



## **Key Success Factors Affecting the Cost Performance of Value Engineering-Based Green Retrofitting on Rivers Using Envision Guidelines**

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**Abstract**

**Background:** Rivers in Indonesia face serious challenges related to water quality and river management due to weak infrastructure governance, highlighting the need for cost-effective river restoration.

**Objective:** This study aims to analyze the key success factors influencing the cost performance of Value Engineering (VE)-based green river retrofits guided by Envision v3.

**Method:** The study employed a quantitative survey method involving 68 respondents, including project managers, field engineers, supervisors, consultants, and Watershed Authority personnel. Data were analyzed using multiple linear regression in IBM SPSS Statistics Version 25. Three independent variables (river characteristics (X1), Envision guidelines (X2), and Value Engineering practices (X3)) were examined for their effects on cost performance (Y). All constructs demonstrated strong reliability and validity.

**Results:** The results confirmed that X1, X2, and X3 significantly and jointly influenced cost performance ( $F= 9.422$ ;  $p < .001$ ), yielding the regression equation:  $Y= 4.398 + 0.046(X1) + 0.045(X2) + 0.135(X3)$ . Value Engineering exerted the strongest influence, as indicated by the highest regression coefficient (0.135). The ten most influential success factors identified through the mean rank analysis were predominantly associated with the Value Engineering dimension, particularly cost savings identification, functional clarity, structured planning, and top management commitment.

**Conclusion:** The results demonstrate that disciplined Value Engineering practices can significantly improve the cost performance of green river retrofit projects.

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### **INTRODUCTION**

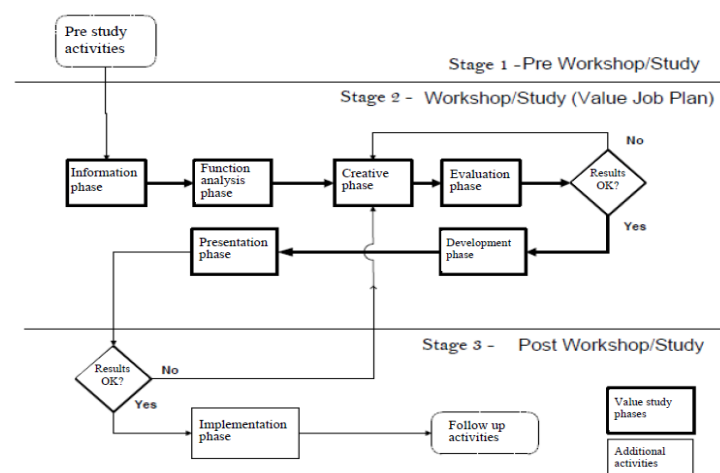
According to data from *Badan Pusat Statistik Lingkungan Hidup Indonesia*, total suspended solids (TSS) levels in several major rivers in Indonesia range between 50 and 400 mg/L, well above the threshold established by Government Regulation No. 82/2001 (Statistik, 2024). A simulation experiment was conducted using a case study of the Ciliwung River in DKI Jakarta Province, applying a population growth scenario with planned additions to wastewater management infrastructure by 2030 and comparing these conditions with the projected impacts of climate change. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), and nitrate (NO<sub>3</sub>) concentrations were simulated to evaluate river pollution. The simulation results indicated that water quality in 2030 would deteriorate compared with the baseline year of 2000

due to population growth and climate change, even after accounting for the planned wastewater management infrastructure. Furthermore, the impact of population growth was substantially greater than that of climate change. The simulated concentrations of  $\text{NO}_3$ , BOD, and COD ranged from 6.07 to 13.34 mg/L, 7.65 to 11.41 mg/L, and 20.16 to 51.01 mg/L, respectively (Halik et al., 2026; Kumar et al., 2017). Therefore, ensuring the availability of safe, high-quality water and sustainable water management for all by 2030 remains a priority under the United Nations Sustainable Development Goals (SDGs), with the development of green infrastructure recognized as a key pathway toward achieving this objective (Bai et al., 2026; Yuan et al., 2020).

