



## Optimisation of Building Maintenance Scenarios Using Life Cycle Cost Analysis at Manado State Polytechnic

\*Yosua Gilberth Cristovel Rondonuwu<sup>1</sup>, Geertje Efraty Kandiyoh<sup>2</sup>, Sandri Linna Sengkey<sup>3</sup>

<sup>1,2,3</sup>Politeknik Negeri Manado, Manado, Indonesia

\*)Corresponding author ([gilberthyosua@gmail.com](mailto:gilberthyosua@gmail.com))

Received : 23 September 2026 Revised : 14 Oktober 2026 Accepted : 28 Oktober 2026

### Abstract

*This study compares maintenance scenarios for the Integrated Lecture Building at Manado State Polytechnic through FEMA P-154 Rapid Visual Screening (RVS) and life cycle cost analysis. Six nonstructural and building-services packages are compared under reactive maintenance (S0), scheduled preventive maintenance (S1), and minor nonstructural retrofit with preventive maintenance (S2). The recorded RVS score of 2.0 lies at the screening cut-off; documented defects warrant structural engineering evaluation. Costs are expressed in modelled constant-2026 rupiah over 2027–2046. A researcher-selected nominal benchmark of 6%, obtained by upward rounding of the supplied BI-rate mean, is converted through Fisher using assumed inflation of 2.5%, giving a real rate of 3.414634%. Revised present-value costs are IDR 112.896, 112.863, and 113.503 billion for S0, S1, and S2. S1 saves only IDR 33.00 million (0.029%) relative to S0. Demolition at year 20, a 10% demolition allowance and 5% inventory salvage are explicit hypothetical disposal assumptions. S1 has a marginal conditional advantage, dependent on assumed price dates, cost allocations, equivalent service requirements and structural verification.*

**Keywords:** Building Maintenance; Rapid Visual Screening; Life Cycle Cost; Preventive Maintenance; Minor Retrofit.

---

© Diterbitkan oleh Jurnal Teknik Sipil Cendekia 2026. This article is distributed under a Creative Commons Attribution-ShareAlike 4.0 International License.

### INTRODUCTION

Maintaining educational buildings supports continuity of teaching, asset preservation, and protection of users from deteriorating components. Repair decisions often arise from operational complaints or visible damage. However, expenditure in a particular year does not, by itself, demonstrate the effectiveness of a maintenance scenario. Comparing strategies requires specifying the components addressed, intervention timing, service levels maintained, and costs incurred throughout the analysis period.

Kandiyoh et al. [1] combined visual evaluation and life cycle cost analysis (LCCA) for a teaching building of the Civil Engineering Department at Manado State Polytechnic. Their study compared reactive maintenance, preventive maintenance, and minor retrofit combined with preventive maintenance. This approach provides a relevant analytical structure for GKT by linking technical needs to cost implications. However, the reference building differs from GKT. Its material test results, geometric conditions, effectiveness coefficients, and costs therefore cannot be treated as GKT data.

Haryanto et al. [2] examined Rapid Visual Screening (RVS) for educational facilities in Indonesia, while Pratama et al. [3] investigated its application to healthcare facilities. Kusumayani and Angga [4] demonstrated the use of screening to develop vulnerability profiles and prioritise further evaluation. These studies illustrate the value of structured observations, although differences in building typology and inspection scope must be considered when adapting a procedure. Photographs of maintenance conditions cannot replace all parameters required by an RVS form.

In building economic analysis, Krisnanda [5] grouped costs into initial, operating, maintenance, and replacement costs. Rizky [6] used a 20-year horizon for a banking office building. Utari and Samad [7] included demolition costs in their analysis of a dormitory building. These studies show that analytical boundaries determine the reported cost structure. LCC estimates that include initial construction are not equivalent to estimates covering only maintenance decisions for an existing asset.

Studies of the KONI building in Tapin Regency [8] and the Telaga rental flats [9] based their cost calculations on component identification and management records. Wahyudiono and Andardi [10] included equivalent annual costs in their dormitory analysis, while Puhessti [11] examined cost components and residual value in a residential building. This literature supports explicit cost disaggregation rather than using a single budget figure to represent an entire strategy. For earthquake risk, Weber et al. [12] also showed that fragility models must be appropriate to the characteristics of the buildings assessed.

