Journal of Business, Social and Technology
Volume 7, Issue 4, 1831-1849
e_ISSN: 2807-6362
https://bustechno.polteksci.ac.id/index.php/jbt/index
DOI: doi.org/10.59261/bustechno.v7i4.803

Optimizing Lapen Pavement Selection Using Value Engineering and Multi-Criteria Decision Methods

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Article Info:
Article history:
Received: July 20, 2026
Revised: September 03, 2026
Accepted: September 07, 2026
Available Online: September 12, 2026

Keywords:
Alternative Development; Entropy Weighting Method; Lapen Makadam; TOPSIS; Value Engineering.

Abstract

Background: The Provision of Infrastructure, Facilities, and Utilities (PPSU) Program is one of the regional government's programs aimed at improving the quality of basic settlement infrastructure, particularly through the construction of environmental roads using *Penetration Macadam (Lapen)* pavement.
Objective: This study aims to apply Value Engineering (VE) as an efficiency and optimization strategy for *Lapen* work by integrating the Entropy method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).
Methods: The research uses a descriptive quantitative approach involving 55 respondents consisting of Commitment-Making Officials (PPK), Technical Activity Implementation Officers (PPTK), planning consultants, supervisory consultants, field supervisors, implementing contractors, and road experts. Data were collected using a Likert-scale questionnaire comprising 13 indicators representing the functional and cost aspects of the four alternatives. The questionnaire results were tested for validity and reliability.
Results: The results showed that Alternative 4 (A4) obtained the highest assessment index, at 86.32%. Entropy weighting resulted in a weight of 0.441 for the function variable and 0.120 for the cost variable, indicating that the functional aspect was the primary consideration in selecting the alternatives. The TOPSIS analysis ranked Alternative 4 (A4) as the best alternative, with a preference value of 0.5677, followed by Alternative 2 (A2) (0.5407), Alternative 3 (A3) (0.2142), and Alternative 1 (A1) (0.0000). The Value Engineering analysis showed that Alternative 4 (A4) had the highest function-to-cost ratio, thus providing the best value.
Conclusion: Alternative development is recommended by integrating the advantages of Alternative 2 (A2), particularly its cost efficiency, ease of implementation, and use of local materials, into Alternative 4 (A4).

To cite this article: Indayani, O., Karyawan, I. D. M. A., & Ngudiyono. (2026). Optimizing Lapen Pavement Selection Using Value Engineering and Multi-Criteria Decision Methods. *Journal of Business, Social and Technology, 7*(4), 1831-1849. https://doi.org/10.59261/bustechno.v7i4.803

INTRODUCTION

Environmental road infrastructure development is one of the government's priorities for improving community accessibility and mobility and supporting the economic growth of residential areas. In West Nusa Tenggara Province, this development is implemented through the Provision of Infrastructure, Facilities, and Utilities (PPSU) Program, which includes the construction of environmental roads, drainage systems, and other settlement infrastructure. In 2025, East Lombok Regency managed 320 PPSU work packages, consisting of 252 pure APBD packages and 68 revised APBD packages, with a total physical budget of Rp69.94 billion. The large number of work packages indicates that the effectiveness of planning and the selection of construction alternatives are crucial factors in improving the efficiency of government budget utilization.

According to records provided by the Public Works and Public Housing Office of East Lombok Regency for 2024, the total length of regency roads and village arterial roads reached 1,018.835 km. Of this total, only 584.693 km (57.38%) of roads were in good condition, while 434.142 km (42.61%) were in moderate to severely damaged condition. The relatively high percentage of damaged roads indicates the need to improve construction quality and select construction methods capable of providing more optimal and sustainable road service performance.

One of the construction types most widely applied in the PPSU Program is *lapis penetrasi macadam* (Lapen), or penetration macadam pavement (Ayunaning & Juliati, 2022; Juliati, 2023). In 2025, there were 120 Lapen work packages, accounting for approximately 37.5% of all PPSU physical work packages in East Lombok Regency, with a total road treatment length of approximately 224.81 km. Lapen is selected because it has a relatively low initial construction cost, employs relatively simple construction methods, and allows the use of local materials. Nevertheless, its implementation still faces various challenges, such as variations in construction quality, inconsistent quality control, budget limitations, and the absence of an objective approach to determining the work alternative that provides the best combination of function and value.

The Value Engineering (VE) approach has been widely used to increase project value by optimizing the balance between functional performance and cost (Chen et al., 2025; Gunduz et al., 2022; Nejatyan et al., 2024). Various studies have shown that VE can generate cost savings in construction projects. However, most research remains oriented toward reducing initial construction costs and is not supported by decision-making methods capable of objectively weighting criteria and evaluating alternatives. Consequently, the alternative selection process remains influenced by subjective considerations and does not fully reflect the actual value of the infrastructure.

The development of Multi-Criteria Decision-Making (MCDM) methods offers a more systematic approach to supporting decision-making. The Entropy Weighting Method can generate data-driven criterion weights based on variations in the observations, while the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) can be used to rank alternatives based on their relative closeness to the ideal solution. The combination of these two methods has been widely applied in various decision-making fields, including the prioritization of infrastructure. However, their application to the evaluation of Lapen work alternatives within a Value Engineering framework remains very limited.

