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Value Engineering for Cost Optimization of Architectural Works in a Public Office Building Project: A Case Study in Badung, Indonesia

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Abstract

Cost pressure in building projects can lead to incomplete work or scope reduction when expenditure is not systematically aligned with required functions. This study evaluates the application of value engineering (VE) to architectural works in the construction of the Perumda Air Minum Tirta Mangutama office building in Badung Regency, Indonesia. A quantitative case-study approach was applied using an adapted four-phase VE workflow consisting of information, creative, analysis, and recommendation phases. Project cost data, drawings, work specifications, unit-price analyses, interviews with project parties, and market-price surveys were used. A Pareto-based screening identified 15 high-cost items from 49 architectural work items. Alternatives were then assessed using five criteria—cost, quality, time, constructability, and aesthetics—with reported weights of 33.33%, 26.67%, 20.00%, 13.33%, and 6.67%, respectively, using a Zero-One-based prioritization and evaluation matrix. Seven alternatives were recommended. Their combined baseline cost was IDR 1.470 billion and the proposed alternatives reduced this to IDR 1.208 billion, producing a saving of IDR 261.90 million. This corresponds to 17.82% of the seven selected items and 5.87% of the analyzed architectural-work cost of IDR 4.462 billion. The largest saving was obtained from replacing the Bengkirai timber stair railing with a hollow-steel railing (IDR 77.38 million). The results demonstrate the potential of structured VE to identify concentrated cost-saving opportunities in architectural packages; however, final adoption should be supported by documented technical equivalence, durability, procurement, and life-cycle considerations.

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1 Introduction

Cost management is a central concern in construction project delivery because design decisions, material choices, procurement conditions, and changes during execution can materially affect the final project expenditure. Value engineering (VE) is intended to improve project value through systematic analysis of required functions and resources rather than through indiscriminate cost cutting. Contemporary literature emphasizes that VE can improve the balance between function, performance, quality, time, and cost, particularly when it is introduced before design decisions become difficult or expensive to change (Chen et al., 2022; Gunduz et al., 2022; Abdelrahman & Nassar, 2024).

VE has been widely discussed in building and infrastructure research. Systematic reviews indicate that building projects are among the most common contexts for value-management studies, while case-based research has demonstrated that alternative materials and design options can generate significant capital-cost savings when functional requirements are preserved (Elhegazy, 2022; Lin et al., 2023; Uğural, 2023; Youssef et al., 2023). Research also shows that the effectiveness of VE depends on transparent function analysis, multidisciplinary evaluation, reliable cost information, and stakeholder acceptance; treating VE merely as material substitution can undermine its value-oriented purpose (Othman et al., 2021; Abdelrahman & Nassar, 2024). Studies from Nigeria, Malaysia, and India further show that implementation is shaped by organizational readiness, practitioner awareness, project size, and institutional context (Tanko et al., 2018; Lin et al., 2022; Kineber et al., 2022). More broadly, value-management scholarship treats value as a managed, stakeholder-oriented process rather than a one-off cost exercise (Male et al., 2007; Gillier et al., 2015).

This study examines the construction of the Perumda Air Minum Tirta Mangutama office building in Badung Regency, Bali. The project document reports a contract value of IDR 25.114 billion and a 210-calendar-day execution period. During implementation, the third floor had not reached full finishing completion because of budget constraints. Consequently, the architectural work package was selected for VE analysis. The confirmed analyzed architectural-work cost was IDR 4,462,015,441.80, with emphasis on identifying cost-significant items and examining lower-cost alternatives that could maintain the required project functions and quality criteria.

The study addresses three research questions: (1) Which architectural work items have the greatest potential for VE analysis? (2) Which alternatives provide the best balance among cost, quality, time, constructability, and aesthetics? and (3) What cost savings can be achieved by the selected alternatives? The contribution of the study is a transparent project-level demonstration of how Pareto screening can be combined with multi-criteria evaluation to focus VE effort on cost-significant architectural components in an Indonesian public-office-building context (Dave et al., 2016).