Between 2015 and 2022, 85 countries actively participated in river ecosystem restoration initiatives under the United Nations Water Convention (Fenten & Dieperink, 2024), reflecting a global consensus that environmental interventions are essential to mitigate further ecosystem degradation (Skinner et al., 2023). Sustainability assessment has been defined as the process of identifying, predicting, and evaluating the potential impacts of development initiatives across three key dimensions: economic, environmental, and social sustainability (Devuyst, 2000; Li et al., 2025). Among the assessment frameworks capable of evaluating civil infrastructure projects of various types and scales, Envision is recognized as one of the three most prominent systems (Diaz-Sarachaga et al., 2016; Sharma et al., 2025). Developed by the Institute for Sustainable Infrastructure (ISI), Envision comprises 64 credits totaling 1,000 points across five categories and awards Bronze, Silver, Gold, or Platinum certification at thresholds of 20%, 30%, 40%, and 50% of the total score, respectively (Infrastructure, 2018; Rahat et al., 2023).

Modeling and empirical studies have demonstrated that integrating urban green infrastructure can reduce downstream flood risk while generating social benefits, including expanded recreational spaces, improved mental health, and increased property values (Basak et al., 2021; Sousa et al., 2025). However, water management policies continue to be evaluated primarily based on financial costs because these are relatively straightforward to quantify (Brouwer et al., 2015; Marín et al., 2025). A meta-analysis of river restoration projects in Europe reported an average restoration cost of €310,000 per hectare, with project budgets remaining generally stable between 1989 and 2016 (Stoffers et al., 2024; Szałkiewicz et al., 2018). These findings underscore the need for cost optimization approaches that maintain ecological and social performance while improving economic efficiency. Cost control remains one of the most critical aspects of project implementation, and ineffective cost management can result in substantial financial consequences (Ximenes, 2025).

Value Engineering (VE) is widely recognized as one of the most effective approaches for complex sustainability-oriented projects because it not only seeks cost savings but also strives to achieve an optimal balance among function, quality, performance, and cost through a systematic, multidisciplinary methodology (Al-Ghamdi & Al-Gahtani, 2022; Imron & Husin, 2021). The Value Engineering methodology follows a structured process known as the Job Plan (International, 2007; Sulvinajayanti et al., 2025), which is implemented by a multidisciplinary team to improve project value through functional analysis. The VE Job Plan consists of a series of sequential phases (Figure 1).



**Figure 1.** Value Engineering Job Plan

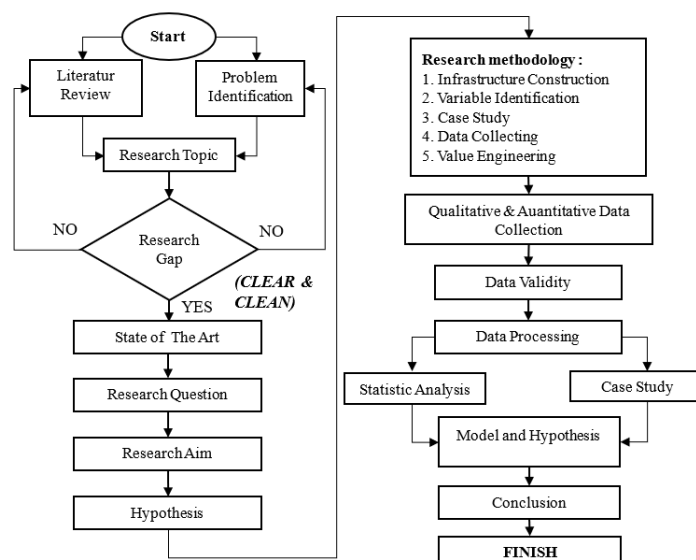
This study integrates the Value Engineering and Envision frameworks, an approach that remains uncommon in practical green river improvement projects, particularly in the Indonesian context, where river normalization projects are still largely planned without formal sustainability rating systems or systematic cost engineering. The cost performance improvement method employed in this study, Value Engineering, focuses on enhancing the function and value of green river retrofit projects while maintaining cost-effectiveness. Previous research integrating the Building Information Modeling (BIM), Blockchain, and Envision frameworks for green river projects reported cost savings of 3.69% at the Improved level, 3.72% at the Enhanced level, 4.39% at the Superior level, 4.92% at the Conserving level, and 5.17% at the Restorative level (Arif & Husin, 2024). However, that study primarily emphasized cost savings through volume optimization rather than improving project function and value.