Based on a review of previous studies, three research gaps form the basis of this study. First, Value Engineering research on road projects generally has not employed objective weighting methods; therefore, the alternative evaluation process remains influenced by assessor subjectivity. Second, research integrating Entropy Weighting and TOPSIS is more commonly applied to determining road maintenance or treatment priorities rather than evaluating design alternatives within a Value Engineering framework. Third, no study has been identified that specifically integrates Value Engineering, Entropy Weighting, and TOPSIS to select alternatives for *lapis penetrasi macadam* (Lapen) work within the PPSU Program.

This study offers novelty by integrating the Entropy Weighting Method, TOPSIS, and Value Engineering into a single analytical framework. The Entropy Weighting Method is used to establish indicator weights objectively, TOPSIS is used to rank the alternatives and identify the best alternative, and VE is used to optimize the balance between function and cost. In this study, VE is applied after TOPSIS identifies the best alternative, which then serves as the basis for developing recommendations. The study is expected to provide a scientific contribution in the form of an evaluation model for the value of environmental road infrastructure, as well as practical benefits in the form of technical and policy recommendations for planning Lapen road construction that is more efficient, higher in quality, and sustainable.

With the integration of the Entropy Weighting Method, TOPSIS, and Value Engineering, this study focuses not only on cost savings but also on improving the overall functional value of the infrastructure. This approach allows each Lapen road work alternative to be assessed using multiple indicators in a more measurable manner, including functional, cost, risk, technical, and sustainability aspects. Thus, the selection process is based not only on the lowest cost but also on the alternative's ability to provide optimal benefits to the community and the regional government.

The study findings are expected to inform the formulation of more targeted environmental road development strategies, particularly for the PPSU Program in East Lombok Regency. Additionally, the evaluation model developed in this study can help the regional government determine development priorities, optimize budget utilization, and improve the quality of settlement infrastructure services. By applying a value-based approach, the construction of Lapen environmental roads is expected to support community mobility, strengthen regional connectivity, and promote more sustainable regional development.

METHOD

This study adopted a descriptive quantitative approach with the Multi-Criteria Decision Making (MCDM) method integrated with Value Engineering (VE). This approach was selected because it can provide an objective decision-making process through criteria weighting, alternative ranking, and value evaluation based on the balance between functional performance and cost. The method integration is carried out using the Entropy Weighting Method to determine criteria weights objectively, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to determine the best alternative, and Value Engineering to evaluate the value of each alternative based on the comparison of function and cost. VE is applied to the alternative selected through TOPSIS to formulate development recommendations.

The research location in East Lombok Regency is one of the areas implementing the PPSU Program with a considerable number of work packages. In 2025, there were 320 work packages, consisting of 252 Pure APBD and 68 Revised APBD packages spread across 21 sub-districts. Of these, 120 packages are for Macadam Penetration (Lapen) work, which was chosen as the research population because they have uniform work characteristics and relevance to the research objectives. The research population was all 120 Lapen work packages of the 2025 PPSU Program. The required sample was calculated with the Slovin formula with an error tolerance of 10%, which yielded a minimum requirement of 55 respondents.

$$n = \frac{N}{1 + Ne^2}$$

in which:
n = sample size
N = population size (120 packages)
e = error tolerance (10%)

Respondents were selected using the Stratified Proportional Random Sampling method, a sampling technique that divides the population based on sub-district areas and then proportionally determines the number of respondents according to the number of work packages in each sub-district. This technique was chosen so that all sub-districts are represented in the study. The respondents consisted of parties directly involved in the implementation of Lapen work, namely Commitment Making Officials (PPK), Technical Activity Implementation Officials (PPTK), Planning Consultants, Supervisory Consultants, Construction Service Providers, and Road and Pavement Experts. This research collected primary and secondary data. Primary data was obtained through distributing questionnaires using a five-point Likert scale, from score 1 (strongly disagree) to score 5 (strongly agree), for the predetermined alternatives. The research instrument consisted of 13 Value Engineering indicators comprising Function and Cost Variables. Before analysis, all instruments were tested using the Pearson Product Moment validity test and Cronbach's Alpha reliability test thereby ensuring that the indicators could measure the research variables consistently. Secondary data was obtained from the Housing and Settlement Area Office of West Nusa Tenggara Province, including data on PPSU work packages, planning drawings, Budget Plans (RAB), technical work specifications, and other supporting documents.

The initial stage of the research was to develop Lapen work alternatives based on field observations, function analysis using the Function Analysis System Technique (FAST), Cost Model, Pareto Diagram, literature review, and discussions with practitioners. The four alternatives evaluated include:

1) Alternative 1 (A1): Existing Lapen as the baseline condition.
2) Alternative 2 (A2): Lapen with refinement of the aggregate configuration according to Lapen technical specifications to improve interlocking, asphalt penetration effectiveness, and layer stability.
3) Alternative 3 (A3): Lapen with improved Aggregate Base Layer (LPA) structure to increase structural capacity.
4) Alternative 4 (A4): Lapen with optimization of implementation methods through material quality control, asphalt content regulation, compaction, and quality supervision.