The GKT case requires integrating evidence that serves different purposes. Expenditure records identify paid works, price lists provide an estimation basis, inventories describe asset quantities, and visual documentation identifies signs requiring investigation. Combining these sources without classification can cause double counting or imply that all assets require simultaneous replacement. This study develops a traceable analytical basis before identifying an optimum strategy.

The study assesses GKT using RVS, classifies maintenance needs into six packages, and compares S0, S1, and S2 through LCCA over 20 years. The results are presented as cost comparisons conditional on intervention schedules and scope, together with an examination of safety and service continuity implications.

The following objectives address the identified research gap and support maintenance planning for higher education buildings such as GKT at Manado State Polytechnic:

1. To assess the structural and nonstructural conditions of GKT using RVS in accordance with FEMA P-154.
2. To analyse institutional maintenance and repair expenditure records and classify them into preventive maintenance packages for further evaluation.
3. To simulate alternative maintenance strategies—reactive maintenance (S0), scheduled preventive maintenance (S1), and minor retrofit combined with preventive maintenance (S2)—using LCCA.
4. To identify a cost-efficient and sustainable maintenance scenario that supports user safety, minimises life cycle costs, and sustains the long-term operation of educational facilities.

## METHOD

### Study building and research design

A descriptive quantitative case study was conducted on the Integrated Lecture Building (GKT) at Manado State Polytechnic. Table 1 summarises its technical characteristics based on RVS documentation and previous research [13]. The approximately 10,500 m<sup>2</sup> reported in the previous study is treated here as the total area of six above-ground floors and one basement. The bored-pile foundation is based on information from building management. Construction began in 2014, was completed in 2020, and the building entered service in 2021 [13].

**Table 1. Technical characteristics of the GKT building**

| Technical parameter            | Description                                                                  |
|--------------------------------|------------------------------------------------------------------------------|
| Building use                   | Educational and administrative facilities                                    |
| Storeys                        | Six above ground and one basement                                            |
| Total floor area               | Approximately 10,500 m <sup>2</sup> , including the basement*                |
| Lateral force-resisting system | Reinforced concrete moment-resisting frame; RVS type C1                      |
| Soil classification            | Class C (very dense soil or soft rock), as recorded in the RVS documentation |
| Foundation                     | Bored piles, according to building management information                    |
| Construction history           | Started in 2014; completed in 2020; occupied in 2021                         |
| Coordinates                    | 1.519778° N; 124.888238° E                                                   |
| RVS inspection date            | 4 June 2025                                                                  |

Sources: GKT RVS documentation (4 June 2025), building management information, and Tompodung [13]. \*The approximate area reported in [13] is treated in this study as the aggregate floor area, including the basement. Structural and soil classes follow the RVS records; the area is not an as-built measurement performed in this study.

The valuation date is the end of 2026 ( $t = 0$ ); year-end flows for  $t = 1-20$  cover 2027–2046. The source scenario workbook supplies intervention quantities and schedules. The historical construction amount of IDR 74,761,914,000 is assigned an assumed end-2020 price date, matching completion, and restated to IDR 88,348,488,438.53 at modelled end-2026 prices. This is a common accounting baseline, not a new investment in 2026. Historical expenditure is restated by year before being used as an assumed first-year corrective backlog in S0; it is not treated as an actual 2027 payment record.

Table 2 summarises the data sources and their analytical functions.

