,550,650.

**Keywords:** Cost, Engineering, Green, Structure, Value

## 1 Introduction

All countries and regions, including Indonesia, are affected by climate change, which is caused by various factors (Peginusa et al., 2024). The construction industry is one of the factors that negatively impact the environment. The reduction of green spaces, excessive energy consumption, and the use of non-eco-friendly building materials contribute to global warming (Damar et al., 2023). Recent research indicates that the construction sector accounts for approximately 25% of global CO<sub>2</sub> emissions (Karlsson et al., 2021). This phenomenon of climate change underlies the importance of implementing the Green Building concept in the construction industry sector

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(Ratnaningsih et al., 2019). Building construction, particularly structural work and its environmental impact, is inherent in every phase (Kimsan, 2023). The concept of green buildings in sustainable construction serves as a solution and foundation for environmentally friendly construction practices. The application of sustainable construction concepts, despite the risk of increased costs, can be mitigated through the value engineering method (Susetyo, 2019). Value Engineering (VE) or value analysis is one of the methods used to conduct cost-saving studies (Atabay & Galipogullari, 2012). The VE (Value Engineering) concept involves several systematic stages commonly used to reduce the level of cost inefficiency/unnecessary cost losses that may arise during the implementation/construction phase. Additionally, the application of the VE concept provides several benefits that add value when implemented in construction projects (Thoengsal, 2018). The strength of Value Engineering lies in its systematic, structured, and methodical approach to analyzing the value of a core problem concerning its function or utility, while ensuring consistent quality and project upkeep (Diputera et al., 2018). One of the objectives of implementing the value engineering technique is to identify design functions, allowing suitable alternative functions to be selected in accordance with preferences while reducing costs (Yusuf et al., 2021). The development of tourism has led to continuous economic growth in the South Badung region, accompanied by massive civil and infrastructure development. However, the negative aspect of this development is its contribution to adverse environmental impacts, particularly in the Badung area. Therefore, it is necessary to conduct research on the selection of more environmentally friendly materials and construction methods for structural work. This aims to mitigate the negative impacts while maintaining the building's quality. The objective of this study is to identify structural building work in the Six Palm Villa project that can be optimized through value engineering. The Six Palm Villa, Type B3-Main House, experienced a cost increase during the planning phase, necessitating a value engineering analysis to achieve optimal costs. The value engineering method was carried out in stages, beginning with the collection of data from the latest project budget, followed by a functional analysis using the F.A.S.T. diagram method. The next stage involved creativity to generate alternative material recommendations. Once the best alternative was selected, calculations were performed to determine the most economical and efficient cost and implementation time.

## 2 Methodology

This study employs the value engineering analysis method, which follows a structured workflow consisting of the following stages: information phase, functional analysis phase, creative phase, evaluation phase, development phase, and presentation phase. The core concept of Value Engineering is optimizing the cost of a product or service by applying engineering principles. This technique aims to achieve at least the same level of quality as initially planned while minimizing costs (Nandito et al., 2020). Each stage has specific achievement indicators, as outlined in the following table.