All alternatives were then evaluated using the Multi-Criteria Decision Making approach.

Data Analysis Stages

Weighting using Entropy (Entropy Weighting Method)

The Entropy Weighting Method serves to establish the weight of each indicator objectively according to variation within the data from the respondent assessments. The greater the variation of an indicator, the more information it contains, so the weight of that indicator becomes higher.
The procedure begins by normalize the decision matrix using Equation (1).

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (1)$$

in which:
x_{ij}= value of alternative i on criterion j
p_{ij}= normalized value

Next, the Entropy value is computed through Equation (2).

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln(p_{ij}) \qquad (2)$$

With

$$k = \frac{1}{\ln(m)}$$

The next step is to determine the degree of diversification. (3)

$$d_j = 1 - e_j \qquad (3)$$

The weight of each criterion is computed through Equation (4).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \qquad (4)$$

in which:
w_j= criterion weight
d_j= degree of diversification

The derived weights provide the basis for the alternative ranking process in the TOPSIS method.

Ranking using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The TOPSIS method serves to establish the best alternative by considering proximity to the positive ideal and separation from the negative ideal. The weights resulting from Entropy are then used in the TOPSIS method to determine the best alternative. The analysis steps consist of:
The procedure begins by normalize the decision matrix using Equation (5).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (5)$$

The weighted decision matrix is computed through Equation (6).

$$v_{ij} = w_j r_{ij} \quad (6)$$

Next, the positive ideal solution and negative ideal solution are determined. (7,8)

$$A^+ = \{\max(v_{ij})\} \quad (7) \qquad A^- = \{\min(v_{ij})\} \quad (8)$$

The distances to the ideal solutions are calculated using Euclidean distance. (9,10)

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^+)^2} \quad (9) \qquad D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^-)^2} \quad (10)$$

The preference value for each alternative is computed through Equation (11).

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (11)$$

C_i The alternative attaining the greatest preference value () is designated as the preferred alternative.

Sensitivity Analysis

A sensitivity analysis was undertaken to examine the stability of the ranking results against changes in indicator weights. The test was carried out using two scenarios: increasing and decreasing the weights by ±10% on the indicator with the largest Entropy weight. Then, the TOPSIS calculation was repeated to determine changes in preference values or alternative rankings. Sensitivity analysis was computed through the following formulas.
Weight increase is calculated using Equation (12).

$$w_j' = w_j + (w_j \times p) \quad (12)$$

Weight decrease is calculated using Equation (13).

$$w_j' = w_j - (w_j \times p) \quad (13)$$

where:
w_j'= sensitivity result weight
w_j= initial weight
p= percentage change in weight (10%)
The new weights are then reused in the TOPSIS calculation to obtain new preference values and changes in the alternative ranking.

Value Engineering Evaluation

The concluding analytical stage seeks to evaluate the value of each alternative using the Value Engineering concept. Value is calculated based on the balance between functional performance and cost to identify the option that provides the highest function-to-cost ratio.

The alternative attaining the greatest value is recommended as the optimal option to be applied to Macadam Penetration work in the PPSU Program in East Lombok Regency. The function value is calculated based on the weighted scores of all indicators using Equation (14).

$$F = \sum_{j=1}^{n} (w_j \times S_j) \quad (14)$$

where:
F= function value
w_j= Entropy weight
S_j= indicator score
Furthermore, the Value Engineering value is calculated using Equation (15).

$$V = \frac{F}{C} \qquad (15)$$

where:
V = Value Engineering value
F = function value
C = construction cost

The alternative attaining the largest Value is recommended as the preferred option because it provides the highest function for the cost incurred.

Method Integration Framework

This research integrates three analysis methods sequentially. The Entropy Weighting Method serves to establish indicator weights objectively based on respondent data variation. These weights are then used as input for the TOPSIS method to obtain the priority order of alternatives according to proximity to the ideal solution. Subsequently, the best alternative is evaluated using the Value Engineering approach by comparing function value and cost to identify the option with the highest value. To test the model's consistency, a sensitivity analysis was conducted by changing indicator weights by ±10% before recalculating using TOPSIS.

RESULTS AND DISCUSSION

Information Stage of Lapen Work

At this information stage, information is collected through the budget plan (RAB). From the Lapen calculation data, the Cost Model structure of the Lapen work can be seen. In this study, the author took the Budget Plan for Work Package 64.005 PPSU, Kelayu Jorong Village, Selong District, East Lombok Regency, with an initial budget ceiling of Rp. 195,459,000. (One Hundred Ninety-Five Million Four Hundred Fifty-Nine Thousand Rupiah). The image shows the existing condition of the initial survey before the implementation of the environmental road improvement activities using Lapen in the hamlet of Kelayu Jorong Village, Selong District, East Lombok Regency.

Figure 1. *Documentation of Lapen Work Package 64.005*

Break Down Cost Model

The application of Value Engineering is carried out on work items that contribute significant costs and thus have potential for savings. Analysis of work categories needs to be performed. The work weights can be seen in Figure 2.