**Table 2. Data sources and analytical functions**

| Data                  | Function            |
|-----------------------|---------------------|
| Records for 2022–2026 | Expenditure history |

| Data                                      | Function                     |
|-------------------------------------------|------------------------------|
| Damage inspection photographs             | Signs and locations          |
| Inventory and quantities                  | Asset quantities             |
| 2026 prices and local unit-price analysis | Cost estimates               |
| GKT RVS form                              | Scores and recommendations   |
| S0–S2 schedules                           | Cash flows for each strategy |

### Research instruments

- Visual evaluation and RVS: The instrument was adapted from the 2015 edition of FEMA P-154 [14]. It records building identification, survey date, structural type, storey count, soil and seismic information, irregularities, pounding potential, basic score, modifiers, and final score. The form and parameters must suit the site conditions. Indications involving load-bearing elements require expert inspection before retrofit measures are selected. The RVS checklist systematically records structural and nonstructural vulnerabilities.
- Cost records and budget documents: Institutional maintenance and repair expenditure reports provide the principal economic data for LCCA.

### Data collection

- Visual inspection: Site surveys and photographic documentation were used to assess building conditions, focusing on façades, ceilings, canopies, glass panels, doors, and windows.
- Financial data collection: Maintenance and repair budget data were obtained from institutional records and classified into preventive maintenance packages.

### Data analysis

- Seismic vulnerability assessment: RVS scores were analysed to identify risk levels and screen building performance under seismic loading.
- LCCA compares S0, S1 and S2 using constant-2026-price cash flows and a

real discount rate of 3.414634146%. The 6% nominal benchmark is converted using the Fisher relationship with an assumed annual inflation rate of 2.5%. Discounted total costs are reported as cost NPV and converted to equivalent annual cost (EAC) in constant-2026 rupiah. Price dates and missing-data assumptions are explicit below.

- Comparative analysis: Technical findings concerning safety and risk reduction are considered alongside economic results concerning cost efficiency to identify the preferred maintenance strategy.

### Maintenance scenario structure

The scenario structure follows Kandiyoh et al. [1], with scope and parameters drawn from GKT data. S0 represents corrective responses after functional failure, S1 scheduled preventive measures, and S2 additional minor nonstructural interventions. S2 does not represent strengthening of the primary lateral force-resisting system. P1–P6 cover nonstructural components and building services; structural assessment and any required rehabilitation must be separately scoped. All scenarios require equivalent minimum safety and service conditions, and no scenario justifies deferring investigation of observed structural defects.

Table 3 defines the scenarios and their principal cost drivers.

**Table 3. Scenario definitions and cost drivers**

| ID | Action                                    | Cost drivers                                                          |
|----|-------------------------------------------|-----------------------------------------------------------------------|
| S0 | Reactive                                  | Disruption frequency; corrective and emergency costs                  |
| S1 | Scheduled preventive                      | Inspection, servicing, and replacement intervals                      |
| S2 | Minor nonstructural retrofit + preventive | Additional initial works and corrective costs; benefits not monetised |

Works are grouped into P1: ceilings, façades, and aluminium composite panels (ACP); P2: doors, windows, glazing, and ventilation; P3: walls, plaster, finishes, and coatings; P4: electrical systems and lighting; P5: air

conditioning and mechanical systems, including lifts; and P6: sanitary fittings, plumbing, and the basement. These packages define the intervention scope; cost timing follows the cash-flow and schedule worksheets.

### Price basis and discount-rate interpretation

Consistent with life-cycle costing principles [15], [16], constant-price cash flows are discounted at a real rate. For a source cost  $C_y$  dated at the end of year  $y$ ,  $C_{2026} = C_y \times \prod (1 + \pi_k)$ , for  $k = y + 1$  through 2026. Published annual CPI inflation is 1.87%, 5.51%, 2.61%, 1.57% and 2.92% for 2021–2025 [18]. Full-year 2026 inflation is assumed to be 2.5%. The construction amount is assumed to have an end-2020 price date; expenditure uses its recorded year. Operating, preventive, replacement, inventory and S2 intervention/corrective estimates are assigned end-2026 prices where individual quotation dates are unavailable. CPI is a general-price proxy, not a construction-specific index. These assumptions establish one model price basis without claiming verified market revaluation.