The specific objective of this study is to identify the key factors that most strongly influence improvements in the cost performance of Value Engineering-based green river retrofit projects. The findings are expected to assist project owners, consultants, and river basin authorities in identifying design and material alternatives that reduce life-cycle costs through Value Engineering while supporting the credibility and application of third-party sustainability rating systems. In addition, this research is expected to strengthen public trust and encourage stakeholder participation in decision-making through the Envision framework, which is particularly important for river projects that directly affect local residents and surrounding communities.

## METHOD

This research employed a quantitative survey method. Quantitative research involves the collection and analysis of numerical data to examine relationships among variables, test hypotheses, and draw objective conclusions. In contrast, qualitative research aims to develop an in-depth understanding of phenomena, generate theories, and describe reality (Elhegazy, 2020; Hamed et al., 2026).

Data collection for this study was conducted from November 2025 to April 2026 and consisted of three sequential stages. The first stage involved expert validation, during which a questionnaire was distributed to five experts with a minimum of 20 years of professional experience and at least a bachelor's degree (Sarjana [S1]). The purpose of this stage was to establish the content validity of the proposed research variables and their associated indicators. The second stage comprised a pilot survey, in which the same questionnaire was administered to three individuals directly involved in the project to evaluate the clarity, relevance, and comprehensibility of each indicator before full-scale implementation. In the third stage, the finalized questionnaire was distributed to 67 respondents who were actively involved in the Green River Construction Project Control activities. The collected data were analyzed using IBM SPSS Statistics Version 25.



**Figure 2.** Research flow diagram

The minimum required sample size was determined using the Cochran-type formulation with the following formula (1, 2, 3):

$$Z \left( \frac{\varepsilon}{2} \right) = \frac{1 - \varepsilon}{2} = \frac{1 - 0.05}{2} = 0.475 \quad (1)$$

$$m = \frac{Z^2 \times P \times (1 - P)}{\varepsilon^2} = \frac{0.96}{0.0025} = 384.16 \quad (2)$$

$$n = \frac{m}{1 + (m - \frac{1}{N})} = \frac{384.16}{5.79} = 66.35 \approx 67 \quad (3)$$

Z = The values are taken from the Z distribution table (1.96)

P = Degree of variation between population elements (0.5)

$\varepsilon$  = Limited population sample value (0.05)

N = Number of sub-factor variables (80)

n = Minimum number of respondents required

The questionnaire was distributed online via Google Forms over approximately 45 days (March–April 2026) to an initial target of 75 respondents, including project managers, site managers, site engineers, supervisors, consultants directly or indirectly involved in the case-study project, and relevant personnel from the Balai Besar Wilayah Sungai (River Basin Authority). A six-point Likert scale (1 = strongly disagree to 6 = strongly agree) was used to measure respondents' levels of agreement for each indicator (Joshi et al., 2015; Rokeman, 2024; Taherdoost, 2017). The data were classified into primary and secondary data. Primary data were collected directly from respondents through a structured questionnaire (Likert-scale survey), semi-structured in-depth interviews, direct field observations, and supporting site documentation. The questionnaire items for each variable were developed based on national and international journal articles, government regulations, and sector-specific guidelines relevant to the research topic. Secondary data consisted of the project layout, bill of quantities, and construction drawings for the case-study river corridor (Joshi et al., 2015; Rokeman, 2024; Taherdoost, 2017).

The minimum required sample size was determined using an appropriate sample size calculation method. Three independent variables and one dependent variable were specified. X1 (river characteristics) comprised 26 indicators grouped into natural, social/regulatory, and technical factors. X2 (Envision guideline) comprised 30 indicators derived from the five Envision v3 categories: Resource Allocation, Natural World, Leadership, Climate and Resilience, and Quality of Life. X3 (Value Engineering) comprised 17 indicators representing the information, function, creative, evaluation, and study phases of the Value Engineering (VE) Job Plan. The dependent variable, cost performance (Y), comprised six indicators categorized into internal cost components (materials, labor, equipment, and indirect costs) and external cost components (material price fluctuations and cost escalation resulting from environmental constraints).

