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Original Article

Optimization of Hospital Construction Projects Using Integrated Value Engineering and Life Cycle Cost Analysis for Improving Cost Efficiency: A Case Study of Hermana Lembean Hospital

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Abstract *- Hospital buildings constitute a large commitment, both financially and operationally, over their service lives. Therefore, the decisions about the construction material compel a consideration of the initial construction costs and the future costs associated with the maintenance and the replacement of the construction. Material selection in construction, however, is characterized by a strong focus on the first costs, bending the economics for the overall construction lifecycle. Value Engineering integrated with Life Cycle Costing presents a more robust framework for comparing construction options. This study examines the architectural component of the Hermana Lembean Hospital project. This study combines VE and LCC for a single framework assessment. The primary data source was the project's Bill of Quantities, technical specifications and drawings. A Pareto analysis was first used to identify the primary cost elements, and then, the VE job plan was used to develop and assess material options. The selected alternatives were then assessed using a 20-year LCC analysis with an annual discount rate of 8%. The results show that architectural work is the largest cost component, amounting to Rp 2,456,544,915.00 or 38.93% of the total project cost. The implementation of VE reduced the initial cost from Rp 924,197,538.00 to Rp 893,603,302.00, resulting in a cost saving of 3.31%. Meanwhile, the total LCC decreased from Rp 1,239,146,878.51 to Rp 1,138,403,872.00, resulting in a saving of 8.13%. The best alternatives were lightweight brick, ready-mix mortar, Nippon Paint, Nippon Weather bond, and GRC ceiling panels. This study demonstrates that the integration of VE and LCC can produce more efficient decisions than considering only initial costs.*

Keywords *- Cost Efficiency, Hospital Construction, Life Cycle Cost, Optimization, Value Engineering.*

1. Introduction

Hospital construction projects represent one of the most complex categories of building development due to the stringent functional, technical, and regulatory requirements that must be satisfied throughout their service life. In addition to providing a safe and comfortable environment for patients and healthcare personnel, hospital facilities must ensure operational reliability, adaptability, and long-term sustainability. Consequently, decisions made during the design and construction stages have substantial implications not only for the initial capital investment but also for the future maintenance, rehabilitation, and replacement costs incurred throughout the building life cycle [1, 7].

The increasing demand for cost-efficient healthcare infrastructure has intensified the need for comprehensive cost management strategies that extend beyond the conventional focus on minimizing initial construction costs. Traditional project evaluation frequently prioritizes first-cost considerations during the design stage while overlooking future expenditures associated with maintenance, repair, replacement, and facility operation. Such an approach may result in economically inefficient decisions, where materials with lower initial costs ultimately generate significantly higher ownership costs over the building's service life. Therefore, sustainable decision-making in hospital construction requires evaluation methods capable of considering both immediate and long-term economic impacts [1, 5, 18]. Value Engineering (VE) has been successfully used to reduce costs in bridge construction [14], schools [19], and green hospitals [8]. Recent work has shown the expanding applicability of Value Engineering beyond traditional cost analysis. For example, Liang et al. [9] developed a stakeholder-focused framework for the assessment of function during the construction material selection process, which allows for greater alignment of the project outcome with stakeholder expectations. long been recognized as a systematic methodology for while Value Engineering focuses on function-cost relationships, Life Cycle Cost (LCC) analysis considers the facility's economic performance throughout the entirety of the facility's life. Unlike Value Engineering, which primarily focuses on construction costs, Life Cycle Cost counts future costs on the maintenance, repairs, replacements, operations, and the facility's residual value. Incorporating these costs allows LCC to create more sustainable, economically viable, and affordable solutions. [1, 5, 18]. Life Cycle Cost has been utilized on various infrastructures, from simple buildings to complex bridges and more. LCC has been used, both deterministically and probabilistically, to estimate the financial feasibility of various infrastructures over many years. [1, 18].

Even with the popularity of both models, they've rarely been used together. Value Engineering is primarily concerned with functional value and the reduction of construction costs, which is typically accomplished through alternative designs and/or material substitutions [8, 9, 19]. Life Cycle Costs, on the other hand, is primarily concerned with the costs of alternatives that are selected [1, 5, 18]. Very few studies have evaluated both functional performance and the costs incurred during the long-term ownership of a facility. This concern is even more important for hospital projects, because the materials selected impact the facility's maintenance and operations for a long number of years.

This phenomenon can be noted in Indonesia as well. Most studies leverage Value Engineering to manage construction costs during the design phase and treat Life Cycle Cost as an independent metric after design. A limited number of studies have integrated both into a single evaluation system, especially for hospital building projects. This is a serious concern because the design phase consumes a large construction budget and has a significant impact on the maintenance of the facility. The Hermana Lembean Hospital project was picked as the case to study this problem in practice. The project's cost data indicate that the design accounts for Rp 2,456,544,915.00 or 39.03% of the total project cost. Since this package accounts for the highest cost, other project cost components will have a significant impact on the overall project cost. The study, therefore, focuses on the analysis of the wall design, wall plastering, wall skimming, and interior and exterior painting as well as the ceiling.

This study's major contribution is the combination of Value Engineering with Life Cycle Cost integrated into a single evaluation system for hospital projects. Instead of looking at functional and economic performance individually, the method looks at the performance of different materials developed. Functional performance, initial construction cost, anticipated maintenance cost and replacement, and the ownership cost over the 20-year service life of the material is combined and used to evaluate the materials. The method provides the opportunity to select materials that will functionally and economically serve the purpose over the operational life of the building.