The supplied BI series contains 20 monthly observations for January 2025–August 2026, using the last decision in each month, with mean 5.2375% [17]. The researcher rounds upward to the next whole percentage point:  $i = 6\%$ , adding 0.7625 percentage points. This is a chosen nominal comparison benchmark, not an exact mean, a BI appraisal requirement or a project financing rate. Assumed inflation  $\pi = 2.5\%$  uses the midpoint of the Government's 2025–2027 target [18]; extending it through 2046 is a research assumption, not an official forecast. Fisher gives  $r = (1.06/1.025) - 1 = 0.03414634146$ .  $NPV = \sum C_t / (1 + r)^t$ , with salvage negative;  $EAC = NPV \times r / [1 - (1 + r)^{-20}]$ . The A/P factor is 0.069818689. Future real costs have zero additional real escalation. Escalating these same flows by 2.5% and discounting at nominal 6% gives identical PVs.

### Verification and limits of inference

Verification independently sums the revised component cash flows, reconciles NPV and EAC, and checks equivalence between constant-price/real-rate and escalated-price/nominal-rate calculations. Unrounded rates and costs are used internally. The

companion response provides the price-conversion factors, assumptions and reconciliation. Arithmetic consistency does not validate failure frequencies, prices or intervention effectiveness.

## RESULTS AND DISCUSSION

### Building condition and RVS interpretation

The GKT RVS form records six above-ground storeys and one basement, 2014 as the construction year, and an inspection on 4 June 2025. Construction started in 2014 and completion in 2020 is used for building age. The form marks structural type C1 and soil class C. Its recorded score is  $1.0 - 0.4 + 1.4 = 2.0$ : basic score, plan-irregularity deduction and post-benchmark addition, respectively [14]. The post-benchmark classification and local code applicability require documentary verification. An unchanged reproduction of the supplied form is included in the companion supporting material with English annotations.

Table 4 presents the reconstructed RVS score and the evaluation entries recorded on the form.

**Table 4. Reconstruction of RVS results**

| Parameter                                  | Value |
|--------------------------------------------|-------|
| C1 basic score                             | 1.0   |
| Plan irregularity                          | -0.4  |
| Post-benchmark                             | +1.4  |
| Final score                                | 2.0   |
| Detailed structural evaluation on the form | No    |
| Level 2 screening                          | No    |

The score  $S = 2.0$  lies exactly at the commonly adopted FEMA P-154 cut-off [14], not above it. Although the Level 1 form labels the numerical trigger “score less than cut-off”, equality is not evidence of safety. Significant structural damage or deterioration is a separate evaluation trigger. This study therefore recommends detailed evaluation by a qualified structural engineer because the records describe column cracks, floor-1 steel-deck corrosion and basement-beam cracking/seepage. The original “No” evaluation entry is retained only as a historical record, not endorsed as the study recommendation. The C1 minimum score  $S_{\text{MIN}} = 0.3$  is a scoring lower bound, not the

cut-off. Mixed crack-width units in the source are not treated as verified measurements.

The original form marks “Other” exterior falling hazards, with ACP identified in its explanatory notes, yet marks no nonstructural hazards in its final entry. These entries require reconciliation. The recorded floor-area figure also conflicts with the approximately 10,500 m<sup>2</sup> adopted from [13]; this study treats that value as an assumed aggregate area, not a new measurement. These discrepancies remain subject to verification against the building records. P1–P6 address nonstructural components and services only. Structural investigation and any necessary strengthening require a separate scope and budget. The economic ranking is conditional on equivalent structural safety; it cannot justify deferral of the observed defects.

### Classification of maintenance needs

P1 – Ceilings, façades, and ACP: inspection of panels and connections, cleaning, removal of damaged sections, and local replacement. Measures to prevent falling components require design if anchorage weaknesses are confirmed.

P2 – Doors, windows, glazing, and ventilation: inspection of hinges, locks, frames, sealants, and glazing supports; repair or replacement of nonfunctional parts.

P3 – Walls, plaster, finishes, and coatings: plaster repairs, treatment of moisture sources, repainting, and protective coatings.

P4 – Electrical systems and lighting: inspection of installation points and replacement of lighting and closed-circuit television (CCTV) equipment according to the inventory.

P5 – Air conditioning and mechanical systems: servicing and repair of air conditioners and lifts to maintain function and service continuity.