Questionnaire responses were tabulated using Microsoft Excel and analyzed with IBM SPSS Statistics Version 25. Internal consistency was evaluated using Cronbach's alpha (acceptable threshold > 0.60), while item validity was assessed by comparing the Pearson corrected item-total correlation (r-calculated) with the critical r-table value at  $\alpha = 0.05$ . Classical assumption testing included the one-sample Kolmogorov–Smirnov test to assess the normality of residuals (significance > 0.05 indicating normal distribution), the Durbin–Watson statistic to detect autocorrelation, and tolerance/variance inflation factor (VIF) diagnostics to evaluate multicollinearity (no multicollinearity indicated by tolerance > 0.10 and VIF < 10). The hypothesized relationships were analyzed using multiple linear regression, as expressed in Equation (4).

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \quad (4)$$

Where Y is cost performance; a is the regression constant; b1, b2 and b3 are the regression coefficients of X1 (river characteristics), X2 (Envision guideline) and X3 (Value Engineering practice), respectively. Model significance was tested with the F-test (simultaneous influence, decision rule:  $F\text{-count} > F\text{-table}$  and significance  $< 0.05$ ) and the partial influence of each predictor was tested with the t-test (decision rule:  $t\text{-calculated} > t\text{-table}$  and significance  $< 0.05$ ). Following the quantitative analysis, indicator mean scores were ranked to identify the ten most influential success factors, which were then validated with the same expert panel consulted in the earlier qualitative stage.

## RESULTS AND DISCUSSION

### Respondent Profile

Of the 75 questionnaires distributed, 68 were returned (a 90.6% response rate), exceeding the minimum required sample of 67. Table 1 summarizes the demographic and professional profile of the 68 respondents.

**Table 1**

*Respondent profile (n = 68)*

| Category        | Group           | N (%)     |
|-----------------|-----------------|-----------|
| Gender          | Female          | 57 (84%)  |
|                 | Male            | 11 (16%)  |
| Age             | 25-30 years     | 8 (12%)   |
|                 | 31-35 years     | 19 (28 %) |
|                 | 36-40 years     | 34 (50%)  |
|                 | > 40 years      | 7 (10%)   |
|                 |                 |           |
| Position        | Director        | 2 (3%)    |
|                 | Project manager | 8 (12%)   |
|                 | Site manager    | 14 (21%)  |
|                 | Site engineer   | 17 (25%)  |
|                 | Supervisor      | 23 (34%)  |
|                 | Consultant      | 4 (6%)    |
| Work experience | 1-2 years       | 3 (4%)    |
|                 | > 5 years       | 9 (13%)   |
|                 | > 10 years      | 21 (31%)  |
|                 | > 15 years      | 27 (40%)  |
|                 | > 20 years      | 8 (12%)   |

### Reliability and Validity

Internal consistency was excellent for all four constructs, with every item-corrected Cronbach's alpha exceeding the 0.60 threshold (X1: 0.975–0.976; X2: 0.973–0.975; X3: 0.957–0.960; Y: 0.782–0.830), confirming that the questionnaire was reliable. Item validity was likewise confirmed for all indicators: every Pearson corrected item-total correlation exceeded the critical  $r\text{-table} = 0.235$  ( $\alpha = 0.05$ ,  $df = 68 - 2 = 66$ ), with significance (2-tailed) = 0.000 for every item, well below the 0.05 threshold.

**Table 2**

*Value of Cronbach's alpha X1 (Green retrofitting river)*

| Sub factor | Scale mean if item delete | Cronbach's $\alpha$ range | Result   |
|------------|---------------------------|---------------------------|----------|
| X1.1.1     | 94.87                     | 0.975                     | Reliable |
| X1.1.2     | 94.76                     | 0.975                     | Reliable |
| X1.1.3     | 94.94                     | 0.975                     | Reliable |
| X1.1.4     | 95.03                     | 0.975                     | Reliable |
| X1.1.5     | 94.76                     | 0.975                     | Reliable |
| X1.1.6     | 94.90                     | 0.976                     | Reliable |
| X1.2.1     | 94.88                     | 0.976                     | Reliable |
| X1.2.2     | 94.82                     | 0.975                     | Reliable |
| X1.2.3     | 94.66                     | 0.975                     | Reliable |