With this in mind, this research analyzes the application of an integrated Value Engineering-Life Cycle Cost methodology to the optimization of the architectural elements of the project of the Hermana Lembean Hospital. The intention is to identify the opportunities for the reduction of the costs of construction and further assess if the selected options are economically favorable during the entire service life of the building. In Table 1, the present research is situated in relation to prior research, with emphasis on the research object, the methodology, and the main contribution of each of the studies. It further provides a description and emphasis on the differentiating aspect of the research which is the framework of the research.

Table 1. Comparison between previous studies and the present research

Authors	Research Object	Method	Main Findings
Hatami & Morcouse (2016)	Bridge Infrastructure	LCC	Developed deterministic and probabilistic LCC models for bridge management.
Imron & Husin (2021)	Green hospital project	VE + LCC	Improved project cost performance through VE and LCC.
Liang et al. (2023)	Building projects	VE	Developed a stakeholder-oriented building function assessment framework.
Youssef et al. (2023)	Educational buildings	VE	Identified design alternatives to improve project value.
This Study	Hermana Lembean Hospital (Indonesia)	Integrated Value Engineering + Life Cycle Cost	Evaluates architectural material alternatives using functional analysis and 20-year LCC assessment to identify the optimum solution considering both initial and long-term costs.

2. Materials and Methods

A quantitative case study on the construction of the Hermana Lembean Hospital was used to carry out this research. The study fused Value Engineering (VE) with Life Cycle Cost (LCC) analysis to study the impact of different architectural material options on the project of construction within the constraints of acceptable technical performance and quality. The approach proposed further was the consideration of the costs of future maintenance and replacement during the service life of the building. The investigation was carried out in six main phases. It began with the collation of data related to the project. Dominant cost elements were identified with the aid of Pareto analysis. The identified work items were subjected to the Value Engineering job plan, as well as the Life Cycle Cost analysis. The general overview of these activities is shown in Figure 1.

2.1. Research Data

The analysis was performed using both primary and secondary data. Primarily, data were collected from the Hermana Lembean Hospital Construction Project. Secondarily, data were gathered from Value Engineering and Life Cycle Cost analysis textbooks and publications.

2.1.1. Data Preparation

Prior to analysis, all project documentation was organized to ensure the availability of relevant information at each stage of the study. The project documentation included the following:

a) Bill of Quantities (BoQ)
The Bill of Quantities (BoQ) included information on the construction costs of each work package, including preparation, structural, architectural, Roofing, and MEP work. This data were the foundation for identifying the dominant cost elements.

b) Working Drawings and Technical Specifications
The architectural drawings and the associated construction and architectural work specifications were reviewed to identify the type, size, and construction and installation methods of the materials of the architectural work considered in this study.

c) Unit Price Analysis (AHSP)
The construction cost of the existing design and the Value Engineering proposed solutions was assessed using the Indonesian Standard Unit Price Analysis (AHSP).

d) Maintenance and Replacement Data

To determine the Life Cycle Cost per the selected analysis period, we used information on maintenance and replacement records and their associated costs.

Further information was obtained from journal articles, Indonesian construction standards, government regulations, AHSP references, manufacturers' technical catalogues, and studies on Value Engineering and Life Cycle Cost analysis. These sources of information were used to aid in the assessment of other materials and the results.

2.2. Identification of Dominant Cost Components

This analysis step targeted identifying the work packages that comprised the bulk of the total project cost. The Pareto Principle (the 80/20 rule) was used to assess the construction activities that contributed the most toward the total cost. Construction cost data obtained from the Bill of Quantities were ranked in order from highest to lowest. (1).

$$P_i = (C_i / \Sigma C_i) \times 100 \quad (1)$$

Where
P_i = percentage contribution of work item $_i$
C_i = cost of work item $_i$
ΣC_i = total project cost.

The total percentage was then employed to identify work packages that achieved the maximum percentage in the budget for overall construction. Analysis revealed architectural work accounted for 39.03% of the overall project cost, making it the most viable candidate for further Value Engineering analysis. Items of the architecture selected for this study included the construction of walls, wall plastering, wall skim coating, wall and ceiling painting, and ceiling work.

2.3. Value Engineering Analysis

The Value Engineering procedure in this study adopts the job plan of SAVE International and Miles [10, 20]. The study was divided into five sequential phases starting from the collection of information and ending with the identification of the preferred alternative.

2.3.1. Information Phase

During this phase, the design as it was, was analyzed to collect information related to cost of construction, specifications of materials, and the functional requirements and the interrelationship of the various work items of architectural systems.

2.3.2. Function Analysis Phase

Each architectural item was analyzed to determine the difference between the primary and the supporting function. This was important in retaining the necessary characteristics when replacement materials were proposed.

2.3.3. Creative Phase

Alternative materials were based on literature review, interviews with construction professionals, and surveys of materials available in Indonesia. Instead of focusing on cost, the first step was to identify alternatives that would provide the functions of the building. The proposed alternatives met the following constraints to be considered:

- inverted construction and functional performance;
- met the building regulations in Indonesia;
- available in the local marketplace;
- provisions for construction of a hospital;
- supported standard construction methods.

2.3.4. Evaluation Phase

When possible alternatives were identified, the technical and economic viability was assessed for each option. The technical assessment included the functional performance, the construction and maintenance, and the integration with the existing building. The economic assessment included the construction cost and the Life Cycle Cost of the option.

2.3.5. Development Phase

The most feasible alternatives were developed into complete design proposals and subsequently evaluated through Life Cycle Cost analysis to determine their long-term economic performance.

2.4. Life Cycle Cost Analysis

The alternatives generated through Value Engineering were subsequently evaluated using Life Cycle Cost (LCC) analysis over a 20-year service life, representing the expected operational period of the hospital building. An annual discount rate of 8% was adopted based on prevailing economic conditions and commonly applied engineering economic practices.