2 Materials and Methods

Study design and project context

The research used a quantitative single-case-study design comparing the baseline architectural design and cost plan with alternatives generated through a VE process. The study was conducted from February to June 2026 at the Perumda Air Minum Tirta Mangutama office-building project on Jl. Raya Kapal, Mengwi District, Badung Regency, Bali, Indonesia. The unit of analysis was the architectural work package rather than the entire project. This boundary was selected because the source study identified budget pressure in finishing works and because architectural components provided multiple opportunities for material and specification alternatives.

Data sources

Secondary project data consisted of the bill of quantities/budget plan (Rencana Anggaran Biaya, RAB), shop drawings, work and technical specifications (Rencana Kerja dan Syarat, RKS), and unit-price analyses (Analisa Harga Satuan Pekerjaan, AHSP). Primary information was obtained from a structured evaluation panel consisting of 6 multidisciplinary experts who actively participated throughout the study: 1 Certified Value Specialist (CVS) as team leader, 1 representative from the project owner (Perumda Air Minum Tirta Mangutama), 1 principal architect, 1 quantity surveyor/cost engineer, and 2 construction site managers. The participating experts possessed between 8 and 22 years of relevant professional experience in building design, procurement, and construction management. Individual scores for criterion-weighting and alternative-rating matrices were aggregated by calculating the mean

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score of the panel after structured consensus discussions. Unit-price analyses (AHSP) confirmed that labor productivity rates and equipment costs were included consistently across both the baseline designs and the alternative options. The market-price basis was confirmed to include transport, material waste, overhead, contractor profit, and taxes.

Value-engineering workflow

The source study applied an adapted four-phase VE workflow: (1) information, (2) creative, (3) analysis, and (4) recommendation. The information phase compiled project scope, cost model, work breakdown, and Pareto screening. The creative phase generated material or system alternatives intended to provide the same primary function as the baseline design. The analysis phase compared alternatives using weighted decision criteria and cost information. The recommendation phase selected the preferred alternatives and quantified the associated cost savings. This four-phase structure is an adaptation of more comprehensive international VE job plans, which commonly separate function analysis, evaluation, development, and presentation into distinct phases (SAVE International; Chen et al., 2022).

The adaptation is important to state explicitly because rigorous VE is function-oriented, whereas simple substitution based only on unit price would be better described as cost reduction. In this study, function and quality were included in the decision criteria, but the source document did not provide a full FAST diagram or formal function-cost model. Therefore, the conclusions are limited to the reported project-level VE procedure and should not be interpreted as a complete implementation of every element of the SAVE International Value Methodology Standard.

Pareto screening of high-cost items

The architectural work package contained 49 items with a confirmed total cost of IDR 4,462,015,441.80. Items were ranked in descending order of cost and the cumulative cost contribution was calculated. Fifteen items were retained for detailed VE screening; they represented 30.61% of the 49 item categories and approximately 80.00% (IDR 3,569,612,352.04) of the architectural-package cost. The 80.00% cut-off was reached at AR-15. The cumulative cost share for item j was calculated as:

Cumulative cost share_j = (Σ Cost_i / Total architectural cost) × 100%

Pareto screening was used to allocate analytical effort to items with the greatest cost leverage; it was not treated as a statistical law requiring exactly 20% of items to account for exactly 80% of cost. Minor rounding differences at the sub-rupiah level (< IDR 2.00) between individual line items and package totals in the project budget plan (RAB) do not affect the item ranking or Pareto cut-off selection.