**Table 1.** Research Stages and Achievement Indicators

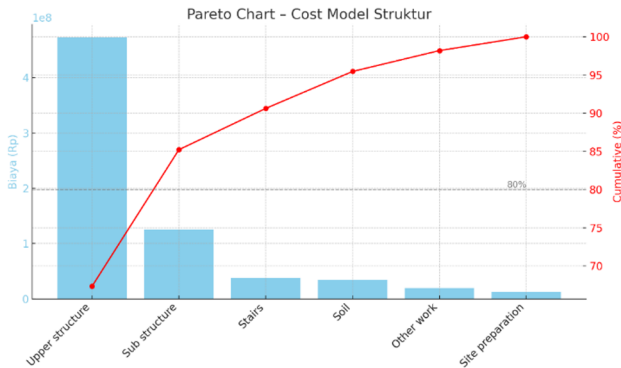
No.	Activity description	Achievement indicator
1	Conducting a project site survey and obtaining permission from the executing contractor to carry out the research activities.	Permission granted by the executing contractor.
2	Collecting secondary data from the related project.	Secondary data gathered, including cost estimates (RAB), unit price analysis (AHSP), and schedule.
3	Data Analysis 1:	
3.1	Identifying research subjects based on secondary data using a Pareto diagram.	A list of high-cost structural work items is compiled.
3.2	Conducting functional analysis on the identified list.	Criteria aligned with the Green Building concept are established.
3.3	Executing the creativity phase based on the identified work items.	Alternative designs (materials and execution methods) compared to the existing design are proposed.
4	Collecting primary data from the project and material suppliers.	Execution methods and material cost data meeting the established criteria are obtained.
5	Data Analysis 2:	
5.1	Evaluating criteria and alternatives using the zero-one method.	The most suitable alternative is selected from the options.
5.2	Developing the selected alternative in comparison to the existing one.	The most cost- and time-efficient alternative is determined.
5.3	Presenting the finalized results.	Analysis results, including alternative options and the rationale for selection, are documented.
6	Conclusions from the analysis.	Conclusions addressing the research problem are formulated.

Table 1 outlines the entire research methodology, breaking down the Value Engineering process into a structured, step-by-step plan. It’s important because it shows the study was systematic and not arbitrary. Each stage (e.g., Information, Functional Analysis) has a clear goal and a measurable “Achievement Indicator” to ensure the research stays on track. This structure is the backbone of the entire analysis, ensuring rigor and repeatability.

### 3 Result and Discussion

#### 3.1 Result

**Information Phase.** In the information phase, an analysis is conducted using the Pareto principle to identify potential areas for cost-saving measures, as shown in Figure 1.



**Figure 1.** Pareto Diagrams for Structure Work

From Figure 1, the most crucial insight is found where the cumulative percentage line crosses the 80% threshold. The diagram shows that the first two categories—“Upper structure” and “Sub structure”—together account for approximately 85.22% of the total cost of the structural work. This is a classic example of the Pareto Principle in action. The remaining categories (“Stairs”, “Soil”, “Other work”, “Site preparation”) account for only about 14.78% of the total cost.

**Functional analysis phase.** At this phase, as shown in Table 2, the analysis aims to determine the primary function of each structural work component and evaluate whether the incurred costs are proportional to the functional value provided, through the determination of the Cost-to-Worth Ratio.

**Table 2.** Cost to Cost-to-Worth Ratio

Componen	Cost (Rp)	% Cost	Worth	% Worth	C/W ratio
Upper structure	473,091,157	67.34%	5	25%	2.69
Sub structure	125,620,193	17.88%	5	25%	0.72
Stairs	37,959,121	5.40%	3	15%	0.36
Soil	33,991,568	4.84%	4	20%	0.24
Other work	19,167,605	2.73%	2	10%	0.27
Site preparation	12,727,884	1.81%	1	5%	0.36

Table 2 is a core concept in Value Engineering. It moves beyond just cost to assess value. Cost (Rp) & % Cost: Shows the actual monetary expense and its percentage of the total project cost for each component. Worth & % Worth: “Worth” is a subjective score (1-5) assigned by experts, representing the component’s functional importance to the project. A score of 5 for the upper and sub-structure means they are critically important. C/W Ratio: This is the key metric. A ratio greater than 1 (like the Upper Structure’s 2.69) means you are paying more than the function is worth – this is the prime target for cost optimization. A ratio less than 1 means the function is provided at a cost lower than its perceived value – this is efficient. This table clearly identifies the “Upper Structure” as inefficient and the main focus for improvement.