Instead of evaluating only the initial construction expenditure, the Life Cycle Cost calculation also included costs expected to occur during the building operation period. In this study, the total cost of each alternative was obtained by combining three expenditure components:

- Initial construction cost
- Maintenance cost
- Replacement cost

The overall Life Cycle Cost was determined using Equation (2).

$$LCC = IC + PV_{Maintenance} + PV_{Replacement} \quad (2)$$

Where,
IC = Initial Construction Cost
$PV_{Maintenance}$ = Present Value of Maintenance Cost
$PV_{Replacement}$ = Present Value of Replacement Cost
Annual maintenance expenses were converted into present value using Equation (3).

$$PV=A\,(P/A,i,n) \quad (3)$$

Where,
A = annual maintenance cost
i = discount rate (8%)
n = service life (20 years)

Replacement costs that occur during the service life were also discounted to their present value using Equation (4).

$$PV=F(P/F,i,n) \quad (4)$$

Where
F = future replacement cost
n = replacement year

Expressing every future expenditure in present-value terms makes it possible to compare alternatives on the same economic basis, even when maintenance schedules and replacement intervals differ

2.5. Selection of the Best Alternative

After completing the technical evaluation and Life Cycle Cost assessment, all proposed alternatives were reviewed to determine the most suitable option for the hospital project. It was recognized that the option with the lowest construction cost may not be the preferred alternative.

The comparison did not rely solely on the lowest construction cost. Instead, technical performance and long-term economic efficiency were considered together during the final assessment. The alternative options were intended to:

- Sustain the functional performance;
- Meet the governing building and hospital standards;
- Provide the technical feasibility to be constructed; and
- Provide the lowest construction and 20-year Life Cycle Cost.

In consideration of the above, the preferred alternative was selected based on the construction cost for the near-term and the cost for the future construction. Figure 1 illustrates the overall research framework

3. Results and Discussion

3.1. Project Data

The case study project data are as follows:

Project Name	: Hermana Lembean General Hospital Construction Project
Project Location	: Jl. A. Mononutu, Lembean Village, Kauditan District, North Minahasa Regency
Contract Value	: Rp 7.703.899.500,00
Contract Type	: Lump Sum *Fixed Price*
Funding Source	: Hermana Hospital
Construction Period	: 127 calendar days
Start Date	: August 18, 2025
Consultant	: Ar. Sr. Anas Sambine, SJMJ, dan Tim Rumah Sakit Umum Hermana Lembean.
Contractor	: PT. Cakra Buana Megah
Building Area	: 882,7 m2