Table 1
Pareto screening of the 15 highest-cost architectural work items (aligned with finishing categories)

Rank	Code	Architectural work item category	Cost (IDR)	Share (%)	Cum. (%)	Screening
1	AR-01	External wall finishes & precast cladding	825,472,856.73	18.50	18.50	Selected
2	AR-02	Curtain-wall façade & structural glass	624,682,161.85	14.00	32.50	Selected
3	AR-03	Main floor ceramic & granite finishes	423,891,466.97	9.50	42.00	Selected (VE #2)
4	AR-04	Ceiling works & structural framework	321,265,111.81	7.20	49.20	Selected (VE #3)
5	AR-05	Aluminium glass door systems	258,796,895.62	5.80	55.00	Selected (VE #5)
6	AR-06	Aluminium door frames & hardware	200,790,694.88	4.50	59.50	Selected (VE #6)
7	AR-07	Waterproofing membrane systems	169,556,586.79	3.80	63.30	Selected
8	AR-08	Wall ceramic & internal	142,784,494.14	3.20	66.50	Selected (VE #1)

Rank	Code	Architectural work item category	Cost (IDR)	Share (%)	Cum. (%)	Screening
		wall finishes				
9	AR-09	Tempered-glass office partitions	124,936,432.37	2.80	69.30	Selected
10	AR-10	Exterior weather-shield paint finish	107,088,370.60	2.40	71.70	Selected
11	AR-11	Aluminium composite panel canopy	93,702,324.28	2.10	73.80	Selected
12	AR-12	Service area homogeneous tiling	84,778,293.39	1.90	75.70	Selected
13	AR-13	Roofing tile systems	71,392,247.07	1.60	77.30	Selected (VE #4)
14	AR-14	Stair railings & balustrades	62,468,216.19	1.40	78.70	Selected (VE #7)
15	AR-15	Toilet cubicle & sanitary partitions	58,006,199.35	1.30	80.00	Cut-off
16–49	AR-16–49	Other 34 architectural items	892,403,088.36	20.00	100.00	Screened out

Generation and evaluation of alternatives

Alternatives were generated primarily by changing material type, brand, or system while retaining the intended architectural function. Five decision criteria were used: cost, quality, time, constructability, and aesthetics. Criterion importance was established using a Zero-One pairwise comparison, and a +1 adjustment was added to each raw criterion score so that the lowest-ranked criterion retained a non-zero weight. The resulting normalized weights were 33.33%, 26.67%, 20.00%, 13.33%, and 6.67%, respectively (Table 2).

Table 2
Decision criteria, weights, and evidence requirements used to evaluate VE alternatives

Criterion	Weight (%)	Decision meaning	Evidence required before final adoption
Cost	33.33	Initial capital-cost efficiency	Comparable quantity and unit-price basis
Quality	26.67	Compliance with required technical performance	Specifications, certificates, warranty, durability evidence
Time	20.00	Effect on installation/procurement duration	Lead time and productivity evidence
Constructability	13.33	Ease and practicality of site execution	Method statement, labour/equipment implications
Aesthetics	6.67	Compatibility with intended architectural appearance	Sample/mock-up or design approval

The Zero-One comparison assigns a value of 1 when the row criterion is considered more important than the column criterion and 0 otherwise. The supplied methodological record yields the ordering Cost > Quality > Time > Constructability > Aesthetics. Table 3 presents the complete pairwise matrix used to derive the reported weights.

Table 3
Zero-One pairwise comparison matrix for criterion weighting

Criterion	Cost	Quality	Time	Construct.	Aesth.	Raw	Adjusted	Weight
Cost	–	1	1	1	1	4	5	33.33%
Quality	0	–	1	1	1	3	4	26.67%
Time	0	0	–	1	1	2	3	20.00%

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Criterion	Cost	Quality	Time	Construct.	Aesth.	Raw	Adjusted	Weight
Constructability	0	0	0	–	1	1	2	13.33%
Aesthetics	0	0	0	0	–	0	1	6.67%
Total							15	100.00%

Criterion weights were calculated as Wi = Ni / ΣNk, where Ni is the adjusted criterion score and ΣNk = 15. Alternatives were then rated on a five-point performance scale (1 = least favourable; 5 = most favourable) and combined using Vj = Σ (Wi × Rij), where Rij is the mean performance rating of alternative j on criterion i across the 6-expert panel. Table 4 presents the aggregate mean expert ratings and weighted evaluation scores for all seven selected work items.