P6 – Sanitary fittings, plumbing, and basement: maintenance of sanitary fixtures, treatment of leaks or seepage, and protection of basement components based on inspection findings.

These packages group technical needs; they are not six alternative strategies. Each scenario combines measures from the same packages with different cost timing. Installation prices, material prices, and service contract costs must be distinguished to avoid charging the same

measure as both routine maintenance and replacement.

### Institutional records and baseline reconstruction

Table 5 summarises institutional expenditure for 2022–2026.

**Table 5. Institutional expenditure records**

| Year  | Cost (IDR million) |
|-------|--------------------|
| 2022  | 670.61             |
| 2023  | 61.79              |
| 2024  | 176.02             |
| 2025  | 217.58             |
| 2026  | 225.91             |
| Total | 1,351.91           |

Historical expenditure for 2022–2026 totals IDR 1,351,909,648.86 at recorded prices. Applying the stated annual price factors gives IDR 1,438,133,231.62 at modelled end-2026 prices. Table 5 retains original nominal expenditure for traceability; the converted total is used in S0. The source records include repairs and refurbishment, and completeness of the 2026 record is unconfirmed. The total is an assumed first-year corrective backlog, not a measured annual failure cost or a validated damage forecast.

The workbook package summary also requires reconciliation before it can serve as a final total budget. Ceiling painting appears in both P1 and P3 subtotals, while preventive package P6 includes work from the minor-retrofit estimate. In the minor-retrofit summary, one plaster-work row and anticorrosion works have not been fully mapped. The following economic discussion uses the source schedules with the stated price and discount corrections and does not add the package summary again as an additional cost.

### Scenario development and cost schedules

Table 6 sets out the cost allocations that distinguish the three modelled scenarios.

**Table 6. Modelled differences between scenarios**

| Parameter                             | S0       | S1 | S2    |
|---------------------------------------|----------|----|-------|
| Year 1 corrective costs (IDR million) | 1,438.13 | 0  | 26.54 |

| Parameter                                      | S0       | S1  | S2     |
|------------------------------------------------|----------|-----|--------|
| Years 2–20 corrective costs (IDR million/year) | 0        | 0   | 26.54  |
| Year 1 replacement (IDR million)               | 8,616.83 | 0   | 0      |
| Preventive programme                           | No       | Yes | Yes    |
| Additional initial intervention (IDR million)  | 0        | 0   | 259.17 |

S0 includes replacement expenditure of IDR 8,616,828,152.09 in year 1 and no subsequent replacements. This is an aggregate input; the quantities, prices, and rationale for first-year allocation have not been traced to an itemised schedule. The model is therefore better interpreted as a scenario concentrating interventions at the beginning of the period than as a complete run-to-failure representation predicting failures over 20 years.

In S1 and S2, preventive programme costs are IDR 330,111,226 in year 1 and IDR 324,261,700 in routine years. Periodic increases correspond to scaffolding, sealant, painting, and roofing works. The active replacement intervals are 6 years for doors, 8 years for windows, 10 years for sanitary fixtures, 5 years for CCTV, 4 years for downlights, and 6 years for RM lamps. The highest replacement costs occur in years 8 and 16, each amounting to IDR 1,868,484,968.38. These intervals are simulation parameters requiring support from service-life and actual-condition data.

S2 adds a local initial intervention of IDR 259,168,418.29 and annual corrective costs of IDR 26,537,386.77. In contrast, the S1 corrective-cost column contains zero. This difference is not evidence that S1 eliminates damage, particularly because the workbook corrective-reduction parameter for S1 remains 0%. This asymmetric cost treatment must be considered when interpreting the ranking. Benefits from reduced risk, reduced downtime, or extended service life attributable to retrofit are not monetised in the cash flows.

### LCC components and terminal costs

The modelled end-2026 construction baseline of IDR 88,348,488,438.53 and annual

operation of IDR 725,498,740 are common to all scenarios. Construction is a restated historical accounting amount, not a future avoidable cash outlay. Table 9 therefore excludes this common baseline to clarify the maintenance decision. The full totals in Tables 7–8 describe the study's accounting boundary rather than payments incurred throughout the building's actual construction history.