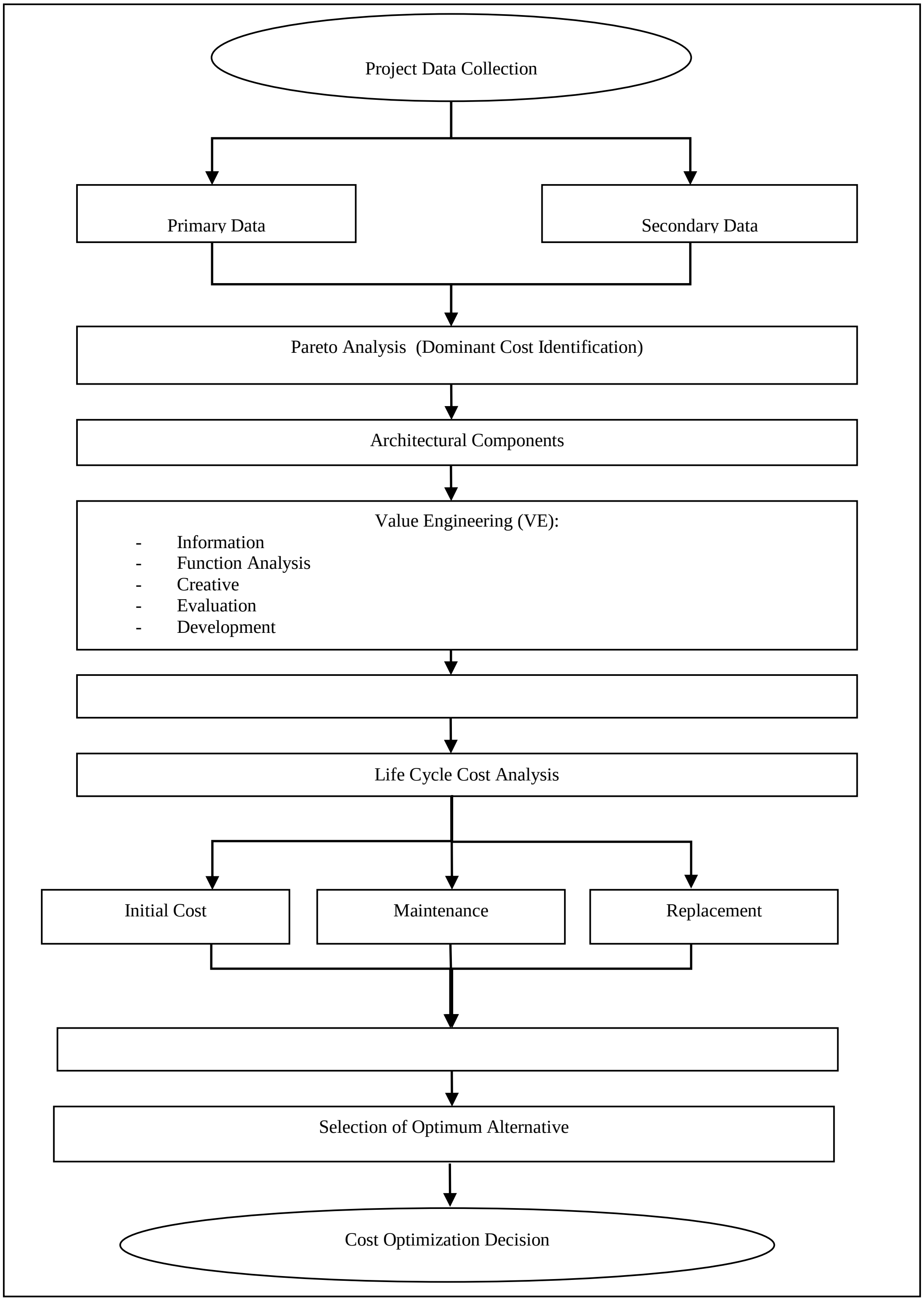

Fig. 1 Research framework

The Hermana Lembean General Hospital project was selected as the case study because it represents a medium-scale healthcare construction project with a relatively high proportion of architectural work. The project adopts a lump-sum contract with a total construction value of Rp 7.70 billion. Since architectural work accounts for the largest share of the project budget, the project provides an appropriate case for evaluating the effectiveness of the integrated Value Engineering and Life Cycle Cost framework.

3.2. Identification of Dominant Cost Components

Table 2 presents the distribution of construction costs for the Hermana Lembean Hospital project. Among all work packages, architectural work accounts for the highest proportion of the project budget, amounting to Rp 2,456,544,915.00 or approximately 39.03% of the total construction cost.

Table 2. Highest total cost of Hermana Lembean general hospital construction project

No	Work Item	Total Cost
1	Architectural Work	Rp 2.456.544.915

Following the Pareto principle, Value Engineering should primarily focus on work items that contribute the largest proportion of project costs, since improvements in these components have the greatest potential to reduce overall expenditure. Consequently, the architectural work package was selected as the primary object of analysis. Six architectural work items were identified as suitable candidates for Value Engineering:

- Wall construction work
- Wall plastering work
- Wall skim coating work
- Interior wall painting work
- Eksterior Exterior wall painting work
- Ceiling Work

These work items were selected because they represent significant construction costs while allowing material substitution without compromising the functional requirements of hospital buildings.

3.3. Value Engineering Analysis

3.3.1. Information Phase

The Information Phase focused on identifying the existing construction methods, materials, and associated costs of each selected work item. Tables 3-8 summarize the original design specifications and corresponding construction costs.

Table 3. Design description worksheet

Study Title: Hermana Lembean General Hospital Construction Project
Design Description: 1. Wall Construction Work The wall construction work in the project initially used red bricks. 2. Wall Plastering Work The wall plastering work initially used Portland cement. 3. Wall Skim Coating Work The wall skim coating work initially used Portland cement. 4. Painting Work The interior wall painting initially used Dulux base paint, while the exterior wall painting used Dulux Weathershield. 5. Ceiling Work The ceiling work initially used gypsum boards.

Table 4. Initial cost method worksheet for red brick wall construction

Initial Design Cost Model					**Information Phase**
Building System					
No	Description	Detailed System			Cost (Rp)
		Qty	Unit	Unit Price	
1	Red Brick Wall	2,087.10	m^2	Rp 134,900.00	Rp 281,549,790.00
				Sub Total	Rp 281,549,790.00

Table 5. Initial cost method worksheet for Portland cement wall plastering

Initial Design Cost Model					**Information Phase**
Building System					
No	Description	Detailed System			Cost (Rp)
		Qty	Unit	Unit Price	
1	Portland Cement Wall Plastering	4,174.20	m^2	Rp 56,900.00	Rp 237,511,980.00
Sub Total					Rp 237,511,980.00

Table 6. Initial cost method worksheet for Portland cement wall skim coating

Initial Design Cost Model					Information Phase
Building System					
No	Description	Detailed System			Cost (Rp)
		Qty	Unit	Unit Price	
1	Portland Cement Wall Skim Coating	3,538.05	m^2	Rp 49,600.00	Rp 175,487,280.00
				Sub Total	Rp 175,487,280.00

Table 7. Initial cost method worksheet for interior painting (Dulux)

Initial Design Cost Model					Information Phase
Building System					
No	Description	Detailed System			Cost (Rp)
		Qty	Unit	Unit Price	
1	Interior Painting (Dulux)	2,317.57	m^2	Rp 46,000.00	Rp 106,608,220.00
				Sub Total	Rp 106,608,220.00

Table 8. Initial cost method worksheet for ceiling work

Initial Design Cost Model					Information Phase
Building System					
No	Description	Detailed System			Cost (Rp)
		Qty	Unit	Unit Price	
1	Interior Painting (Dulux)	2,317.57	m^2	Rp 46,000.00	Rp 106,608,220.00
				Sub Total	Rp 106,608,220.00

The original design incorporated the use of red brick masonry, Portland cement plaster and skim coat, Dulux paint systems, and gypsum ceilings. Since these materials are readily available in the construction industry in Indonesia, the use of these materials meant lower cost of construction in terms of the initial outlay. The Information Phase, however, identified several avenues for enhancing value through the use of alternate materials that perform better over the long term. Since the chosen architectural work items represent a significant portion of the total project budget, even marginal improvements will most likely provide a significant decrease in overall project costs.

3.3.2. Function Analysis

After the baseline design was set, each chosen architectural work item was examined to determine the work item's primary and secondary functions.

The purpose of this phase was to allow for the suggested alternative to work item's primary and secondary functions.

Improvements of cost to function ratios were expected in this scenario. The functional analysis for selected architectural components is presented in Table 9.