COST MODEL
ALTERNATIVE 1 - (A1)

ACTIVITY	:	1.04.05.1.01 PROVISION OF SETTLEMENT INFRASTRUCTURE AND UTILITIES SERVICES
WORK PACKAGE	:	PACKAGE 64.005 PPSU KEL. KELAYU JORONG, SELONG DISTRICT, EAST LOMBOK REGENCY
LOCATION	:	KELURAHAN KELAYU JORONG, SELONG DISTRICT, EAST LOMBOK REGENCY
FISCAL YEAR	:	2025

NO	WORK ITEM DESCRIPTION	UNIT	QUANTITY	ANALYSIS CODE	UNIT PRICE (IDR)	TOTAL CONTRACT PRICE (IDR)	WORK WEIGHT (%)
I.	PRELIMINARY WORKS						
1	Project Signboard	LS	1.00	@	250,000.00	250,000.00	0.13
2	Occupational Health and Safety (OHS)	LS	1.00	@	1,000,000.00	1,000,000.00	0.51
3	Site Clearing and Surveying	LS	1.00	@	1,250,000.00	1,250,000.00	0.64
4	Mobilization and Demobilization	LS	1.00	LS	4,000,000.00	4,000,000.00	2.05
II.	LAPEN WORKS						
1	Class B Aggregate Base Course Works	M3	65.88	E.4	541,414.60	35,666,769.29	18.25
2	Penetrated Macadam (LAPEN) Works	M3	50.17	F.36	2,669,207.79	133,922,496.17	68.52
	TOTAL I + II					Rp. 176,089,265.46	
	VAT 11%					Rp. 19,369,819.20	9.910
	PHYSICAL CONSTRUCTION COST					Rp. 195,459,084.66	
	ROUNDING					Rp. 195,459,000.00	100.000

Figure 2. *Cost Model for Lapen Alternative 1 (A1)*
Source: Author's Analysis Results (2026)

The work included in the contract scope for Package 64.005 PPSU, Kelayu Jorong Village, Selong District, East Lombok Regency, includes preliminary work and Lapen work. Grouping each type of work item is necessary to simplify the analysis process. From the grouping results, it is known that in the Lapen work, the macadam penetration layer work item has the highest work weight, which is 68.52%, thus having the potential for Value Engineering (VE) feasibility testing.

Pareto Distribution

Based on the Pareto analysis of the Lapen road work cost structure, it is known that the Macadam Penetration Layer work contributes the largest cost at 76.06% of the total construction cost, followed by the Aggregate Base Layer Class B work at 20.26%. These two components cumulatively reach 96.32% of the total project cost. Therefore, the Value Engineering analysis is focused on these two work items because they have the greatest potential for cost savings compared to other work components. The Pareto analysis results is reported in Table 1.

Table 1
Pareto Analysis of Work Costs

No	Work Description	Contract Amount + VAT (IDR)	% Cost	% Cumulative Cost
1	Macadam Penetration Layer Work	48,653,970.75	76.05	76.05
2	Aggregate Base Layer Class B Work	39,590,113.91	20.25	96.31
3	Mobilization & Demobilization	4,440,000.00	2.27	98.58
4	Site Clearing and Measurement	1,387,500.00	0.71	99.29
5	K3 (Occupational Health and Safety)	1,110,000.00	0.57	99.86
6	Project Name Board	277,500.00	0.14	100.00

Source: Data Processing Results (2026)

If illustrated in a diagram, the cost composition for Lapen infrastructure handling can be seen in the Figure 3.