**Creative phase.** In the creative phase, as shown in Table 3, alternatives and criteria for further analysis are identified. The criteria include material efficiency optimization, structural design optimization, the use of sustainable and eco-friendly materials, and construction time and cost efficiency. The alternatives that meet the criteria are listed in Table 3. It demonstrates the brainstorming process. For each problematic high-cost component (Columns/ Beams, Slab, Roof), the team generated multiple creative alternatives. The alternatives are judged against key principles of Green Building and VE: material efficiency, sustainability, and cost/time savings. They range from using high-strength materials (Alternative 1 for columns) to completely changing systems (hollow core slabs) or utilizing different materials (lightweight steel). This shows a comprehensive search for solutions, not just a single idea.

**Evaluation phase.** The evaluation phase employed the zero-one method to identify the optimal alternative. From Tables 4, 5, and 6 for all three components (Columns/ Beams, Slab, Roof), Alternative 1 scored 100%, meaning it perfectly satisfied all four green and efficiency criteria. This provides a clear, defensible rationale for why these specific alternatives were chosen for further development.

**Development phase.** The development phase involved a detailed analysis of the selected alternatives from both technical and cost perspectives. From Tables 7, 8, and 9, after selecting the best alternatives, this phase involves detailed cost estimation to determine if the theoretical ideas are financially viable. Each table breaks down the cost for the new alternative into Materials, Labor, and Equipment. This granular view is essential for accurate comparison and ensures no hidden costs are missed. It transitions from concept to a concrete, actionable cost estimate (e.g., IDR 7,480,000 per m<sup>3</sup> for a precast column) that can be directly compared to the original design’s cost.

**Table 3.** Cost to Cost-to-Worth Ratio

Componen	Alternative 1	Alternative 2	Alternative 3	Alternative 4		
C1 column H200	Use of high-strength reinforced precast concrete (e.g., 10D13 rebars) to reduce concrete volume and accelerate installation time.	Substitution of WF 300×150 steel beams with composite columns (steel-concrete combination) to reduce weight and material costs.	Implementation of lightweight steel beams with equivalent strength to WF250×125 but reduced weight.	Application of prestressed reinforced concrete beams to reduce beam dimensions and material volume.		
C2 column WF 300×150						
13×30 cm C1 concrete column, 8D13, 2 pcs						
B1 beam WF300×150						
B1 beam WF250×125						
B2 beam WF200×100						
Slab floor bondex 0.75					Implementation of hollow core slab system using Bondex slab + cast concrete to reduce dead load and material costs.	Use of the waffle slab system to reduce concrete volume in low-load areas.
15 cm concrete slab floor, wire mesh M8 1 layer						
Truss C7575					Replacement of the C7575 truss with a light-gauge steel truss for cost reduction and easier installation.	Use of recycled composite roof tiles as a substitute for Gemini or Duco Mati Grey to reduce costs and environmental impact.
Rafter Calsiplank 20 cm						
Roof concrete tile duco matt grey						

**Table 4.** Zero One for Column and Beam Work

Alternative	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Total Score
Alternative 1	1	1	1	1	100 %
Alternative 2	1	1	0	0	70 %
Alternative 3	1	0	1	1	70 %
Alternative 4	0	1	1	0	50 %

**Table 5.** Zero One for Slab work

Alternative	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Total Score
Alternative 1	1	1	1	1	100 %
Alternative 2	0	1	1	0	50 %

**Table 6.** Zero One for Roof Work

Alternative	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Total Score
Alternative 1	1	1	1	1	100 %
Alternative 2	1	0	1	1	70 %

**Table 7.** Cost Analysis Precast Concrete Column

Coloum	Total Cost (Rp)
Materials	6,880,000
Labor	450,000
Equipment	150,000
Total	7,480,000

**Table 8.** Cost Analysis Hollow Core Slab

Coloum	Total Cost (Rp)
Materials	210,000
Labor	30,000
Total	240,000

**Table 9.** Cost Analysis Hollow Core Slab

Coloum	Total Cost (Rp)
Materials	160,000
Labor	20,000
Equipment	5,000
Total	185,000