Table 9. Function analysis of selected architectural work item

Work item	Primary Function	Secondary Function
Wall	Separate rooms	Thermal Insulation
Plaster	Surface protection	Improve Appearance
Skim Coat	Surface finishing	Improve Paint Adhesion
Paint	Surface protection	Aesthetic
Ceiling	Cover utilities	Improve acoustic performance

Based on Table 9, the chosen work items' primary functions are related to the operational functions of the hospital building. Secondary functions of the work items are related to the comfort, durability, and serviceability of the building. As a result, the value engineering alternative for the chosen work items was to enhance cost, constructability, and long term economic value, while retaining the primary functions of the work items.

3.3.3. Creative Phase

During the Creative Phase, multiple alternative materials were suggested with no consideration for cost.The primary objective was to generate feasible alternatives capable of maintaining or improving functional performance while offering potential economic benefits throughout the building life cycle.

Table 10. Creative phase worksheet

Creative Phase	Item: Wall Installation Work, Plastering, Coating, Painting, Ceiling	Function: Supporting
This stage represents the creative phase of the Value Engineering study, which aims to generate as many ideas as possible to fulfill the required functions without evaluating them during this phase.		
WALL CONSTRUCTION		
Lightweight Brick		
WALL PLASTERING		
Portland Cement		
WALL SKIM COATING		
Ready-mix mortar (MU)		
INTERIOR PAINTING		
Nippon Paint		
EXTERIOR PAINTING		
Nippon Weatherbond		
CEILING		
GRC Ceiling		

The proposed alternatives include:

- Lightweight brick replacing conventional red brick
- Ready-mix mortar replacing Portland cement skim coating
- Nippon Paint replacing Dulux interior paint
- Nippon Weatherbond replacing Dulux Weathershield
- GRC ceiling replacing gypsum ceiling

These alternatives were selected based on technical characteristics, durability, maintenance requirements, constructability, and market availability within Indonesia.

3.3.4. Evaluation Phase

Tables 11-22 present the technical evaluation and unit price analysis for each proposed alternative. Rather than selecting alternatives solely based on the lowest initial construction cost, the evaluation considered several criteria, including:

- Functional performance;
- Structural compatibility;
- Durability;
- Maintenance requirements;
- Ease of construction;
- Material availability; and
- Long-term economic performance.

Consequently, several alternatives with slightly higher initial costs remained under consideration because they were expected to generate lower maintenance and replacement costs over the building service life.

Table 11. Advantages and disadvantages of wall construction work

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	Red Brick	1. Lower Cost 2. Widely Available 3. Doesn’t require special adhesive 4. Easy to install	1. Heavy weight 2. Non-uniform dimensions 3. Slower Installation 4. More prone to cracking
Alter-native	10 cm Lightweight Brick	1. Lightweight 2. Precise dimensions 3. Faster installation 4. Better thermal and sound insulation 5. Lowers cracking potential	1. Higher material cost 2. Requires special adhesive 3. Lower compressive strength

Table 12. Advantages and disadvantages of wall plastering work

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	Portland Cement Plaster	1. Lower Material Cost 2. Flexible Mixture	1. Dependent on labor quality 2. Longer execution time 3. More prone to hairline cracks

Table 13. Advantages and disadvantages of wall skim coating work

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	Portland Cement	1. Lower Cost	1. Rougher surface

		2. Easy Application	2. Higher cracking potential
Alter-native	Ready-Mix Mortar	1. Smoother finish 2. Less cracking 3. Faster application	Higher Cost

Table 14. Advantages and disadvantages of interior wall painting

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	Dulux	1. Sharper Color 2. High Coverage 3. Durable	Relatively Expensive
Alter-native	Nippon Point	1. More Economical 2. Good Quality	Slightly lower durability than Dulux

Table 15. Advantages and disadvantages of exterior wall painting

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	Dulux Weathershield	1. More Economical 2. Good Protection	High Cost
Alter-native	Dulux Weatherbond	1. More Economical 2. Good Protection	Slightly lower durability than Dulux Weathershield

Table 16. Advantages and disadvantages of ceiling work

Alter-native	Specifi-cation	Advantages	Disadvantages
Initial	9 mm Gypsum	1. Lower initial cost 2. Easy Installation 3. Wide range of variation 4. Aesthetic appearance 5. Generally safe for residential use 6. Smooth and aesthetic finish 7. Easy to shape (flexible design)	1. Not water-resistant 2. Vulnerable to impact 3. Prone to mold 4. Shorter service life 5. Higher maintenance
Alter-native	4 mm GRC	1. Water-resistant 2. Mold-resistant 3. Longer service life (15-20 years) 4. Lower Maintenance 5. Stronger and more impact-resistance	1. Higher cost 2. More difficult installation 3. Finishing is not as smooth as gypsum

Unit Price Analysis of Work Items

Table 17. Unit price analysis for the alternative 10 cm lightweight brick wall

Type of Work: Installation of 1 m² of 10 cm lightweight brick wall using ready-mix mortar					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	8.75	pcs	Lightweight Brick	Rp 11,000.00	Rp 96,250.00
	3.429	kg	Ready-Mix Mortart	Rp 3,000.00	Rp 10,287.00
Labor	1	m^2	Labor Cost		Rp 23,058.00
Total					Rp 129,500.00

No	Qty	Unit	Desc.	Unit Price	Total
1	2087.1	m^2	Super Lightweight Brick	Rp 129,500.00	Rp 270,279,450.00

Table 18. Unit price analysis for the alternative wall plastering work

Type of Work: Installation of 1 m² of 15 mm thick plastering with a 1PC:5PP mix					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	5.184	kg	Portland Cement (PC)	Rp 1,420.00	Rp 7,361.28

	0.026	m^3	Sand	Rp 175,000.00	Rp 4,550.00
Labor	1	m^2	Labor Cost		Rp 45,010.00
Total					Rp 56,900.00
No	**Qty**	**Unit**	**Desc.**	**Unit Price**	**Total**
1	4,174.20	m^2	Wall Plasterin-g	Rp 56,900.00	Rp 237,511,980.00