Table 7 presents the discounted cost components for each scenario, including terminal costs and salvage.

**Table 7. Present-value cost components (IDR billion)**

| Component                 | S0      | S1      | S2      |
|---------------------------|---------|---------|---------|
| Initial + intervention    | 88.348  | 88.348  | 88.608  |
| Common operation          | 10.391  | 10.391  | 10.391  |
| Scheduled programme       | 0.000   | 4.661   | 4.661   |
| Corrective/minor retrofit | 1.391   | 0.000   | 0.380   |
| Replacement               | 8.332   | 5.028   | 5.028   |
| Demolition                | 4.514   | 4.514   | 4.514   |
| Salvage (deduction)       | -0.080  | -0.080  | -0.080  |
| Total                     | 112.896 | 112.863 | 113.503 |

Demolition at  $t = 20$  (2046) is a hypothetical managed-disposal boundary applied equally to all scenarios. The building would be 26 years past completion, not necessarily at the end of its physical life. Twenty years is chosen to compare maintenance over multiple component renewal cycles; it does not prove that demolition is necessary. Within this disposal experiment, the researcher assumes a gross demolition allowance of 10% of restated construction cost, or IDR 8,834,848,843.85, covering dismantling, handling and clearance. Recoverable material proceeds are assumed at 5% of the IDR 3,140,128,764.49 inventory basis, or IDR 157,006,438.22. This restricted salvage basis excludes land and remaining building service value. The percentages are transparent round-number budgeting allowances in the absence of contractor quotations and recovery inventories, not observed rates or requirements of FEMA, ISO or BI.

The net terminal PV is IDR 4.434 billion, common to S0–S2. Any common change in demolition or salvage adds the same amount to all NPVs and cannot change their absolute ranking. Setting both disposal flows to zero yields IDR 108.463, 108.430 and 109.069 billion; S1 saves 0.030% of S0. This is a terminal-cost boundary check, not a completed continued-use appraisal. Continued use would require residual service values for the building and replaced components; equal residual values would cancel, whereas scenario-specific values could change the ranking. No recommendation to demolish in 2046 is made.

#### Comparison of NPV and equivalent annual cost

Table 8 compares NPV and EAC over the 20-year horizon.

**Table 8. Economic results over 20 years**

| Scenario | NPV (IDR billion) | EAC (IDR billion/year) |
|----------|-------------------|------------------------|
| S0       | 112.896           | 7.882                  |
| S1       | 112.863           | 7.880                  |
| S2       | 113.503           | 7.925                  |

After price restatement and Fisher conversion, S1 has NPV IDR 112,863,382,156.86 and EAC IDR 7,879,973,412.35 per year. Its saving against S0 is IDR 33,002,404.50, or 0.029%. S2 costs IDR 606,256,030.33 more than S0 and IDR 639,258,434.84 more than S1. The revised order is S1–S0–S2. The previous mixed-price calculation, which applied 6% directly, produced a saving of IDR 1.808 billion (1.91%); that result is superseded and is not the corrected study finding.

Table 9 compares the scenarios after excluding the common initial construction cost.

**Table 9. Comparison excluding construction costs**

| Scenario | NPV (IDR billion) | EAC (IDR billion/year) |
|----------|-------------------|------------------------|
| S0       | 24.548            | 1.714                  |
| S1       | 24.515            | 1.712                  |
| S2       | 25.154            | 1.756                  |

Excluding the common construction baseline, S1 saves 0.134% relative to S0, whereas S2 costs 2.470% more. Absolute differences

remain unchanged. NPV and EAC have identical rankings because a common A/P factor is used; they are not independent evidence of effectiveness. The small S1 advantage corresponds to only IDR 2.30 million per year of additional constant-price costs. Unmodelled S1 costs above this equivalent annual amount would reverse its advantage over S0, holding other inputs fixed.

The S2–S1 difference of IDR 639,258,434.84 consists of the initial intervention of IDR 259,168,418.29 and additional corrective-cost PV of IDR 380,090,016.55. Benefits of S2 are not monetised, so its higher modelled cost does not demonstrate that the intervention lacks technical value. Comparing retrofit effectiveness requires equivalent service requirements and consistent treatment of remaining damage costs.