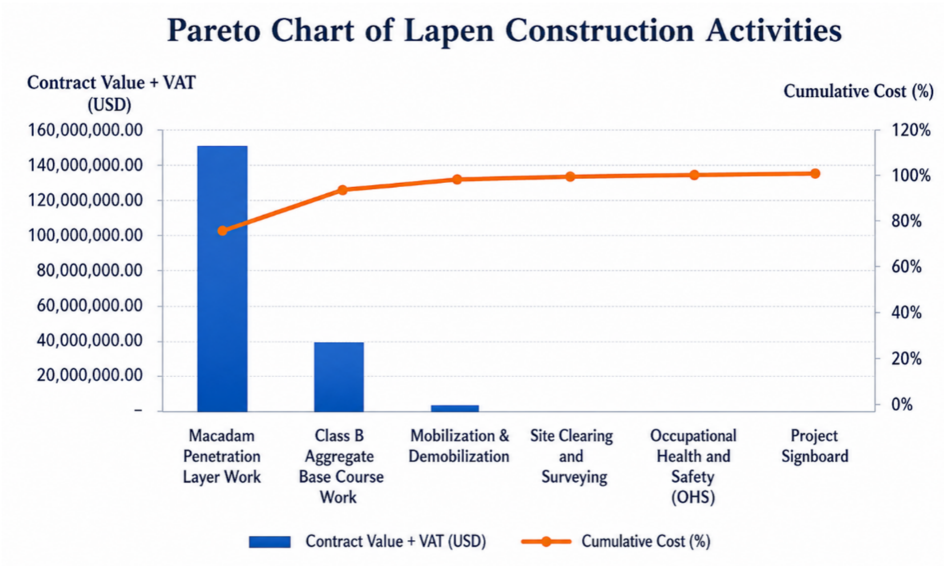

Figure 3. *Pareto Diagram for Lapen Work Alternative 1 (A1)*

Function Analysis

Based on the Pareto analysis results, the Macadam Penetration Layer and Aggregate Base Layer Class B work are the dominant components with a cost contribution of 96.32% of the total project cost. Therefore, function analysis was carried out using the FAST method to identify the basic and supporting functions of these two components. The basic function of the project is to serve traffic, while the supporting functions are achieved by providing a pavement structure capable of supporting vehicle loads and protecting the road surface from damage. The FAST results show that the "Protect Surface" function in the Lapen work and the "Support Structure" function in the Class B LPA work are critical functions that have the largest cost contribution, thus becoming the focus of developing Value Engineering alternatives. The following is a schematic diagram of the FAST for the Lapen work.

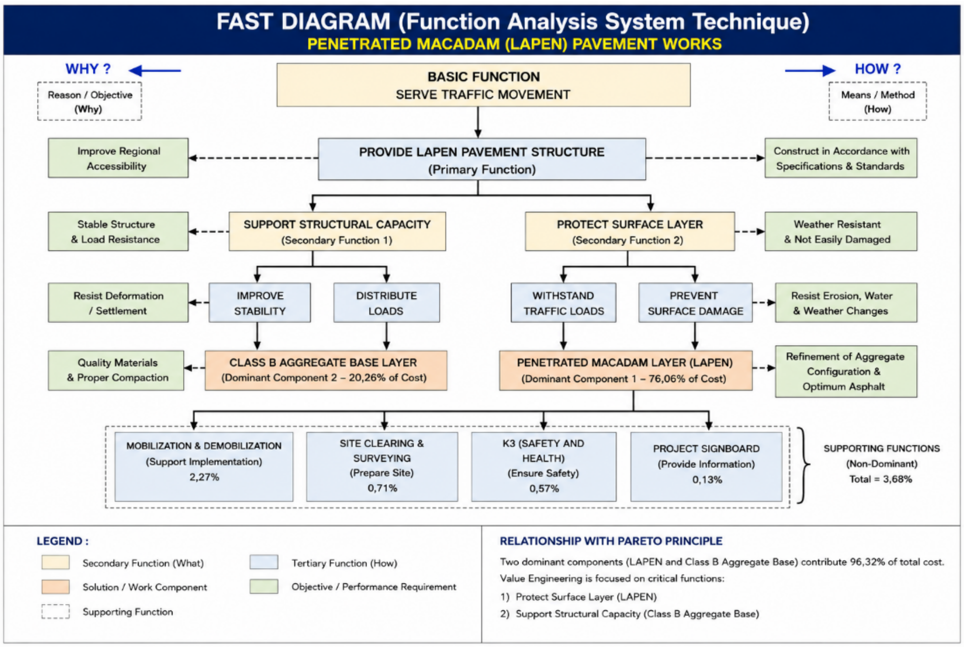

Figure 4. *FAST Diagram*

Determination of Alternatives for Macadam Penetration (Lapen) Work

Determination of Value Engineering Alternatives

Drawing on the results of the Cost Model analysis, function analysis, and the existing conditions of Macadam Penetration (Lapen) work in the PPSU Program in East Lombok Regency, four

Value Engineering (VE) alternatives were established, all still within the scope of Lapen construction (Dewanti et al., 2024; Saputra et al., 2024). These four alternatives were chosen to represent different approaches to improving functions, namely existing conditions, aggregate configuration optimization, structural improvement, and implementation method optimization.

Alternative 1 (A1) is the existing Lapen, used as a baseline to compare the functional improvement and efficiency of other alternatives. Observations showed that aggregate loss and surface cracking were still found, indicating that the Lapen function is not yet optimal (Hidiyati et al., 2023; Mulyana et al., 2026; Rusdi et al., 2025).

Alternative 2 (A2) was developed by refining the aggregate configuration according to Lapen technical specifications without changing the pavement structure. The aggregate configuration is the arrangement of the main stones, choker stones, and cover stones according to Lapen technical specifications. The aim is to increase interlocking, effectively fill the voids between particles, optimize asphalt penetration, stability, and layer durability without changing the Lapen construction concept into a well-graded mix. This approach was chosen because it suits the characteristics of local materials available in East Lombok Regency and maintains the layered aggregate arrangement system characteristic of Lapen construction according to the general Bina Marga specifications (Bangun & Purwantoro, 2024; Rumpesak et al., 2017; Tahapary & Marantika, 2026).

Alternative 3 (A3) involves improving the quality or thickness of the Aggregate Base Layer (LPA) to increase bearing capacity and road service life. Although it provides improved structural performance, this alternative requires higher construction costs compared to other alternatives (Wahyudi et al., 2024).

Alternative 4 (A4) focuses on optimizing implementation methods through material quality control, asphalt content regulation, compaction according to specifications, and work quality supervision. This approach was chosen because it can improve pavement performance without significant structural changes (Arvianto, 2024; Silaban & Aulia, 2025; Uguy, 2026).