Table 19. Unit price analysis for the alternative wall skim coating work

Type of Work: Installation of 1 m^2 of skim coating using Ready-Mix Mortar					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	2.162	kg	Ready-Mix Mortart (MSP)	Rp 3,000.00	Rp 6.486,00
Labor	1	m^2	Labor Cost		Rp 45,010.00
Total					Rp 51,400.00
No	**Qty**	**Unit**	**Desc.**	**Unit Price**	**Total**
1	3,538.05	m^2	Wall Skim Coating (MSP)	Rp 51,400.00	Rp 181,855,770.00

Table 20. Unit price analysis for the alternative interior wall painting

Type of Work: Painting 1 m^2 of new interior wall (1 coat of primer and 2 coats of finish paint)					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	0.10	kg	Interior Primer	Rp 33,000.00	Rp 3.300,00
	0.26	Kg	Interior Finish Paint	Rp 40,000.00	Rp 10,400.00
Labor	1	m^2	Labor Cost		Rp 21,689.50
Total					Rp 35,300.00
No	**Qty**	**Unit**	**Desc.**	**Unit Price**	**Total**
1	2,317.57	Kg	Nippon Paint	Rp 35,300.00	Rp 81,810,221.00

Table 21. Unit price analysis for the alternative exterior wall painting

Type of Work: Painting 1 m^2 of new exterior wall (1 coat of primer and 2 coats of finish paint)					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	0.1	kg	Exerior Primer	Rp 45,000.00	Rp 4.500,00
	0.26	Kg	Exterior Finish Paint	Rp 80,000.00	Rp 20,800.00
Labor	1	m^2	Labor Cost		Rp 25,014.50
Total					Rp 50,300.00
No	**Qty**	**Unit**	**Desc.**	**Unit Price**	**Total**
1	1,109.03	Kg	Nippon Weatherbond	Rp 50,300.00	Rp 55,784,209.00

Table 22. Unit price analysis for the alternative ceiling work

Type of Work: Installation of 1 m^2 of 4 mm cement fiber/GRC ceiling					
Reference: Unit Price Analysis for Cipta Karya Sector No. 47/SE/Dk/2026					
Category	**Coeff**	**Unit**	**Desc.**	**Unit Price**	**Total**
Material	1.21	m^2	4 mm GRC Ceiling	Rp 33,500.00	Rp 40.535,00
	0.01	Kg	Nails	Rp 18,000.00	Rp 180.00
Labor	1	m^2	Labor Cost		Rp 17,755.50
Total					Rp 58,400.00
No	**Qty**	**Unit**	**Desc.**	**Unit Price**	**Total**
1	1,136.33	m^2	4 mm GRC Ceiling	Rp 58,400.00	Rp 66,361,672.00

3.3.5. Development Phase

Following the technical and economic evaluation, the most feasible alternative for each architectural work item was selected and developed into the proposed design alternative. At this stage, the selected materials were finalized based on their ability to satisfy the required functional performance while offering potential long-term economic benefits. These alternatives subsequently served as the basis for the Life Cycle Cost (LCC) analysis presented in the next section.

Table 23. Selected alternatives for development

Work Item	Initial Design	Selected Alternative
Wall Construction	Red Brick	10 cm lightweight brick
Wall Plastering	Portland Cement	Portland Cement
Wall Skim Coating	Portland Cement	Ready-mix mortar (MU)
Interior Painting	Dulux	Nippon Paint
Exterior Painting	Dulux Weathershield	Nippon Weatherbond
Ceiling	9 mm gypsum	4 mm GRC

As shown in Table 23, not all selected alternatives resulted in lower initial construction costs. Several materials, such as ready-mix mortar and GRC ceiling panels, required higher initial investment but were expected to provide lower maintenance requirements and longer service life. Therefore, a Life Cycle Cost analysis was conducted to evaluate the overall economic performance of the selected alternatives over a 20-year service life.

3.4. Value Engineering Results

Table 24 summarizes the initial cost comparison between the original design and the proposed Value Engineering alternatives.

Table 24. Value engineering calculations results

Work Item	Initial Design	VE Alternative	Savings
Wall Construction	Rp 281,549,790.00	Rp 270,279,450.00	Rp 11,270,340.00
Wall Plastering	Rp 237,511,980.00	Rp 237,511,980.00	Rp -
Wall Skim Coating	Rp 175,487,280.00	Rp 181,855,770.00	Rp -6,368,490.00
Interior Wall Painting	Rp 106,608,220.00	Rp 81,810,221.00	Rp 24,797,999.00
Exterior Wall Painting	Rp 60,996,650.00	Rp 55,784,209.00	Rp 5,212,441.00
Ceiling Work	Rp 62,043,618.00	Rp 66,361,672.00	Rp -4,318,054.00

The results demonstrate that Value Engineering does not necessarily reduce the initial cost of every work item. Considerable cost savings were reflected for lightweight brick and interior and exterior painting. Ready-mix mortar with skim coat and GRC ceilings required more initial cost. The largest reduction in initial construction cost was achieved through the replacement of Dulux interior paint with Nippon Paint, resulting in savings of approximately Rp 24.80 million.

Lightweight brick also reduced the construction cost by approximately Rp 11,270,340.00 owing to lower material consumption and improved installation efficiency. Conversely, ready-mix mortar and GRC ceiling systems increased initial construction costs because of their higher material prices. Nevertheless, these alternatives were retained for further evaluation because Value Engineering considers the overall project value rather than initial construction cost alone.

These findings indicate that minimizing initial cost does not always produce the most economical solution over the entire building life cycle.

