Quest Journals
Journal of Architecture and Civil Engineering
Volume 11 ~ Issue 1 (January 2026) pp: 28-39
ISSN(Online): 2321-8193
www.questjournals.org

Research Paper

Value Engineering of Secondary Skin Façade in an Emergency Department Building

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ABSTRACT: *Hospital development in Indonesia has increased significantly in recent years, requiring building designs that prioritize efficiency, sustainability, safety, and user comfort. The façade plays a critical role in hospital buildings as the primary medium for heat and light transfer, directly influencing energy performance and thermal comfort. This study aims to identify the most optimal façade concept and material for hospital buildings using a Value Engineering (VE) approach. A quantitative case study was conducted at the Emergency Department Building of Jakarta Islamic Hospital, Cempaka Putih, focusing on façade works. The VE process included Pareto analysis, Function Analysis System Technique (FAST), Multi-Criteria Analysis (MCA), and Life Cycle Cost Analysis (LCCA). The results indicate that a secondary skin façade with a twin-face system using fire-retardant ACP laser-cut panels is the most optimal alternative. The LCCA results show a 5.19% reduction in life cycle costs compared to the original façade design after accounting for risk mitigation costs. In addition to cost efficiency, the selected façade improves functional performance by enhancing fire safety, maintenance efficiency, and natural daylight utilization. These findings confirm that Value Engineering is an effective method for achieving cost-efficient, safe, and sustainable façade solutions for hospital buildings.*

KEYWORDS: *Value engineering, façade, secondary skin, Hospital*

*Received 08 Jan., 2026; Revised 18 Jan., 2026; Accepted 20 Jan., 2026 © The author(s) 2026. Published with open access at **www.questjournas.org***

I. INTRODUCTION

Hospital development in Indonesia has experienced a consistent increase over the past five years, both in terms of the number of facilities and service capacity. According to the Ministry of Health, the total number of hospitals in Indonesia reached approximately 3,155 units in 2023, comprising 2,636 general hospitals and 519 specialized hospitals (1) This figure represents an increase of around 12.46% compared to 2019, reflecting the growing public demand for high-quality healthcare services. Consequently, hospital buildings are required to be designed not only to meet functional and regulatory requirements but also to achieve efficiency, sustainability, and long-term operational performance.

One of the most critical building components influencing hospital performance is the façade. As the building envelope, the façade serves as the primary interface between indoor and outdoor environments and acts as the main pathway for thermal energy transfer (2). Previous studies and regulations have emphasized that façade design significantly affects energy consumption for cooling and lighting, as well as indoor thermal comfort (3). Therefore, inappropriate façade design can lead to increased energy demand, higher operational costs, and reduced occupant comfort—issues that are particularly critical in hospital buildings that operate continuously.

Among various façade strategies, the secondary skin façade has emerged as a promising solution to improve thermal performance and energy efficiency. A secondary skin façade consists of an inner and an outer layer separated by an air cavity, which functions as a buffer zone to reduce solar heat gain and improve environmental control (4) This concept is especially relevant for hospital buildings, which are characterized by complex spatial arrangements, high occupancy rates, and frequent functional changes.

Despite its potential benefits, the application of secondary skin façades in hospital buildings presents challenges related to material selection. The chosen materials must comply with strict healthcare regulations, ensure safety and durability, minimize maintenance requirements, and remain cost-effective throughout the building's life cycle. In practice, material selection is often driven by initial construction costs rather than long-term performance, which can result in higher operational and maintenance expenses over time.

To address this issue, a Value Engineering (VE) approach is required. Value Engineering, as defined by Miles (1972), is a systematic and creative methodology aimed at identifying and eliminating unnecessary costs, costs that do not contribute to a product's required function, quality, or performance. The application of VE enables decision-makers to balance cost efficiency with functional and technical performance, rather than focusing solely on initial investment (5).

How ever, previous studies on hospital façade design have largely focused on thermal performance or energy efficiency, with limited integration of Value Engineering methods combined with life cycle cost analysis and functional evaluation. This gap highlights the need for a comprehensive approach that simultaneously evaluates façade concepts, material performance, cost efficiency, and long-term sustainability.

Therefore, this study aims to analyze and determine the most optimal façade concept and material for hospital buildings through a Value Engineering approach. By integrating functional analysis, multi-criteria evaluation, and life cycle cost analysis, this research seeks to propose a façade solution that is cost-efficient, functionally optimal, compliant with regulatory requirements, and supportive of sustainable hospital building design.will analyze and compare between the numerical solution and simulation, and also change of angular velocities with time for certain system parameters at varying initial conditions.