| Sub factor | Scale mean if item delete | Cronbach's $\alpha$ range | Result   |
|------------|---------------------------|---------------------------|----------|
| X1.2.4     | 94.87                     | 0.975                     | Reliable |
| X1.2.5     | 94.75                     | 0.975                     | Reliable |
| X1.2.6     | 94.84                     | 0.975                     | Reliable |
| X1.2.7     | 94.78                     | 0.975                     | Reliable |
| X1.2.8     | 94.85                     | 0.976                     | Reliable |
| X1.2.9     | 94.87                     | 0.975                     | Reliable |
| X1.2.10    | 94.85                     | 0.975                     | Reliable |
| X1.2.11    | 94.69                     | 0.975                     | Reliable |
| X1.2.12    | 94.76                     | 0.975                     | Reliable |
| X1.3.1     | 94.87                     | 0.975                     | Reliable |
| X1.3.2     | 94.75                     | 0.975                     | Reliable |
| X1.3.3     | 94.78                     | 0.975                     | Reliable |
| X1.3.4     | 94.85                     | 0.975                     | Reliable |
| X1.3.5     | 94.81                     | 0.975                     | Reliable |
| X1.3.6     | 94.78                     | 0.975                     | Reliable |
| X1.3.7     | 94.87                     | 0.976                     | Reliable |
| X1.3.8     | 94.84                     | 0.975                     | Reliable |

**Table 3***Value of Cronbach's alpha X2 (Envision)*

| Sub factor | Scale mean if item delete | Cronbach's $\alpha$ range | Result   |
|------------|---------------------------|---------------------------|----------|
| X2.1.1     | 122.37                    | 0.974                     | Reliable |
| X2.1.2     | 122.29                    | 0.974                     | Reliable |
| X2.1.3     | 122.31                    | 0.974                     | Reliable |
| X2.1.4     | 122.29                    | 0.974                     | Reliable |
| X2.2.1     | 122.38                    | 0.973                     | Reliable |
| X2.2.2     | 122.31                    | 0.974                     | Reliable |
| X2.2.3     | 122.28                    | 0.974                     | Reliable |
| X2.2.4     | 122.26                    | 0.974                     | Reliable |
| X2.2.5     | 122.28                    | 0.974                     | Reliable |
| X2.2.6     | 122.44                    | 0.974                     | Reliable |
| X2.2.7     | 122.37                    | 0.974                     | Reliable |
| X2.2.8     | 122.50                    | 0.974                     | Reliable |
| X2.2.9     | 122.37                    | 0.974                     | Reliable |
| X2.3.1     | 122.38                    | 0.973                     | Reliable |
| X2.3.2     | 122.38                    | 0.974                     | Reliable |
| X2.3.3     | 122.41                    | 0.974                     | Reliable |
| X2.3.4     | 122.29                    | 0.974                     | Reliable |
| X2.3.5     | 122.24                    | 0.974                     | Reliable |
| X2.3.6     | 122.37                    | 0.974                     | Reliable |
| X2.3.7     | 122.43                    | 0.974                     | Reliable |
| X2.4.1     | 122.26                    | 0.974                     | Reliable |
| X2.4.2     | 122.29                    | 0.974                     | Reliable |
| X2.4.3     | 122.24                    | 0.974                     | Reliable |
| X2.4.4     | 122.51                    | 0.975                     | Reliable |
| X2.4.5     | 122.54                    | 0.974                     | Reliable |
| X2.4.6     | 122.47                    | 0.973                     | Reliable |
| X2.5.1     | 122.25                    | 0.974                     | Reliable |
| X2.5.2     | 122.46                    | 0.974                     | Reliable |
| X2.5.3     | 122.41                    | 0.973                     | Reliable |
| X2.5.4     | 122.41                    | 0.974                     | Reliable |
| X2.5.5     | 122.43                    | 0.974                     | Reliable |