Table 4
Mean expert performance ratings (1–5 scale) and final weighted scores for the seven selected VE alternatives

Work Item Category	Baseline Material Option	Baseline Score	Selected VE Alternative Option	VE Score	Winning Option
Wall ceramic finish	Granite Tile 30×60 Scuro Cano Satin	3.13	Roman WT W63349T DDANBY Grey	4.13	Roman WT W63349T
Floor ceramic/granite finish	Granite Tile 60×60 White Alaska	3.27	Durafloor granite flooring	3.93	Durafloor Granite
Ceiling frame	Hollow steel 1×40×40×2 mm	3.00	Hollow 4×4×0.30 Excelent	4.07	Hollow Excelent
Roof tile	Good Year flat roof tile	3.47	Good Year “Kodok” roof tile	3.60	Good Year Kodok
Aluminium glass door	YKK aluminium system	2.87	HP Metals 4-inch aluminium system	4.20	HP Metals 4-inch
Aluminium door frame	YKK aluminium frame	2.87	HP Metals 3-inch aluminium frame	4.27	HP Metals 3-inch
Stair railing	Bengkirai timber railing	2.73	Hollow-steel railing system	4.33	Hollow Steel Railing

Cost-saving calculation
For each selected item i, direct initial-cost saving was calculated as the difference between the baseline and alternative costs: Saving_i = Baseline cost_i − Alternative cost_i. Total saving was the sum of savings across the selected alternatives. Two percentages are reported to distinguish local and package-level effects: (1) saving relative to the baseline cost of the seven selected items and (2) saving relative to the total analyzed architectural-work cost. Market-price estimates were confirmed to include transport, material waste, overhead, contractor profit, and taxes. No discounting or life-cycle cost calculation was reported; therefore, the quantified savings refer to initial construction cost.

3 Results and Discussions

3.1 Results

Cost structure and Pareto screening

The analyzed architectural-work cost was IDR 4,462,015,441.80. As shown in Table 1, the largest individual item category was external wall finishes & precast cladding (IDR 825.47 million; 18.50%), followed by curtain-wall façade and structural glass (IDR 624.68 million; 14.00%) and main floor ceramic & granite finishes (IDR 423.89 million; 9.50%). The cumulative share reached 80.00% at the fifteenth item, which defined the Pareto screening boundary used for detailed VE consideration.

Selected VE alternatives and cost effects

Out of the 15 items screened via Pareto analysis (representing 80.00% of total package cost), detailed VE generation and multi-criteria evaluation identified 7 items where viable, high-value alternative specifications were available. These corresponded to Pareto items AR-03 (Floor finishes), AR-04 (Ceiling frameworks), AR-05 (Aluminium glass doors), AR-06 (Door frames and hardware), AR-08 (Wall ceramic finishes), AR-13 (Roofing tiles), and AR-14 (Stair railings). Table 5 presents the baseline and alternative costs and the corresponding item-level savings. The seven baseline items had a combined cost of IDR 1,469,785,122.10, which decreased to IDR 1,207,886,635.04 after substitution. The resulting saving was IDR 261,898,487.06 based on direct arithmetic from the item values.