II. RESEARCH METHODOLOGY

This research was conducted at the Emergency Department (ED) Building of Jakarta Islamic Hospital Cempaka Putih, located in Central Jakarta, DKI Jakarta Province. The site was selected because it is a healthcare facility operating 24 hours a day with a high level of activity, requiring optimal façade performance in terms of safety, thermal comfort, and energy efficiency.

The analysis was conducted to evaluate and compare alternative façade concepts and façade materials using a Value Engineering (VE) approach. The analytical process employed a quantitative research approach. Quantitative research is also referred to as a positivist approach, as it is grounded in the philosophy of positivism. This approach adheres to scientific principles, including being theoretical, empirical, testable, open to criticism, objective, measurable, rational, consistent, and systematic (5) .

Data collection in this study aims to support Value Engineering (VE) analysis for the facade work of the Emergency Department (IGD) Building at Rumah Sakit Islam Jakarta. The obtained data serves as the foundation for evaluating functional aspects, technical specifications, and life-cycle cost efficiency across various alternative facade concepts and materials. The data collection techniques employed include secondary and primary data.

1. Data collection techniques.

a. Secondary data consists of information obtained indirectly from documents or written sources In this research, secondary data encompasses reference books and project documentation, including contract documents, as-built drawings, and structural calculations for the IGD Building at Rumah Sakit Islam Jakarta.
b. Primary data is gathered directly from research participants (6). This includes technical specifications of facade materials and insights from building management personnel, which are used to analyze maintenance cost efficiency based on differences in design concepts and applied material types.

2. Data collection techniques.

The research stages follow Circular Letter No. 11/SE/Db/2022 on Technical Implementation Guidelines for Value Engineering (7).

a. Information stage, Gathering preliminary data and information.
b. Function analysis stage, Identifying existing functions and linking them into a Function Analysis System Technique (FAST) diagram a method for depicting logical relationships among system functions by addressing "how" and "why" questions in diagrammatic form (7).
c. Creativity stage, Collecting data through interviews, literature reviews, and primary data–based material analysis to identify the most suitable alternative materials that align with functional value and replace the original materials.
d. Idea evaluation stage, Employing two methods
    - Multi-Criteria Analysis (MCA), which aims to derive added value for each alternative through comparative evaluation against predefined criteria (7)
    - Life Cycle Cost Analysis (LCCA), representing the total system costs over its life cycle, including design costs, investment (construction and supervision), maintenance, land acquisition, and potential revenue generated by the system (7).

e. Idea development stage, Developing ideas into viable alternatives while considering associated risks (7).
f. Alternative evaluation stage, Re estimating life-cycle value by incorporating risk mitigation costs.
g. Recommendation preparation stage Compiling proposed alternatives along with the underlying rationale (7)
h. Presentation stage Presenting Value Engineering study results, supported by rationale to inform decision-making on recommendations (7).