**Table 4***Value of Cronbach's alpha X3 (Value Engineering)*

| Sub factor | Scale mean if item delete | Cronbach's $\alpha$ range | Result   |
|------------|---------------------------|---------------------------|----------|
| X3.1.1     | 70.19                     | 0.959                     | Reliable |
| X3.1.2     | 70.10                     | 0.958                     | Reliable |
| X3.1.3     | 70.16                     | 0.959                     | Reliable |
| X3.1.4     | 70.12                     | 0.958                     | Reliable |
| X3.1.5     | 70.07                     | 0.960                     | Reliable |
| X3.1.6     | 70.19                     | 0.958                     | Reliable |
| X3.2.1     | 70.10                     | 0.958                     | Reliable |
| X3.2.2     | 70.22                     | 0.958                     | Reliable |
| X3.2.3     | 70.12                     | 0.958                     | Reliable |
| X3.2.4     | 70.03                     | 0.959                     | Reliable |
| X3.3.1     | 70.03                     | 0.958                     | Reliable |
| X3.3.2     | 70.09                     | 0.959                     | Reliable |
| X3.4.1     | 70.09                     | 0.957                     | Reliable |
| X3.4.2     | 70.06                     | 0.958                     | Reliable |
| X3.5.1     | 70.06                     | 0.958                     | Reliable |
| X3.5.2     | 70.21                     | 0.959                     | Reliable |
| X3.5.3     | 70.16                     | 0.957                     | Reliable |

**Table 5***Value of Cronbach's alpha Y1 (Cost performance)*

| Sub factor | Scale mean if item delete | Cronbach's $\alpha$ range | Result   |
|------------|---------------------------|---------------------------|----------|
| Y1.1.1     | 20.49                     | 0.824                     | Reliable |
| Y1.1.2     | 20.40                     | 0.782                     | Reliable |
| Y1.1.3     | 20.57                     | 0.814                     | Reliable |
| Y1.1.4     | 20.46                     | 0.791                     | Reliable |
| Y1.2.1     | 20.51                     | 0.830                     | Reliable |
| Y1.2.2     | 20.59                     | 0.792                     | Reliable |

**Classical Assumption Test**

Residual normality was confirmed by the one-sample Kolmogorov-Smirnov test, which returned a significance of 0.200 for X1, X2 and X3 (all > 0.05), indicating normally distributed residuals. The Durbin-Watson statistic was 2.257, which falls between the upper critical bound ( $d_U = 1.700$ ) and  $4 - d_U = 2.300$ , indicating no autocorrelation. Multicollinearity diagnostics likewise showed no violation: tolerance values for X1, X2 and X3 were 0.995, 0.920 and 0.921 respectively (all > 0.10), with corresponding VIF values of 1.005, 1.087 and 1.086 (all < 10), confirming the regression model satisfied all classical assumptions required for unbiased coefficient estimation.

**Multiple Linear Regression**

Table 6 presents the partial (t-test) results for each predictor. All three independent variables showed a statistically significant positive influence on cost performance.

**Table 6***Partial regression coefficients (t-test) for cost performance (Y)*

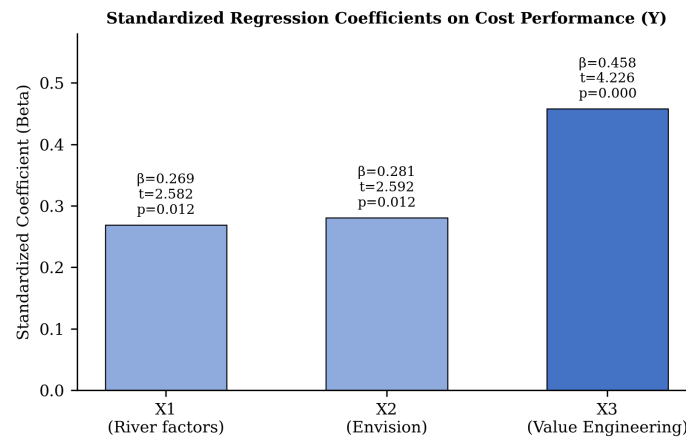
| Predictor             | B     | Std. Error | B     | t     | Sig.  |
|-----------------------|-------|------------|-------|-------|-------|
| (Constant)            | 4.398 | 3.953      | -     | 1.113 | 0.270 |
| X1-River              | 0.046 | 0.018      | 0.269 | 2.582 | 0.012 |
| X2-Envision Guideline | 0.045 | 0.017      | 0.281 | 2.592 | 0.012 |
| X3-Value Engineering  | 0.135 | 0.032      | 0.458 | 4.226 | 0.000 |

Critical t-table value ( $\alpha/2 = 0.025$ ,  $df = 64$ ) = 1.998; all t-calculated values exceed the critical value.