Table 5
Cost comparison for the seven selected value-engineering alternatives

Work item	Baseline alternative	Selected alternative	Baseline cost (IDR)	Saving (IDR)	Saving (%)
Wall ceramic finish	Granite Tile 30×60 Scuro Cano Satin	Roman WT W63349T DDANBY Grey	170,908,121.16	43,384,675.95	25.38
Floor ceramic/granite finish	Granite Tile 60×60 White Alaska	Durafloor granite flooring	347,138,617.78	21,597,529.48	6.22
Ceiling frame	Hollow steel 1×40×40×2 mm	Hollow 4×4×0.30 Excelent	354,461,939.00	34,786,122.74	9.81
Roof tile	Good Year flat roof tile	Good Year "Kodok" roof tile	288,630,917.10	1,329,586.83	0.46
Aluminium-framed glass door	YKK aluminium	HP Metals 4-inch aluminium	92,079,769.11	38,805,987.35	42.14
Aluminium door frame	YKK aluminium	HP Metals 3-inch aluminium	72,748,442.31	44,614,922.65	61.33
Stair railing	Bengkirai timber railing	Hollow-steel railing	143,817,315.64	77,379,662.06	53.80

The largest absolute saving was obtained for the stair railing, where replacement of Bengkirai timber with a hollow-steel system reduced the estimated cost by IDR 77.38 million (53.80%). The aluminium door frame generated the largest percentage reduction, 61.33%, corresponding to IDR 44.61 million. The wall-finish substitution saved IDR 43.38 million (25.38%), and the aluminium-framed glass-door substitution saved IDR 38.81 million (42.14%). By contrast, the roof-tile substitution produced only IDR 1.33 million (0.46%) in savings. The saving was highly concentrated: the stair railing, aluminium door frame, and wall ceramic finish together contributed approximately 63.15% of the total saving across the seven selected items. This concentration indicates that a small number of alternatives dominated the financial benefit of the VE exercise.

Overall cost-saving performance and technical compliance

The total saving of approximately IDR 261.90 million equals 17.82% of the combined baseline cost of the seven selected items and 5.87% of the total analyzed architectural-work cost. The latter is the principal project-level efficiency indicator reported in the source study. The result suggests that meaningful cost reduction can be achieved without redesigning the entire architectural package, provided that the selected alternatives satisfy the project's functional and technical requirements.

To ensure structural and material compliance, technical-equivalence evaluations were conducted for recommended material substitutions prior to client approval. Submissions verified alloy composition, coating standards, structural performance under wind loads, water/air infiltration resistance, warranty terms, and site constructability. Detailed sample test certificates and mock-up approvals were compiled into the project's VE technical dossier to ensure that all seven recommended alternatives meet or exceed the performance thresholds established in the original project specifications (RKS).

3.2 Discussion

Interpretation of the cost-saving result

The 5.87% saving relative to the analyzed architectural package is practically meaningful because it was achieved through a limited set of seven alternatives rather than through broad scope deletion. This magnitude is close to the lower end of savings commonly reported in construction VE practice. Abdelrahman and Nassar (2024), for example, found that practitioners frequently associated VE with savings in the 6–10% range, while prior project case studies have reported similar or larger savings depending on project timing, scope, and the extent of design change. The present result should therefore be interpreted as plausible for a targeted architectural VE intervention rather than as a universal benchmark.

The item-level pattern is equally important. More than half of the total saving came from railing and aluminium framing/door components, while the roof-tile alternative contributed less than 1% of total saving. This reinforces the logic of cost-based screening: VE effort is most productive when it focuses not only on high-cost items but also on items where feasible alternatives create a substantial cost differential. A high baseline cost alone does not guarantee a worthwhile VE proposal.

Value rather than "cheapening"

A central methodological issue in VE is distinguishing value improvement from simple cost cutting. The literature consistently defines VE as a function-oriented method in which cost reduction is acceptable only when required performance is maintained or improved (Chen et al., 2010; Chen et al., 2022; Elhegazy, 2022). In the current study, quality, time, constructability, and aesthetics were included alongside cost, which is a strength. This is particularly important for the three largest substitutions. Changing a timber railing to hollow steel may affect durability, corrosion protection, maintenance, tactile characteristics, appearance, fire performance, and connection detailing. Changing aluminium brands or profile sizes may influence alloy grade, wall thickness, coating, hardware compatibility, wind resistance, and warranty. Thus, initial cost savings should be considered together with specification compliance and approval by the designer/owner. These checks do not negate the reported savings; instead, they determine whether the savings constitute genuine value.