3. Stages of the Value Engineering Research Process

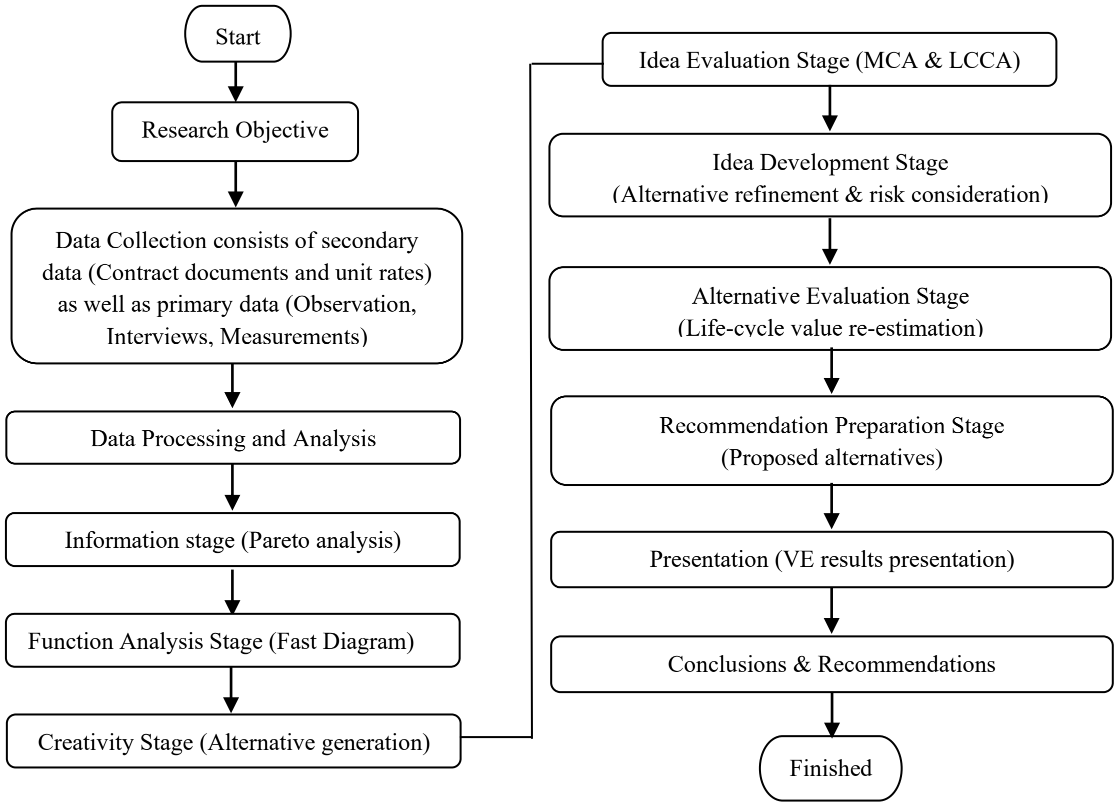


Figure 1. Research Flow
Source: Processed Results, 2025

III. RESULTS AND DISCUSSION

1. Information stage, Gathering preliminary data and information.

a. Cost Breakdown

Cost breakdown is the process of systematically decomposing the cost components of the IGD (Emergency Department) building construction project at RSIJ Cempaka Putih into structured work elements, arranged from the largest to the smallest cost.

Table 1. Breakdown Cost

Uraian Pekerjaan	Total
MEEP	Rp. 22.610.592.676,53
Architectural Works	Rp. 17.812.540.061,76
Structural Works	Rp. 16.496.548.650,76
Preparation Works	Rp. 1.170.217.176,57
Interior Works	Rp. 871.749.659,09
Supporting Buildings	Rp. 244.351.775,28
Medical Equipment	Rp. 244.000.000,00
Total	**Rp. 59.450.000.000,00**

Source: Contract documents (2023-2024)

b. Level 1 Pareto Analysis

Based on the cost breakdown model, a Pareto analysis was conducted to identify critical work items representing approximately 20% of the inputs that contribute to about 80% of the total project cost.

Table 2. Breakdown Cost lavel 1

Uraian	Total (Rp) (Jutaan)	Bobot %	Kumulatif %
MEEP	22.610,59	38,03	38,03
Architectural Works	17.812,54	29,96	68,00
Structural Works	16.496,55	27,75	95,74
Preparation Works	1.170,22	1,97	97,71
Interior Works	871,75	1,47	99,81
Supporting Buildings	244,35	0,41	99,51
Medical Equipment	244,00	0,41	100,00
Total	**59.450.00**		

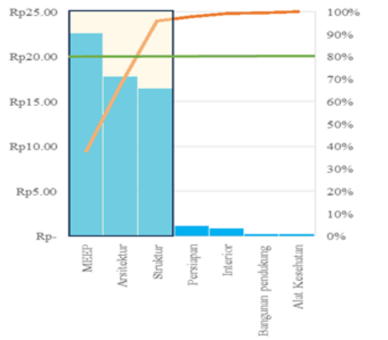


Figure 1: Level 1 Pareto Chart

Based on the discussion results and information obtained from stakeholders, the focus of this study was limited to façade works, as the structural and MEP works had already been optimized during the construction implementation stage. The optimization included adjustments to MEP equipment specifications and the utilization of existing structural elements in certain buildings.

c. Level 2 Pareto Analysis

The Level 2 cost breakdown model was conducted for architectural works by further detailing major architectural cost components to identify dominant cost elements.

Table *3. Breakdown Cost lavel 2*

Uraian	Total (Rp) (Jutaan)	Bobot %	Kumulatif %
Interior Walls	4.467,40	25,08	25,08
Façade Works	4.229,51	23,74	48,82
Flooring	3.511,87	19,72	68,54
Doors and Windows	3.021,39	16,96	85,50
Ceiling	1.029.31	5,78	91,28
Interior Painting	816,91	4,59	95,87
Sanitary Works	645,96	3,63	99,49
Others	90,20	0,51	100,00
Total	**17.812,54**		

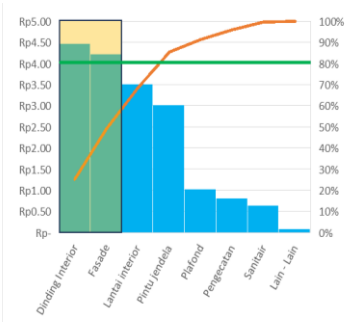


Figure 2: Level 2 Pareto Chart

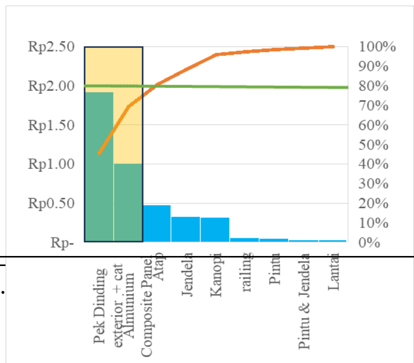
Based on the results of the Level 2 Pareto analysis, the two architectural work items with the highest cost contributions are interior wall works and façade works. Based on input from stakeholders, interior wall works were not analyzed further, as they already meet the functional requirements and standards of hospital buildings. This compliance is demonstrated through the application of specialized materials, including the use of sandwich panels in operating rooms and several laboratory spaces, as well as the installation of lead shielding in radiology and CT scan rooms.