3.5. Life Cycle Cost Analysis

Tables 25–30 present the Life Cycle Cost (LCC) evaluation for all proposed alternatives over a 20-year analysis period using an 8% discount rate.

Table 25. Comparison of initial cost and life cycle cost for wall installation work

Wall Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 281,549,790.00	Rp 270,279,450.00
Total Initial Cost	Rp 281,549,790.00	Rp 270,279,450.00

2. Maintenance Cost a. Annual Maintenance (1.5%) b. Factor P/A (N=20, I=8.00)	Rp 4,220,000.00 9.818	Rp 4,050,000.00 9.818
Total Maintenance Cost	Rp 41,432,582.059	Rp 39,763,497.000
3. Replacement Cost a. Wall Work b. Factor P/F (N=20, I=8.00)	- -	- -
Total Replacement Cost	-	-
Total Present Worth Cost	Rp 322,982,372.059	Rp 310,042,947.000
Life Cycle Cost Worth Saving		Rp 12,939,425.059
Saving		4,01%

Table 26. Comparison of initial cost and life cycle cost for wall plastering work

Wall Plastering Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 237,511,980.00	Rp 237,511,980.00
Total Initial Cost	Rp 237,511,980.00	Rp 237,511,980.00
2. Maintenance Cost a. Annual Maintenance (1.5%) b. Factor P/A (N=20, I=8.00)	Rp 3,560,000.00 9.818	Rp 3,560,000.00 9.818
Total Maintenance Cost	Rp 34,952,604.771	Rp 34,952,604.771
3. Replacement Cost a. Wall Work b. Factor P/F (N=20, I=8.00)	- -	- -
Total Replacement Cost	-	-
Total Present Worth Cost	Rp 272,464,584.771	Rp 272,464,584.771
Life Cycle Cost Worth Saving		Rp -
Saving		0,00%

Table 27. Comparison of initial cost and life cycle cost for wall skim coat work

Wall Skim Coat Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 175,487,280.00	Rp 181,855,770.00
Total Initial Cost	Rp 175,487,280.00	Rp 181,855,770.00
2. Maintenance Cost a. Annual Maintenance b. Factor P/A (N=20, I=8.00)	Rp 3,500,000.00 9.818	Rp 2,270,000.00 9.818
Total Maintenance Cost	Rp 34,363,515.926	Rp 22,287,194.615
3. Replacement Cost a. Wall Work b. Factor P/F (N=20, I=8.00)	- -	- -
Total Replacement Cost	-	-
Total Present Worth Cost	Rp 209,850,795.926	Rp 204,142,964.615
Life Cycle Cost Worth Saving		Rp 5,707,831.311
Saving		2,72%

Table 28. Comparison of initial cost and life cycle cost for interior wall painting work

Interior Wall Painting Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 106,608,220.00	Rp 81,810,221.00
Total Initial Cost	Rp 106,608,220.00	Rp 81,810,221.00
2. Maintenance Cost a. Annual Maintenance b. Factor P/A (N=20, I=8.00)	 Rp 3,198,200.00 9.818	 Rp 2,454,300.00 9.818
Total Maintenance Cost	Rp 31,400,399.039	Rp 24,096,679.182
3. Replacement Cost a. Wall Work b. Factor P/F (t=5, I=8.00)	 - 1.469	 - 1.469
Total Replacement Cost	Rp 72,555,763.198	Rp 55,678,661.758
Total Present Worth Cost	Rp 210,564,382.236	Rp 161,585,561.940
Life Cycle Cost Worth Saving		Rp 48,978,820.296
Saving		23,26%

Table 29. Comparison of initial cost and life cycle cost for exterior wall painting work

Exterior Wall Painting Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 60,996,650.00	Rp 55,784,209.00
Total Initial Cost	Rp 60,996,650.00	Rp 55,784,209.00
2. Maintenance Cost a. Annual Maintenance b. Factor P/A (N=20, I=8.00)	 Rp 2,439,800.00 9.818	 Rp 2,231,300.00 9.818
Total Maintenance Cost	Rp 23,954,316.045	Rp 21,907,232.310
3. Replacement Cost a. Wall Work b. Factor P/F (t=5, I=8.00)	 - 1.469	 - 1.469
Total Replacement Cost Total Present Worth Cost	Rp 41,513,295.065 Rp 126,464,261.110	Rp 37,965,795.305 Rp 115,657,236.615
Life Cycle Cost Worth Saving		Rp 10,807,024.495
Saving		8,55%

Table 30. Comparison of initial cost and life cycle cost for ceiling work

Ceiling Work		
Life Cycle	20 Years	
Interest Rate	8%	
	Initial Design	Alternative
1. Initial Cost a. Construction Cost	Rp 62,043,618.00	Rp 66,361,672.00
Total Initial Cost	Rp 62,043,618.00	Rp 66,361,672.00
2. Maintenance Cost a. Annual Maintenance b. Factor P/A (N=20, I=8.00)	 Rp 1,550,000.00 9.818	 Rp 830,000.00 9.818

Total Maintenance Cost	Rp 15,218,128.482	Rp 8,149,062.348
3. Replacement Cost a. Wall Work b. Factor P/F (t=15, I=8.00)	 - 3.172	 - -
Total Replacement Cost Total Present Worth Cost	Rp 19,558,735.921 Rp 96,820,482.402	- Rp 74,510,734.348
Life Cycle Cost Worth Saving		Rp 22,309,748.054
Saving		23,04%

Unlike the initial cost comparison, the LCC analysis demonstrates that several alternatives with higher construction costs become more economical after maintenance and replacement costs are considered.

The lightweight brick alternative produced a total present worth cost of Rp 310.04 million compared with Rp 322.98 million for the original red brick system, yielding life cycle savings of approximately 4.01%.