The resulting regression equation is given in Equation (5):

$$Y = 4.398 + 0.046(X1) + 0.045(X2) + 0.135(X3) \quad (5)$$

Figure 3 visualizes the standardized coefficients (Beta), showing that Value Engineering practice (X3) had the strongest standardized effect on cost performance, followed by the Envision guideline (X2) and river characteristics (X1).



**Figure 3.** Standardized regression coefficients ( $\beta$ ) of the three predictors on cost performance, with t-statistics and significance levels.

The simultaneous influence of the three predictors was tested with the F-test, summarized in Table 7. The model was significant, with F-calculated (9.422) exceeding the critical F-table value of 2.746 at significance = 0.000, confirming that river characteristics, the Envision guideline and Value Engineering practice jointly explain a significant share of the variation in cost performance.

**Table 7**

*Analysis of variance (F-test) for the regression model.*

| Source     | Sum of Square | df | Mean Square | F (Sig.)         |
|------------|---------------|----|-------------|------------------|
| Regression | 269.285       | 3  | 89.895      | 9.422<br>(0.000) |
| Residual   | 610.595       | 64 | 9.540       |                  |
| Total      | 880.279       | 67 |             |                  |

### Most Influential Success Factors

Ranking the mean score of all 80 sub-factor indicators identified the ten most influential success factors for cost-performance improvement in green river retrofitting, listed in Table 8. Notably, all ten top-ranked factors belong to the Value Engineering construct (X3), consistent with X3's dominant standardized regression coefficient.

**Table 8**

*The ten most influential success factors (ranked by mean Likert score)*

| Rank | Indicator | Description                                    | Mean |
|------|-----------|------------------------------------------------|------|
| 1    | X3.5.1    | Potential cost savings                         | 4.47 |
| 2    | X3.4.1    | Creative warm-up exercises                     | 4.45 |
| 3    | X3.3.1    | Primary function                               | 4.40 |
| 4    | X3.3.2    | Secondary function                             | 4.40 |
| 5    | X3.2.1    | Mature, structured planning                    | 4.38 |
| 6    | X3.1.5    | Multidisciplinary VE team                      | 4.36 |
| 7    | X3.2.4    | Imprecise project specification interpretation | 4.36 |
| 8    | X3.4.2    | Idea-simulation techniques                     | 4.36 |
| 9    | X3.1.4    | Top-management support                         | 4.34 |
| 10   | X3.1.6    | Commitment from involved parties               | 4.32 |

## Discussion

The regression results confirm that Value Engineering (VE) (X3) exerts the strongest influence on cost performance among the three predictors and that all ten of the most influential success factors originate from the VE dimension, particularly potential cost savings, structured functional analysis, and multidisciplinary team involvement. This pattern is consistent with recent international reviews of VE practice. After examining publication trends spanning five decades, Chen et al. (2022) report that current VE research increasingly emphasizes integration with other disciplines and application across diverse project domains, a trajectory that the present study extends by coupling VE with an internationally recognized sustainability rating framework in a river-infrastructure context. At the same time, in a systematic review of 104 value management studies published between 2001 and 2021, Lin et al. (2023) found that research addressing the implementation status of VE in infrastructure projects is conspicuously absent from the literature. The present study directly addresses this gap by empirically demonstrating VE's dominant role in improving cost performance for a green river retrofit project, thereby contributing new evidence to an under-researched area of the international VE literature.

The dominance of VE over both the site-specific river-condition variable (X1) and the Envision guideline variable (X2) also carries important implications for international sustainability rating practice. Although Envision has become a globally recognized infrastructure sustainability framework, with more than 5,000 registered assessors worldwide by 2023 (Yu & Pan, 2023), comparative reviews of the leading infrastructure sustainability rating systems (Envision, CEEQUAL, and the Infrastructure Sustainability (IS) rating scheme) consistently indicate that their effectiveness in developing-country contexts remains underexamined relative to their well-established application in advanced economies (Diaz-Sarachaga et al., 2016; Sharma et al., 2025). By demonstrating that a disciplined VE process, rather than sustainability rating framework compliance alone, contributes the greatest improvement in cost performance, the present findings suggest that practitioners in developing countries adopting Envision or comparable frameworks should regard certification not as a substitute for systematic value improvement, but as a complementary framework within which VE can be effectively implemented.