**Presentation phase.** This stage involves comparing the initial cost with the selected alternative cost. Table 10 synthesizes the results of the development phase. It calculates the total cost impact of implementing all the chosen alternatives (Precast Columns, Hollow Core Slab, Lightweight Steel Roof) based on the project’s specific quantities (volume and area). The final total of IDR 55,550,650 represents the new, optimized projected cost for these structural elements. The final result, as shown in Table 11, proves the success of the Value Engineering exercise. It directly compares the Initial Design cost with the Optimal Alternative cost from Table 10. The table also shows the absolute savings (e.g., IDR 4,581,536 saved on the slab) and shows the relative savings. The total saving of IDR 9,007,241 (13.95%) is a significant figure that demonstrates the powerful financial benefit of applying VE alongside green principles. It conclusively shows that being environmentally friendly (through material reduction and better systems) can also be highly economical.

**Table 10.** Cost Summary of Selected Alternatives

Work item	Spesification	volume	Unit price (Rp)	Total cost (Rp)
Precast Concrete Column	13×30 cm, 10D13 reinforcement, K-300	0.27 m <sup>3</sup>	7,480,000/m <sup>3</sup>	2,019,600
Hollow Core Slab	15 cm panel, 1.2 m width, K-250	102.85 m <sup>2</sup>	240,000/m <sup>2</sup>	24,648,000
Lightweight Steel Roof Frame	0.75 mm thickness, G550 galvanized	155.93 m <sup>2</sup>	185,000/m <sup>2</sup>	28,847,050
<b>TOTAL</b>				<b>55,550,650</b>

**Table 11.** Cost Optimization Analysis

Work item	Initial design	Optimal alternative	Cost different	%
Precast Concrete Column	2,034,502	2,019,600	14,902	0.73 %
Hollow Core Slab	29,256,536	24,648,000	4,581,536	15.7 %
Lightweight Steel Roof Frame	33,275,853	28,847,050	4,428,803	13.3 %
<b>TOTAL</b>	<b>64,557,891</b>	<b>55,550,650</b>	<b>9,007,241</b>	<b>13.95 %</b>

### 3.2 Discussion

During the information phase, based on the Pareto 80/20 principle, it was found that 85.22% of the total structural cost is attributed to two components: the upper structure (67.34%) and the substructure (17.88%). These components will be prioritized for cost control as they dominantly influence the total structural work cost. In the functional analysis phase, the determination of the C/W ratio follows this principle: if the ratio value exceeds 1, the cost is disproportionate to the value (inefficient), whereas if the ratio is less than or equal to 1, the cost is proportional (efficient). Based on the C/W ratio analysis results, the upper structure shows a ratio of 2.69, indicating inefficiency, thus requiring optimization measures. During the creative phase, four criteria and corresponding alternatives that met the established requirements were identified, enabling progression to the subsequent evaluation stage. The evaluation phase, using the zero-one method, yielded the following results: Alternative 1, high-strength reinforced precast concrete, achieved the highest score of 100%. For floor slab work, Alternative 1 (hollow core slab system) was selected as the optimal solution. Similarly, for roof work, Alternative 1 (substitution of C7575 truss with light-gauge steel truss) emerged as the best choice. After determining the optimal alternatives through the zero-one method, the process proceeded to the development phase to assess potential cost efficiencies. During the development phase, the execution costs for each chosen alternative were determined. Subsequently, these costs were compared to the baseline costs in the presentation stage. The cost optimization analysis table demonstrates that

the selected alternative yields savings of IDR 9,007,241, representing 13.95% of the recommended replacement work costs.

## 4 Conclusion

The recommended material alternatives based on green building concepts for the structural work of Six Palm Villa Type B3-Main House are Precast concrete columns to replace 13×30 cm C1 concrete columns with 8D13 reinforcement (2 pieces), Hollow core slabs to replace 0.75 mm Bondex floor slabs, and Lightweight steel roof frames to replace C7575 trusses. The most cost-effective implementation alternative for the structural work of Six Palm Villa Type B3-Main House, based on the selected option, amounts to IDR 55,550,650. The achievable cost savings total IDR 9,007,241, representing 13.95% of the recommended replaceable work costs.

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