The four alternatives were then evaluated using the Entropy Weighting Method to derive objective weights for each criterion and the TOPSIS method to determine the best alternative based on function, cost, technical performance, constructability, and environmental aspects. A synthesis of the four alternatives appears in Table 2.

Table 2

Synthesis of Determining Lapen Alternatives Based on the Value Engineering Approach

Function Analysis (FAST) Result	Existing Problem	Literature Basis	Alternative Developed	Reason for Selection
Bind Aggregate	Ravelling, aggregate easily loosens	Rumpesak et al. (2017) and Sakti (2025) state that the arrangement of constituent aggregates affects interlocking and stability of the Lapen layer.	A2 -- Refinement of aggregate configuration according to Lapen technical specifications, not a well-graded mix.	To improve aggregate interlocking so that stability increases with relatively small additional cost.
Withstand Traffic Loads	Structural degradation on several sections	Wahyudi (2024) explains that increasing the structure extends pavement service life.	A3 -- Improvement of LPA structure	To increase structural capacity to accept traffic loads.
Improve Surface Stability	Uneven surface and easily damaged	Arvianto (2024) explains that the quality of the implementation method affects pavement quality.	A4 -- Optimization of implementation method	Functional improvement through quality control and work methods.
Provide Road	Decrease in	Hidiyati et al. (2023)	A1 -- Existing	As a baseline to

Function Analysis (FAST) Result	Existing Problem	Literature Basis	Alternative Developed	Reason for Selection
Service	user comfort	show that surface damage reduces road service levels.		compare functional and cost improvements.

Source: Author's Analysis Results, 2026

From the results of the synthesis for determining Lapen alternatives based on the Value Engineering approach, existing problems, literature studies, theory, and selection reasons, the proposed alternatives can be seen in Table 3.

Table 3
Lapen Alternatives

Alternative	Development Focus	Objective
A1	Existing	Baseline condition for comparison
A2	Refinement of aggregate configuration according to Lapen technical specifications	To improve aggregate interlocking and stability at a low cost
A3	Improvement of LPA structure	To increase structural capacity and service life
A4	Optimization of implementation method	To improve work quality through quality control and process efficiency

Source: Author's Analysis Results, 2026

Validity Test

The validity test was undertaken to assess the ability of each questionnaire item to measure the variables studied. The validity test was carried out using the Pearson Product Moment correlation between the score of each item and the total score of the instrument. An item meets the validity criterion when the calculated r value is greater than the table r value at a 5% significance level.

The decision criteria are:

1. If $r_{calculated} > r_{table}$, the item is declared **valid**.
2. If $r_{calculated} \leq r_{table}$, the item is declared **invalid**.

The number of respondents in this study was 55, so the degrees of freedom (df) were:

$$df = n - 2df = 55 - 2 = 53$$

Based on the Pearson Product Moment distribution table at a 5% significance level, the r table value is 0.266. The results of the validity test for the research instrument appear in Table 4.

Table 4
Validity Test for Value Engineering Indicators

No.	Code	r-count	r-table (sig. 5%)	Conclusion (Valid if r-calculated > r-table)
1	F1	0.791	0.266	valid
2	F2	0.801	0.266	valid
3	F3	0.691	0.266	valid
4	F4	0.714	0.266	valid
5	F5	0.609	0.266	valid
6	F6	0.817	0.266	valid
7	F7	0.781	0.266	valid
8	F8	0.836	0.266	valid
9	F9	0.754	0.266	valid
10	F10	0.792	0.266	valid
11	C1	0.751	0.266	valid
12	C2	0.780	0.266	valid
13	C3	0.696	0.266	valid

Source: Data Processing Results (2026)

Based on the validity test results in Table 3, all research indicators have calculated r values greater than the table r value of 0.266. The calculated r values ranged from 0.609 to 0.836. These findings demonstrate that all question items can measure the aspects being studied and have a strong relationship with the total instrument score. Thus, all indicators are declared valid and suitable for use in data collection for this research.

Reliability Test

The reliability test was undertaken to assess the consistency level of the research instrument in measuring the same variables. The reliability test was carried out using the Cronbach's Alpha method. An instrument satisfies the reliability requirement when the Cronbach's Alpha value is greater than 0.70. The following table shows the Reliability Criteria.

Table 5

Reliability Criteria

Cronbach's Alpha Value	Interpretation
> 0.90	Very Reliable
0.80 -- 0.90	Reliable
0.70 -- 0.80	Quite Reliable
0.60 -- 0.70	Less Reliable
< 0.60	Not Reliable

Source: Literature Study

The results of the reliability test for the research instrument appear in Table 6.

Table 6

Research Instrument Reliability Test Results

NO	Variable	N = 55		
		Number of Questions	Cronbach's Alpha	Description
1	Function	10	0.937	Very Reliable
2	Cost	3	0.937	Very Reliable

Source: Data Processing Results (2026)

The reliability test results show that the research instrument has a Cronbach's Alpha value of 0.937. This value is above the minimum required limit of 0.70. This finding indicates that the research instrument has a very high level of internal consistency. Thus, all question items in the questionnaire are declared reliable and can be used as a data collection tool in this study.