This observation also resonates with findings from other developing-country contexts. Aghimien, Oke, and Aigbavboa (2018), examining barriers to value management adoption across African construction industries, reported that limited institutional awareness and weak client demand, rather than technical unfamiliarity, remain the principal constraints on broader VE implementation (Ikram & Es-sadki, 2026). This pattern is broadly consistent with the still-emerging body of Indonesian VE research, including recent local applications to green hospital cost optimization (Imron & Husin, 2021; Riyanto et al., 2026) and HVAC system selection (Al-Ghamdi & Al-Gahtani, 2022). Taken together, these parallels indicate that the success factors identified in the Bekasi River case particularly top-management commitment and adherence to the structured VE Job Plan stages are not merely local phenomena but reflect a broader pattern of VE maturity observed across both developed and developing economies, thereby reinforcing the cross-cultural transferability of the present findings.

The relevance of this study also extends to the global discourse on green river infrastructure. Although urban river restoration and green retrofitting have become mainstream practices in the Global North, comparable initiatives in the Global South, including Latin America and Southeast Asia, remain relatively scarce and underdocumented, with planning and implementation lagging conceptual adoption (Pradilla & Hack, 2024). The Bekasi River case provides empirical evidence from a Southeast Asian context, where formal sustainability rating systems and systematic cost engineering remain uncommon in river normalization projects, thereby helping to address the same evidentiary gap identified for Latin American cities. In this respect, the present findings not only inform river management practice in Indonesia but also offer a transferable VE–Envision integration model for river basin authorities in other developing regions seeking to combine cost discipline with internationally recognized sustainability standards.

Several limitations should be acknowledged. First, the study relies on a single case study, the Bekasi River at Babelan, which, although providing rich contextual depth, limits the statistical

generalizability of the regression model to other river typologies, climatic zones, and institutional settings. Replication across multiple river basins would strengthen the external validity of the findings. Second, the cross-sectional survey design captures respondents' perceptions at a single point in time and cannot establish the directionality or long-term stability of the observed relationships. A longitudinal research design following a project throughout its entire life cycle would provide a more robust understanding of how VE-driven cost savings evolve from planning through construction and operation. Third, although the sample of 68 respondents satisfied the minimum sample size determined using the Slovin formula, it remained concentrated among professionals directly involved in a single case-study project, which may introduce common method bias and limit the diversity of professional perspectives represented. Finally, cost performance was evaluated using planning- and design-stage quantity takeoff and *Rencana Anggaran Biaya* (RAB) data rather than actual life-cycle expenditures. Consequently, the long-term sustainability of the reported cost savings across different Envision certification levels could not be empirically verified. Future research is therefore encouraged to extend the present model to multiple river basins, incorporate longitudinal life-cycle cost tracking, and evaluate the VE–Envision integration model in other Global South contexts to further validate its cross-cultural applicability.

### CONCLUSION

This study aims to examine the success factors that influence the cost performance of Value Engineering (VE)-based green renovations on rivers under the Envision v3 guidelines. Multiple linear regression analysis confirms that river characteristics (X1), Envision guidelines (X2), and Value Engineering practices (X3) each have a statistically significant positive effect on cost performance (Y), either partially or simultaneously, as expressed in the equation  $Y = 4.398 + 0.046(X1) + 0.045(X2) + 0.135(X3)$  ( $F = 9.422$ ;  $\text{sig.} = 0.000$ ). This finding results in Value Engineering being the most influential variable, where the ten most influential success factors come from the Value Engineering dimension, specifically those related to the identification of cost savings, clarity of primary and secondary project functions, structured Value Engineering planning, multidisciplinary team involvement, and top management commitment.

Overall, the integration of Envision v3-based green retrofitting with a disciplined Value Engineering process is an effective strategy for improving the cost performance of river infrastructure projects. Future research is recommended to extend this model to other watersheds with different socio-environmental characteristics and to incorporate life-cycle cost analysis for a more comprehensive long-term cost performance evaluation.

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### AUTHOR CONTRIBUTION STATEMENT

Nela Devila participated in the study conceptualization, research design, data collection, and interpretation. Albert Eddy Husin assisted in the direction, development, and supervision of the manuscript. All authors reviewed and approved the final version of the manuscript

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