### Analytical limitations

The study is a conditional single-case simulation. Missing price dates are assumed; CPI is a general proxy, full-year 2026 inflation is assumed, and the 2.5% long-term inflation path is not a forecast. The 6% nominal benchmark is researcher-selected and no project-specific required return is estimated. Price and discount consistency has been corrected, but the inputs remain uncertain. Zero additional corrective costs in S1, concentrated first-year S0 replacements, and unverified component renewal intervals influence the narrow ranking. The 20-year disposal boundary and 10%/5% terminal allowances lack site-specific validation. Remaining service values under continued use are outside this disposal model.

Benefits from risk reduction, reduced service downtime, extended service life, and environmental impacts have not been quantified in the cash flows. RVS provides initial screening and does not replace detailed structural capacity evaluation. The NPV and EAC comparisons therefore establish cost rankings within the specified model. Application requires equivalent service levels and verification of the technical needs of each scenario.

### CONCLUSION

The recorded RVS score of 2.0 lies at the default FEMA P-154 cut-off and must be considered alongside the documented column

cracks, steel-deck corrosion and beam seepage. Structural verification is necessary before implementing a maintenance preference. The six packages cover nonstructural and building-services needs; their costing does not establish the adequacy of structural rehabilitation.

Using modelled constant-2026 prices and the Fisher-consistent real discount rate of 3.414634%, S1 has NPV IDR 112,863,382,156.86 and EAC IDR 7,879,973,412.35. S1 saves IDR 33,002,404.50 (approximately IDR 33.00 million or 0.029%) against S0 and costs IDR 639,258,434.84 less than S2. The revised ranking is S1–S0–S2.

S1's cost advantage is marginal and conditional on the assumed first-year S0 corrective and replacement allocation, zero additional S1 corrective costs, the stated price and inflation assumptions, and equal terminal treatment. Common construction and terminal costs cancel from absolute differences but affect percentage savings. S1 is the lowest-cost configuration under these conditions; implementation requires equivalent service performance and structural engineering verification.

### NOTATION

N = number of units; V = quantity;  $i$  = nominal discount rate;  $\pi$  = inflation rate;  $r$  = real discount rate;  $t$  = year index;  $C_0$  = initial cost; O = operation; P = preventive maintenance; K = corrective maintenance; G = replacement; D = demolition; R = material salvage; LCC = life cycle cost; PV = present value; NPV = net present value of costs; EAC = equivalent annual cost; RVS = Rapid Visual Screening.

### BIBLIOGRAPHY

- [1] G. E. Kandiyoh, S. L. Sengkey, R. Tampi, and N. Mantiri, "Optimizing building maintenance strategies using visual evaluation and life cycle cost analysis," *Jurnal Multidisiplin Madani*, vol. 5, no. 11, pp. 1209–1216, 2025, doi: 10.55927/mudima.v5i11.687.