d. Level 3 Pareto Analysis

The Level 3 cost breakdown model was conducted for façade works as a major cost component with significant potential for value improvement. At this stage, façade works were further decomposed into detailed sub-elements to identify cost dominant components and evaluate alternative materials or systems.

Table 4. Breakdown Cost level 3

Uraian	Total (Rp) (Jutaan)	Bobot %	Kumulatif %
Dinding ext + Fin	1.922,76	45,46	45,46
ACP	1,006.94	23,81	69,27
Atap	479,67	11,34	80,61
Jendela	331,93	7,85	88,46
Kanopi	318,04	7,52	95,98
Railing	58,50	1,38	97,36
Pintu	50,00	1,18	98,54



Pintu & Jendela	32,46	0,77	99,31
Lantai	29,21	0,69	100,00
Total	**17.812,54**		

Figure 2: Level 3 Pareto Chart

Based on the Pareto analysis and the defined research scope, the façade work item subjected to Value Engineering analysis is the wall element and its associated finishing.

2. Function Analysis Stage.

Prior to the development of the Function Analysis System Technique (FAST) diagram, the functions of the work were first identified by formulating each function in the form of verb–noun pairs. These functions were then systematically classified into primary functions, secondary functions, supporting functions, and causative functions as the basis for value analysis.

Table 5. Function Identification

Item	Primary Function	Secondary Function	Supporting Function	Causative Function	Design Objective Function	Temporary Function	Long – Term Function
Façade – Wall Element	clad the building	Protect from weather	Regulate climate (heat, wind, and rain)	Generate environmental effects (heat, wind pressure, and rain)	Meet technical specifications	Maintain thermal comfort	Protect activities (safety, privacy, and indoor activities over time)
Façade – Shading Element	Reduce solar radiation	Decrease solar radiation	Control daylight	Generate light (sunlight)	Improve energy efficiency	Reduce glare	

Figure 2: Level 3 Pareto Chart

Based on the identified functions, a structured functional relationship was then developed to understand how each function contributes to the overall performance of the façade system. The logical linkage between primary, secondary, supporting, and causative functions was analyzed using the Function Analysis System Technique (FAST). This diagram illustrates the “how–why” relationships among functions and serves as a foundation for identifying opportunities to improve value through design alternatives.

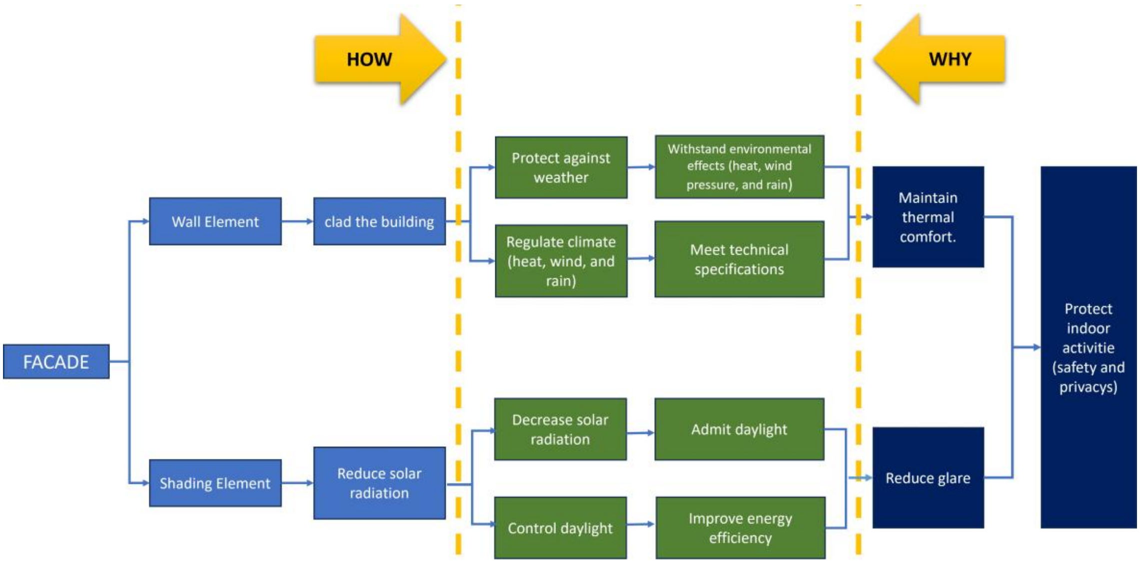


Figure 4. FAST Diagram (Author’s Analysis, 2025)

3. Creativity stage.

The creativity stage aims to systematically develop ideas in order to generate various alternatives. Each alternative is then analyzed based on its advantages and disadvantages as a basis for decision-making.