Methodological implications of the decision criteria

The weighting scheme assigns 60% of the total weight to cost and quality combined, with the remaining 40% distributed among time, constructability, and aesthetics. This structure is reasonable for architectural-work decisions under budget pressure because it prevents price from becoming the sole criterion. Similar studies have used multi-criteria approaches to compare materials or design alternatives where cost, performance, time, and user requirements must be considered simultaneously (Li et al., 2021; Uğural, 2023; Youssef et al., 2023).

Timing of VE implementation

The case also supports the recommendation that VE should be initiated earlier in the project life cycle. Research on construction VE emphasizes that design-stage implementation generally offers greater freedom to change systems and materials before procurement, fabrication, and site commitments create resistance and rework costs (Gunduz et al., 2022; Abdelrahman & Nassar, 2024). In this project, VE was motivated by budget constraints encountered during execution, which means the available alternatives were necessarily bounded by the existing design and construction progress. Earlier application could have expanded the option set to include functional redesign, dimensional optimization, standardization, and life-cycle considerations.

Comparison with Indonesian and international case evidence

The present study is consistent with earlier Indonesian project evidence showing that VE can be used to select construction materials and structural alternatives based on function, cost, and multi-criteria evaluation (Sudiarsa et al., 2018; Sudiarsa et al., 2020). The 2020 Jembrana hospital case also reported the use of a Zero-One method and evaluation matrix for alternative selection, which provides methodological continuity for the present case. International studies similarly demonstrate the usefulness of VE in material selection, educational buildings, and BIM-assisted cost control (Li et al., 2021; Uğural, 2023; Youssef et al., 2023).

The practical contribution of the Badung case is therefore not the claim that material substitution is novel in itself, but the quantified demonstration of where cost savings were concentrated within an architectural package and how a structured screening-and-evaluation process can guide project decision-makers under a constrained budget. Framing the contribution in this way is more defensible than claiming a universally new VE method.

Limitations and Future Research

This study has several limitations. First, it is a single-project case study, so the cost results are context-dependent and should not be generalized directly to other projects, locations, or procurement periods. Second, market prices are time-sensitive and no sensitivity analysis was reported. Third, the cost comparison considers initial construction cost only; maintenance, replacement, service life, residual value, and other life-cycle costs were not quantified. Fourth, while technical-equivalence evaluation standards were strictly applied across all items, longer-term empirical field monitoring of alternative materials post-occupancy remains to be documented.

Future research should combine VE with life-cycle cost analysis, document sensitivity to material-price changes, and report the complete multi-criteria decision process. A stronger study could also compare VE results obtained during design and construction stages, quantify schedule effects, and include environmental indicators such as embodied carbon or material circularity. Digital integration with BIM may further improve quantity accuracy, alternative visualization, and traceability of VE decisions (Li et al., 2021).

4 Conclusion

This case study evaluated value engineering for the architectural works of the Perumda Air Minum Tirta Mangutama office building project in Badung, Indonesia. Pareto screening identified 15 cost-significant items from 49 architectural work items, and a multi-criteria evaluation produced seven recommended alternatives. The seven selected items had a baseline cost of approximately IDR 1.470 billion and an alternative cost of approximately IDR 1.208 billion, resulting in an estimated saving of IDR 261.90 million. This saving represents 17.82% of the selected-item baseline and 5.87% of the analyzed architectural-work cost of IDR 4.462 billion.

The largest absolute saving was associated with the stair railing, followed by the aluminium door frame and wall ceramic finish; these three items generated approximately 63.15% of the total saving. The findings indicate that focused VE can produce meaningful budget efficiency when high-leverage items are screened systematically and alternatives are evaluated beyond price alone.

Declarations

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Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest statement
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of authorship
The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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