- [2] Y. Haryanto, H.-T. Hu, A. L. Han, B. A. Hidayat, A. Widyaningrum, and P. E. Yulianita, "Seismic vulnerability assessment using rapid visual screening: Case study of educational facility buildings of Jenderal Soedirman University, Indonesia," *Civil Engineering Dimension*, vol. 22, no. 1, pp. 13–21, 2020, doi: 10.9744/ced.22.1.13-21.
- [3] A. R. D. Pratama, J. W. Soetjipto, and Krisnamurti, "Evaluation of building vulnerability to earthquake using rapid visual screening (RVS) method," *Jurnal Teknik Sipil dan Perencanaan*, vol. 23, no. 2, pp. 114–124, 2021, doi: 10.15294/jtsp.v23i2.31399.
- [4] N. M. N. Kusumayani and I. N. S. Angga, "Preliminary neighborhood-scale seismic vulnerability profile of residential buildings in a selected urban settlement in Singaraja Bali using FEMA P-154 rapid visual screening," *Jurnal Teknik Sipil Cendekia*, vol. 7, no. 3, pp. 567–580, 2026, doi: 10.51988/jtsc.v7i3.582.
- [5] S. F. Krisnanda, "Implementasi life cycle cost pada gedung Bank Mandiri Syariah Yogyakarta," *FROPIL (Forum Profesional Teknik Sipil)*, vol. 8, no. 1, pp. 46–55, 2020, doi: 10.33019/fropil.v8i1.1780.
- [6] D. A. Rizky, "Analisis life cycle cost pada gedung kantor unit perbankan (studi kasus: Gedung kantor unit perbankan di Kabupaten Batubara)," *INTEKNA: Jurnal Informasi Teknik dan Niaga*, vol. 25, no. 1, pp. 48–58, 2025. [Online]. Available: <https://ejurnal.poliban.ac.id/index.php/intekna/article/view/14940>
- [7] R. P. Utari and A. Samad, "Analisis pengendalian biaya konstruksi gedung asrama dengan metode life cycle cost," *Jurnal Ilmiah Universitas Batanghari Jambi*, vol. 21, no. 1, pp. 387–391, 2021, doi: 10.33087/jiubj.v21i1.1335.
- [8] H. Cahyadi, Abdurrahman, and S. P. Atmojo, "Analisis biaya siklus hidup Gedung Komite Olahraga Nasional Indonesia (KONI) Kabupaten Tapin," *PADURAKSA*, vol. 11, no. 1, pp. 24–32, 2022, doi: 10.22225/pd.11.1.3974.24-32.
- [9] I. K. Doda, A. Utiahrman, and A. U. Sumaga, "Analisis life cycle cost pada gedung Rumah Susun Sederhana Sewa (Rusunawa) Telaga, Gorontalo," *Composite Journal*, vol. 5, no. 1, pp. 10–19, 2025, doi: 10.37905/cj.v5i1.139.
- [10] S. Wahyudiono and F. R. Andardi, "Analisis life cycle cost (LCC) pada pembangunan gedung asrama putri di Malang," *Jurnal Konstruksi*, vol. 24, no. 1, pp. 1–11, 2026, doi: 10.33364/konstruksi/v.24-1.2991.
- [11] I. N. Puhessti, "Life cycle cost pada gedung boarding house daerah Glagahsari, Yogyakarta," *FROPIL (Forum Profesional Teknik Sipil)*, vol. 9, no. 1, pp. 18–28, 2021, doi: 10.33019/fropil.v9i1.2297.
- [12] R. Weber, P. Cummins, and M. Edwards, "Fragility of Indonesian houses: Scenario damage analysis of the 2006 Yogyakarta and 2009 Padang earthquakes," *Bull. Earthq. Eng.*, vol. 22, no. 9, pp. 4705–4743, 2024, doi: 10.1007/s10518-024-01930-z.
- [13] C. T. Tompodung, "Perhitungan life cycle cost pada Gedung Kuliah Terpadu Politeknik Negeri Manado," undergraduate thesis, Dept. Civil Eng., Politeknik Negeri Manado, Manado, Indonesia, 2025.
- [14] Federal Emergency Management Agency, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, 3rd ed., FEMA P-154. Washington, DC, USA: FEMA, 2015.
- [15] *Buildings and Constructed Assets—Service Life Planning—Part 5: Life-Cycle Costing*, ISO 15686-5:2017, International Organization for Standardization, Geneva, Switzerland, 2017.
- [16] J. Kneifel and D. Webb, *Life Cycle Costing Manual for the Federal Energy Management Program*, NIST Handbook 135, 2025 ed. Gaithersburg, MD, USA: National Institute of Standards and Technology, 2025, doi: 10.6028/NIST.HB.135e2025.
- [17] Bank Indonesia, "BI-Rate." Accessed: Oct. 14, 2026. [Online]. Available: <https://www.bi.go.id/id/statistik/indikator/bi-rate.aspx>

- [18] Bank Indonesia, “Inflation target.” Accessed: Oct. 14, 2026.  
[Online]. Available:  
<https://www.bi.go.id/en/statistik/indikator/target-inflasi.aspx>