A. Advantages and Disadvantages of Façade Concept Alternatives

As shown in Table 6, the secondary skin façade demonstrates superior performance compared to the single-skin system, despite limitations related to maintenance and fire safety. To address these issues, a secondary skin façade with a twin-face system is proposed, consisting of a conventional curtain wall or thermal wall combined with a single-glazed outer layer and an interlayer cavity of 500–600 mm to facilitate maintenance access (8)

Table 6. Comparison of Secondary Skin and Single Skin Façade Systems

ASPEK	Secondary Skin	Single Skin
Thermal Performance	Reduces solar heat gain before reaching the inner façade	Direct solar heat gain
Energy Performance	Lowers cooling load and operational energy demand	Higher cooling energy demand
Indoor Comfort	Improves thermal stability and visual comfort (glare reduction)	Higher risk of overheating and glare
Environmental Protection	Provides additional protection against weather exposure	No secondary environmental barrier
Maintainability	Higher maintenance complexity	Simple and direct maintenance
Initial Cost	Higher initial investment	Lower initial cost
Sustainability Impact	Supports energy-efficient and green building strategies	Limited sustainability contribution
Structural Implication	Requires additional structural support	No additional structural requirement

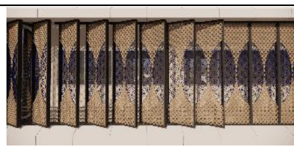
Source: Author's Analysis, 2025

B. Advantages and Disadvantages of Façade Concept Alternatives

Secondary skin façade materials that comply with Minister of Health Regulation No. 40/2022 on technical requirements for hospital buildings and the Green Hospital Guidelines (9) must exhibit adequate hardness, smooth and non-porous surfaces, water resistance, fire resistance, and corrosion resistance. Based on these criteria, the materials considered in this study are Aluminum Composite Panel (ACP), aluminum vertical fins, and Wood Plastic Composite (WPC).

Prior to evaluating the advantages and disadvantages of each material, a material specification analysis was conducted using a secondary skin façade with a twin-face system approach, as summarized in Table 7.

Table 7. Material Specifications and Secondary Skin Façade Concept Using a Twin-Face Approach

Material	Specification	Service Life	Unit Cost	Weight	Design
Laser cutting ACP Laser cutting	Seven FR	20 – 30 years	IDR. 1.276.000 / M^2	ACP weight: 5.50 kg/m² Assumption : one panel = 30 kg	 *Source: Author's Analysis, 2025*
Aluminium vertical fins	Ex. Hunter Douglas	≥ 40 years	IDR. 3.500.000 / M^2	4.90 kg/m² Assumption : one panel = 17.885 kg	 *Source: Author's Analysis, 2025*
WPC vertikal fins	Ex. Duma	20 – 30 years (repainting every 5 Years)	IDR. 1.266.000 / M^2	1.25 kg/m Assumption based on design: one panel = 38 kg	 *Source: Author's Analysis, 2025*

Based on Table 7, a comparative analysis of the advantages and disadvantages of façade materials was conducted using evaluation indicators derived from the Regulation of the Minister of Health No. 40 of 2022 (10), as well as input from construction practitioners in the selection of façade materials.

Table 8. Secondary Skin Material Alternatives

Indicator	Laser-Cut ACP	Aluminum Vertical Fins	WPC Vertical Fins
Material Cost	Relatively lower than aluminum vertical fins	Higher than the other two materials	Lower than the other two alternatives

Service Life	Moderate service life, lower than aluminum vertical fins	More than 40 years, the longest among the alternatives	20–30 years; requires repainting every 5 years
Installation Time	Faster than WPC	Relatively fast due to prefabrication	Slowest among the alternatives
Availability	Easily available on the market	Relatively limited availability compared to other alternatives	Easily available on the market
Maintenance / Cleaning	More difficult compared to other materials	Easy to clean	Easy to clean

4. Evaluation stage.

The evaluation stage aims to narrow the alternatives generated during the creativity stage to the option with the highest potential value improvement (5)

A. Multi-Criteria Analysis (MCA)

Multi-Criteria Analysis (MCA) was employed to evaluate and rank secondary skin façade alternatives. Evaluation criteria were derived from secondary data, and criterion weights were determined through expert interviews involving five professionals from different backgrounds based on façade functional performance (Table 9).