A different trend was noted for the ready-mix mortar option. While the initial construction cost was higher than the conventional skim coat, the burden was offset by lower maintenance during the service life of the building. The Life Cycle Cost for the ready-mix option was lower than the conventional option by Rp 5.71 million.

The most notable savings was seen on the interior painting. The substitution of Dulux with Nippon Paint resulted in an initial cost of construction and future cost of painting savings of Rp 48.98 million, a 23.26% savings for the life cycle. Similar savings were noted for the exterior painting with Nippon Weatherbond with life cycle savings of Rp 10.81 million.

The GRC ceiling demonstrates the need and importance of the Life Cycle Cost. In this case, the initial construction cost was higher than that of gypsum ceilings, but the cost of gypsum ceiling replacement over the 20 year ceiling life was avoided. The total present worth cost was improved by about 23.04%, from Rp 96.82 million to Rp 74.51 million.In general, the LCC clearly demonstrates that the economic impact of building materials is particularly influenced by the costs of long-term maintenance and replacement, and thus should be a key consideration in Value Engineering.

3.6. Discussion

The results show that integrating Value Engineering with Life Cycle Cost analysis is more valuable than analyzing alternatives based solely on initial construction costs. In many work items analyzed in this study, the option that had the lowest first cost was not the most economical alternative when construction, maintenance, and replacement costs during the building's service life were considered. This outcome is consistent with previous studies that show that Value Engineering enhances the value of a project through the selection of different materials. However, previous studies concentrated mostly on the construction cost element of the design. In this study, the evaluation was extended to include a 20-year Life Cycle Cost analysis, thus enabling the assessment of alternatives based not only on initial costs, but also on costs that are anticipated later on.

The consideration for the choice of construction materials leans towards balancing the immediate costs with those for the future and the longevity of the building. An example of this would be lightweight bricks which have lower costs of installation and maintenance. These bricks, however, require special installation and specialized workers. Similarly, GRC ceiling panels have a higher cost of installation, but their longevity reduces the cost of maintenance and replacement over time. Purchasing an item solely for the purpose of value has the potential to overlook the true value of building in the long term. This idea is especially true for hospital construction projects since the maintenance of the structures and further interruptions of the services provided by the hospital is to be avoided. The model derived in this study is used to evaluate the construction preferences of the owners, contractors, and consultants by the means of the functional performance and the economics of construction over the long term, rather than by the means of construction cost.

The limitations should be considered, as well. The analysis was limited to one hospital project, a 20-year analysis, and an 8% constant discount rate. Life Cycle Cost values could change with different maintenance schedules, service lives, inflation rates, and other economic assumptions. Using the same model to analyze other hospital and building projects would help strengthen the validity of the model.

3.7. Selection of the Optimal Alternative

After conducting the Value Engineering assessment and the subsequent Life Cycle Cost study, the following materials were analyzed and found to be the optimal selections for the Hermana Lembean Hospital project:

- 10 cm lightweight bricks;
- Portland cement plaster;
- Ready-mix mortar (MU) for wall skim;
- Nippon Paint for wall finishes (interior);
- Nippon Weatherbond for wall finishes (exterior);
- 4 mm GRC ceiling panels.

Some of the selected alternatives did not represent the lowest cost of construction. Some alternatives actually involved a greater investment. However, the additional cost was justified by less frequent maintenance and a greater life span. When both the first and future costs were taken into account, these alternatives provided a more favorable economic outcome.

The proposed Value Engineering alternatives also decreased the architectural construction cost from Rp 924,197,538.00 to Rp 893,603,302.00. When the maintenance and replacement costs for 20 years were taken into account, the total Life Cycle Cost was reduced from Rp 1,239,246,165.00 to Rp 1,138,403,872.00. The integrated solutions also achieved an estimated 8.13% overall cost reduction while meeting the functional and operational needs of a hospital building.

4. Conclusion

The aim of this research was to analyze the use of an integrated Value Engineering and Life Cycle Cost approach to optimize cost savings for the Hermana Lembean Hospital construction project. The Pareto analysis showed that the largest section of the project budget was for the architectural work, which totaled Rp 2,456,544,915.00, or 39.03% of the total construction cost. Based on the results of this analysis, wall construction, plastering, wall skimming, wall and ceiling painting, and ceiling work were selected for further analysis. The proposed alternatives showed a reduction in architectural construction costs from Rp 924,197,538.00 to Rp 893,603,302.00 suggesting an initial saving of about 3.31%. This changed after maintenance and replacement costs were included. At a 20-year service life and an 8% discount rate, the total Life Cycle Cost was reduced by Rp 100,842,293.00, resulting in an overall saving of approximately 8.13%. The greatest reductions in Life Cycle Cost were in the interior painting system (23.26%) and in the replacement of gypsum ceiling boards by 4 mm GRC panels (23.04%). The proposed system contains lightweight brick walls, Portland cement plaster, ready-mix mortar skim coating, gypsum ceiling panels, and paints. Although several of these materials involve higher purchase costs, their lower maintenance needs and longer service life provide better economic performance over the building life cycle.

This study also illustrates that the integration of Value Engineering and Life Cycle Cost analysis sets a solid basis for the choice of construction materials in hospital projects. The proposed approach moves beyond the focus on the savings from the initial construction and integrates an assessment of maintenance and replacement costs, providing a more equitable assessment of the overall project value. Although the analysis is limited to one case study, and for the purpose of the study, the economic parameters are assumed to be constant during the analysis period, the focus of the analysis is on the integration of Value Engineering and Life Cycle Cost, and further research should be carried out on other hospital projects taking into consideration different discount rates and inflation, maintenance intervals and price variations of construction materials to assess the range of applicability of the proposed approach.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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