Decision Matrix Compilation

The decision matrix was compiled based on the results of data collection from the Questionnaire Results originating from all implementing actors (PPK, planning consultants, contractors, supervisory consultants), field observations, and validation through expert opinions and stakeholders related to Lapen infrastructure to ensure the suitability of the existing Lapen infrastructure conditions and the research assessment indicators. All data from the questionnaire results were then entered into an assessment matrix table, and calculations were performed for each indicator on all alternatives. Based on the initial calculation results, it appears that the indicator with the highest assessment score is material availability with a score of 928, while the indicator with the smallest influence is the estimated service life with a score of 770. Based on the results of this questionnaire assessment, an initial decision matrix was obtained that represents the relative condition of each alternative against all indicators used. The following is presented in Table 7. Decision Matrix from Questionnaire Results per indicator.

Table 7
Decision Matrix from Questionnaire Results per Indicator

No	Variable	Indicator	Lapen Alternatives				Total
			Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)	
1	Function	F1. Suitability of road function	205	230	213	246	894
		F2. Road layer stability	189	211	197	232	829
		F3. Surface durability	186	217	195	236	834
		F4. Estimated service life	171	194	177	228	770
		F5. Resistance to weather influence based on implementation experience	173	201	183	223	780
		F6. Ease of implementation	208	229	218	250	905
		F7. Material availability	217	238	223	250	928
		F8. Labor availability	208	232	219	249	908
		F9. Environmental impact	192	211	204	234	841
		F10. Use of local materials	206	228	212	251	897
2	Cost	C1. Initial construction cost	193	218	201	233	845
		C2. Maintenance cost	178	206	189	217	790
		C3. Cost efficiency	192	214	204	237	847

Source: Questionnaire Data Analysis Results

Next, the decision matrix was formed based on the average scores of respondents' assessments for each alternative on each research indicator. These average scores were obtained from processing the questionnaire data using a five-level Likert scale. This decision matrix forms the basis for the objective weighting process using the Entropy Weighting Method and is subsequently used in the alternative ranking analysis using the TOPSIS method.

Criteria Weight Analysis using the Entropy Weighting Method

Criteria weights were determined using the Entropy Weighting Method because this method can generate weights objectively based on the level of data variation in each criterion, thereby reducing the influence of subjectivity in the weighting process.

Scale Conversion

Before the Entropy analysis, the questionnaire data from 55 respondents was transformed into a 1-5 rating scale using the average value of each indicator for each alternative. This procedure standardizes the data scale so that it can be used in the normalization stage and Entropy weight calculation. The conversion results show that the average value of each indicator is in the range of

3.11-4.56, indicating that all Value Engineering indicators have a good level of assessment for the four alternatives. A summary of the scale conversion results appears in Table 8.

Table 8
Scale Conversion (Decision Matrix)

No	Variable	Indicator	Lapen Alternatives			
			Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)
1	Function	F1. Suitability of road function	3.73	4.18	3.87	4.47
		F2. Road layer stability	3.44	3.84	3.58	4.22
		F3. Surface durability	3.38	3.95	3.55	4.29
		F4. Estimated service life	3.11	3.53	3.22	4.15
		F5. Resistance to weather influence based on implementation experience	3.15	3.65	3.33	4.05
		F6. Ease of implementation	3.78	4.16	3.96	4.55
		F7. Material availability	3.95	4.33	4.05	4.55
		F8. Labor availability	3.78	4.22	3.98	4.53
		F9. Environmental impact	3.49	3.84	3.71	4.25
		F10. Use of local materials	3.75	4.15	3.85	4.56
2	Cost	C1. Initial construction cost	3.51	3.96	3.65	4.24
		C2. Maintenance cost	3.24	3.75	3.44	3.95
		C3. Cost efficiency	3.49	3.89	3.71	4.31

Source: Author's Analysis Results, 2026

As indicated in Table 8, the findings indicate that all assessment values for each indicator have been successfully converted to a 0-5 scale proportionally. The conversion results show that the comparison pattern between alternatives remains consistent with the initial values, where alternatives with high values in the previous matrix still show relatively higher values after conversion. The differences in values between alternatives for each indicator are still clearly visible, so this conversion process does not remove data characteristics but only standardizes the scale for use in subsequent stages of analysis using the Entropy Weighting method and TOPSIS.

Data Normalization

After the questionnaire data was converted to a 1-5 scale, the next step was data normalization using the Entropy Weighting Method. Normalization converts the value of each alternative into a relative proportion for each criterion placing all observations on a comparable scale before calculating Entropy values and criteria weights.

For example, for the indicator Road Function Suitability, Alternative 1 (A1) has a value of 3.73, with the total value of all alternatives being 16.25, resulting in a normalized value of 0.229. This value indicates that the relative contribution of Alternative 1 (A1) to this indicator is 22.9%.

The normalization results for each criterion sum to 1 because the resulting values are proportion distributions, as per the basic concept of Shannon's information theory (Mohammed et al., 2022; Shannon, 1948). The greater the variation in values between alternatives for a criterion, the more information is obtained, so the resulting Entropy weight is also higher. The normalization results for all alternatives are presented in Table 9.