Material alternatives were assessed through interviews with three experts using a standardized scoring system. The evaluation results were processed using MCA by calculating average scores and multiplying them by the assigned criterion weights (Table 10). The analysis indicates that the laser-cut ACP secondary skin façade achieved the highest overall score (8.10).

Table 9. Criteria Variable

No	**Parameter**	**Criteria Variable (CV)**										**Total**	**Rank**	**Rangking Weight**	**Parameter Weight**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**				
CV1	Construction cost		0	0	1	0	0	0	1	1	1	4	6	0.5	9%
CV 2	Long-term maintenance cost	1		0	1	0	1	1	1	1	1	7	3	0.8	15%
CV 3	Life cycle cost	1	1		1	1	1	1	1	1	1	9	1	1.0	18%
CV 4	Salvage value	0	0	0		0	0	0	0	0	0	0	10	0.1	2%
CV 5	Weather resistance	1	1	0	1		1	1	1	1	1	8	2	0.9	16%
CV 6	Ease of maintenance	1	0	0	1	0		1	1	1	1	6	4	0.7	13%
CV 7	Recyclability	1	0	0	1	0	0		1	1	1	5	5	0.6	11%
CV 8	Aesthetics	0	0	0	1	0	0	0		1	1	3	7	0.4	7%
CV 9	Delivery time	0	0	0	1	0	0	0	0		0	1	9	0.2	4%
CV 10	Construction duration	0	0	0	1	0	0	0	0	1		2	8	0.3	5%
Total														**5.5**	**100%**

Table 10. Average Expert Assessment

Kriteria	**Parameter**	**Total**				**Bobot**	**NILAI**			
		Or	**Alt1**	**Alt2**	**Alt3**	**Parameter**	**Or**	**Alt1**	**Alt2**	**Alt3**
CV1	Construction cost	9	4	3	5	9%	0.81	0.36	0.27	0.45
CV 2	Long-term maintenance cost	3	9	9	7	15%	0.45	1.35	1.35	1.05
CV 3	Life cycle cost	5	8	9	5	18%	0.90	1.44	1.62	0.90
CV 4	Salvage value	3	8	9	6	2%	0.06	0.16	0.18	0.12
CV 5	Weather resistance	3	9	9	7	16%	0.48	1.44	1.44	1.12
CV 6	Ease of maintenance	3	9	9	7	13%	0.39	1.17	1.17	0.91
CV 7	Recyclability	3	8	9	6	11%	0.33	0.88	0.99	0.66
CV 8	Aesthetics	3	9	7	8	7%	0.21	0.63	0.49	0.56
CV 9	Delivery time	9	8	5	6	4%	0.36	0.32	0.12	0.24
CV 10	Construction duration	9	7	3	3	5%	0.45	0.35	0.25	0.15
					Total	**100%**	**4.44**	**8.1**	**7.88**	**6.16**
					Rank		**4**	**1**	**2**	**3**

B. Life Cycle Cost Analysis (LCCA)

This study applies Life Cycle Cost Analysis (LCCA) as the primary value engineering approach to evaluate the economic effectiveness of façade concepts over the building service life. The analysis incorporates key economic parameters, including an interest rate of 4.75%, an inflation rate of 2.74%, and a construction material price escalation index (IHPB) of 1.57%.

The original contract value, based on 2023 data, was adjusted to 2025 prices using the Unit Price Analysis (AHSP), resulting in a cost increase of 6.064%. The LCCA was then conducted over a 50-year analysis period, accounting for construction, maintenance, material replacement, and salvage value components.

For the laser-cut ACP secondary skin façade alternative, functional value was enhanced through material specification adjustments in compliance with hospital building regulations. These adjustments included the use of fire-retardant ACP, replacement of 10 mm clear glass with 8 mm tempered glass, and the addition of façade openings to optimize natural daylighting.

The LCCA comparison indicates that the secondary skin façade yields a lower total life cycle cost than the single skin façade, achieving a cost saving of 10.705%. Therefore, the secondary skin façade concept is considered more economically efficient and sustainable over the long term.

Table 11. Comparison of LCCA between the Secondary Skin Façade Concept and the Original Façade Concept

Description	*Fasade single skin (original)*	*Fasade secondary skin (Alternatifl)*
Design Concept	 Source, Data Project 2023	 *Source: Author's Analysis, 2025*
Construction Cost	IDR. 3.802.260.295,77	IDR. 6.000.513.600,49
Maintenance Cost	IDR. 4.323.564.136,53	IDR. 1.346.647.000,00
Replacement Cost	IDR. 1.599.929.945,86	IDR. 1.352.498.105,20
Salvage Value	IDR. (13.978.087,19)	IDR. (27.521.471,19)
Total	**IDR. 9.711.776.290,97**	**IDR. 8.672.137.234,49**
Saving		**IDR. 1.039.639.056,48**
Prosentase		**10,705 %**

5. Idea Development Stage

The idea development stage involves risk analysis of the selected concept and materials identified during the evaluation stage. The assessment was conducted using questionnaires completed by three experts—namely a contractor, a supervising consultant, and building management—based on the Risk Management Guidelines issued by the Ministry of Public Works and Housing (11)

Table 12. Impact Classification

Level	Risk Category	Cost Impact	Schedule Impact	Safety Impact	Environmental Impact
1	Very Low	Cost increase < 1% (negligible)	No delay	No significant impact	No significant impact
2	Low	Cost increase between 1%–5%	Completion delay < 3 months	Minor injury	Minor environmental incident
3	Moderate	Cost increase between 5%–10%	Completion delay up to 3 months	Serious injury	Incident requiring environmental management intervention

4	High	Cost increase between 10%–50%	Completion delay > 3 months	Fatality	Environmental incident leading to legal claims and public protests
5	Very High	Cost increase > 50%	Completion delay exceeding the fiscal year	Multiple fatalities	Major environmental incident with permanent effects and threats to public health or protected natural resources

Risk levels are determined using a Probability–Impact approach, where the risk value (R) is calculated as the product of probability (P) and impact (I). The classification of risk categories is summarized in Table X

Table 13. Risk Classification

R value = P x I	**Risk Category**	**Symbol**
≤ 5	Very low risk (negligible)	
6 – 9	Low risk (acceptable)	
10 – 15	Moderate risk (critical)	
16 – 25	High-very high risk (unacceptable, planning adjustments required)	

The risk matrix is used to evaluate risk levels by combining the probability or frequency of occurrence with the level of impact. Risk values are determined by multiplying probability and impact (R = P × I) to identify the severity of each risk. This classification helps prioritize risks that require monitoring, mitigation, or immediate corrective action.

Table 14. Risk Matrix

Probability/ Frequency		Impact Very Low 1	Low 2	Medium 3	High 4	Very high 5
Very High	5					
High	4					
Medium	3					
Low	2					
Very Low	1					

Referring to the criteria defined in the table above, risk identification was conducted by collecting expert judgments to determine risk variables with high risk levels. The assessment involved experts from diverse professional backgrounds, namely construction management consultants, building management, and contractors, in order to obtain a comprehensive perspective. The final risk values were determined by averaging the experts' assessments and are subsequently presented in tabular form to facilitate analysis and interpretation

Table 15. Risk Matrix

No	Aspect	Variable	Risk Category	Skor	Description
A	Occupational Health and Safety (OHS)	X1	Falling from height	5,00	Very Low
		X2	Being struck by scaffolding	6,67	Low
		X3	Falling materials hitting workers	13,33	Medium
		X4	Noise generation	9,33	Low
		X5	Injury from sharp material edges	8,89	Low
B	Construction Technical Implementation	X6	Limited working area	8,89	Low
		X7	Use of material technology	10,00	Low
		X8	Design non-conformity	5,33	Low
		X9	Design changes	9,00	Low
C	Cost Aspect	X10	Changes in work scope	8,56	Low
		X11	Material price fluctuation	9,78	Low
		X12	Inaccurate project cost estimation (budget planning)	17,33	High
		X13	Increase in non-technical cost factors	9,00	Low
		X14	Increase in unit prices of materials and labor	8,00	Low
D	Durability Aspect	X15	Material corrosion or degradation	20,22	Very High
		X16	Incorrect material selection	9,78	Low
		X17	Lack of preventive maintenance	12,00	Medium
E	Environmental Aspect	X18	Weather conditions (rain and wind)	10,00	Low
		X19	Delay in material delivery	10,00	Low
		X20	Noise and air pollution around the project site	10,00	Low
F	Policy and Regulatory Aspect	X22	Material selection not complying with regulations	9,33	Low
		X23	Facade concept selection not complying with regulations	9,33	Low

Based on the evaluation of the probability and impact values of the risk variables, two risk categories and events were identified as having **high** and **very high** risk levels. In the subsequent stage, risk mitigation measures were implemented. The following presents the cost analysis for risk mitigation :

a. The risk of inaccurate cost estimation resulting from calculations limited to construction costs was mitigated by engaging experienced Quantity Surveyor experts to provide material recommendations based on the building life-cycle cost approach. This mitigation required two person-months (PM), with a total cost of IDR 135,000,000.

b. Structural steel is susceptible to corrosion due to weather exposure; therefore, protective cladding using Aluminum Composite Panel (ACP) was applied over an area of 366 m², with a unit price of IDR 1,225,315/m², resulting in a total cost of IDR 448,342,878.

c. The total cost required for risk mitigation amounted to IDR 583,342,878.

6. Evaluatin Stage

At the evaluation stage, the Life Cycle Cost Analysis (LCCA) was recalculated by incorporating the costs required for risk mitigation. The revised LCCA results were then compared with the original LCCA and the alternative LCCA without risk considerations. This comparison was conducted to assess the economic performance of the facade alternatives over the building life cycle.

Tabel 15 Perbandingan Nilai LCCA

Description	Original Single skin (Rp)	Alternatif Secondary skin (Rp)	Secondary skin + risiko (Rp)
Construction Cost	IDR. 3.802.260.295,77	IDR. 6.000.513.600,49	IDR. 6.000.513.600,49
Maintenance Cost	IDR. 4.323.564.136,53	IDR. 1.346.647.000,00	IDR. 1.346.647.000,00
Material Replacement	IDR. 1.599.929.945,86	IDR. 1.352.498.105,20	IDR. 1.309.180.452,40
Risk Mitigation Cost	-	-	IDR. 583.342.877,65

Salvage Value	IDR. (13.978.087,19)	IDR. (27.521.471,19)	IDR. (32.100.338,71)
Total	**IDR. 9.711.776.290,97**	**IDR. 8.672.137.234,49**	**IDR. 9.207.583.591,82**
Saving		**IDR. 1.039.639.056,48**	**IDR. 504.192.699,15**
Prosentase		**10,705 %**	**5,192%**

7. Recommendation preparation stage

a. Based on the research findings, this study recommends the application of a secondary skin façade concept using a twin-face approach with laser-cut Aluminum Composite Panel (ACP) material as the most suitable alternative for the building façade.

b. The Life Cycle Cost Analysis (LCCA) results indicate that the secondary skin façade with a twin-face system achieves a cost saving of 5.19% compared to the original façade concept, after incorporating risk mitigation costs into the analysis.

c. The functional performance of the façade is enhanced through the selection of materials that comply with applicable regulations and building standards, as well as through the addition of window openings, which reduces dependence on artificial lighting during daytime operation.

d. Further cost-saving potential could be achieved if future LCCA studies incorporate energy cost reductions resulting from improved thermal and daylighting performance provided by the secondary skin façade system.

e. To maximize economic benefits and effectively manage potential risks, it is recommended that Value Engineering be implemented from the early planning stage through the construction phase, ensuring optimal integration of design, material selection, and risk mitigation strategies.

8. Presentation stage

a. The original construction contract value (2023–2024) increased after adjustment to 2025 prices using an interest rate of 6.064%.
b. Pareto analysis identified exterior wall and façade finishing works as priority items for Value Engineering.
c. A secondary skin façade concept was developed using three compliant material alternatives: laser-cut ACP, aluminum louver fins, and WPC louver fins.
d. The Multi-Criteria Analysis (MCA) results indicate that aluminum louver fins achieved the highest average expert score.
f. Life Cycle Cost Analysis (LCCA) results identify laser-cut ACP as the most cost-effective option, achieving a 10.70% cost efficiency over the building life cycle.
g. Two dominant risks were identified:
   - Structural steel corrosion due to weather exposure, and
   - inaccuracies in long-term operation and maintenance cost estimation.
h. LCCA considering unmanaged risks resulted in 1.62% cost savings, while early risk mitigation increased savings to 5.19%.
i. Functional performance improvements were achieved through:
   - Replacement of 10 mm float glass with 8 mm tempered glass,
   - use of fire-resistant ACP (FR), and
   - additional window openings to enhance daylighting and energy efficiency.

IV. CONCLUSION

This study demonstrates that the implementation of a secondary skin façade concept with a twin-face approach using laser-cut Aluminum Composite Panel (ACP) material results in a 5.19% cost saving compared to the original façade concept, even after explicitly accounting for risk mitigation and management costs within the Life Cycle Cost Analysis (LCCA). Furthermore, the adoption of the secondary skin façade as an alternative design enhances the functional value of the building envelope through the selection of window glazing and ACP materials that fully comply with Indonesian Ministry of Health Regulation No. 40 of 2022, thereby improving safety, durability, and regulatory conformity.

The incorporation of additional window openings within the façade system significantly improves natural daylight penetration, which reduces reliance on artificial lighting during daytime operation. This improvement not only enhances occupant comfort and visual quality, particularly in healthcare environments, but also indicates potential long-term energy efficiency benefits, supporting the application of secondary skin façades as a cost-effective and sustainable solution for hospital buildings.

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