Table 9
Entropy Data Normalization

No	Variable	Indicator	Lapen Alternatives				Total
			Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)	
1	Function	F1. Suitability of road function	0.229	0.257	0.238	0.275	1.00
		F2. Road layer stability	0.228	0.255	0.238	0.280	1.00
		F3. Surface durability	0.223	0.260	0.234	0.283	1.00
		F4. Estimated service life	0.222	0.252	0.230	0.296	1.00
		F5. Resistance to weather influence based on implementation experience	0.222	0.258	0.235	0.286	1.00
		F6. Ease of implementation	0.230	0.253	0.241	0.276	1.00
		F7. Material availability	0.234	0.256	0.240	0.269	1.00
		F8. Labor availability	0.229	0.256	0.241	0.274	1.00
		F9. Environmental impact	0.228	0.251	0.243	0.278	1.00
		F10. Use of local materials	0.230	0.254	0.236	0.280	1.00
2	Cost	C1. Initial construction cost	0.228	0.258	0.238	0.276	1.00
		C2. Maintenance cost	0.225	0.261	0.239	0.275	1.00
		C3. Cost efficiency	0.227	0.253	0.241	0.280	1.00

Source: Author's Analysis Results, 2026

As indicated in Table 9, the findings indicate that the data normalization results produce values in the form of proportions that show the relative contribution of each Lapen alternative to each indicator. The values for each indicator have the same total, making differences between alternatives more measurable and directly comparable. In general, alternatives with higher initial values tend to have larger proportion values after normalization, as seen with Alternative 4 (A4) for several indicators, showing higher figures compared to other alternatives. This normalization process allows data from various different indicators to be used consistently in the Entropy calculation in the next stage.

Analysis of Entropy, Diversification, and Entropy Weight Values

Based on the normalized matrix, the Entropy, diversification, and Entropy weight values were calculated for each indicator. The Entropy value quantifies the degree of variation in the data between alternatives, while the diversification value indicates the amount of information each indicator possesses. A larger diversification value produces a greater objective weight to that indicator.

For example, for the indicator Cost Efficiency, the normalization results produce proportion values for each alternative of 0.22668; 0.25270; 0.24100; and 0.27980. Using the constant (k=0.721348), the Entropy value obtained is 0.998, so the diversification value is 0.002. Based on the total diversification of all indicators, which is 0.03, the Entropy weight for the Cost Efficiency indicator is 0.073.

This finding demonstrates that the Entropy weight is determined by the level of data variation in each indicator. Greater variation within an indicator produces a higher diversification value and, consequently, a larger weight in the decision-making process. A summary of the Entropy, diversification, and Entropy weight values for all indicators appears in Table 10.

Table 10
Results of Entropy, Diversification, and Entropy Weight Calculation

No	Aspect	Indicator	Lapen Alternatives				Entropy (e)	Diversification (d=1-e)	Entropy Weight (w)
			Alt 1 (A1)	Alt 2 (A2)	Alt 3 (A3)	Alt 4 (A4)			
1	Function	F1. Suitability of road function	0.229	0.257	0.238	0.275	0.998	0.002	0.060
		F2. Road layer stability	0.228	0.255	0.238	0.280	0.998	0.002	0.074
		F3. Surface durability	0.223	0.260	0.234	0.283	0.997	0.003	0.105
		F4. Estimated service life	0.222	0.252	0.230	0.296	0.995	0.005	0.156
		F5. Resistance to weather influence based on implementation experience	0.222	0.258	0.235	0.286	0.997	0.003	0.114
		F6. Ease of implementation	0.230	0.253	0.241	0.276	0.998	0.002	0.057
		F7. Material availability	0.234	0.256	0.240	0.269	0.999	0.001	0.037
		F8. Labor availability	0.229	0.256	0.241	0.274	0.998	0.002	0.054
		F9. Environmental impact	0.228	0.251	0.243	0.278	0.998	0.002	0.063
		F10. Use of local materials	0.230	0.254	0.236	0.280	0.998	0.002	0.072
2	Cost	C1. Initial construction cost	0.228	0.258	0.238	0.276	0.998	0.002	0.064
		C2. Maintenance cost	0.225	0.261	0.239	0.275	0.998	0.002	0.070
		C3. Cost efficiency	0.227	0.253	0.241	0.280	0.998	0.002	0.073

Source: Author's Analysis Results, 2026

As indicated in Table 10, the findings indicate that the Entropy values for each indicator are generally close to 1, indicating that most of the data between alternatives has a relatively high level of uniformity. However, there are several indicators with lower Entropy values, such as Material Availability (F7), which indicates a greater variation in values between alternatives. This results in a higher diversification value and a larger Entropy weight for that indicator. Conversely, indicators with relatively similar values between alternatives have low diversification values, so their weights are also small. Overall, these results show that indicators with higher data variation contribute more strongly to differentiating the performance between alternatives in subsequent analyses.

Priority Analysis of Alternatives Using the TOPSIS Method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method serves to establish the best Lapen alternative by considering proximity to the positive ideal and separation from the negative ideal. In this study, the TOPSIS process uses criteria weights obtained from the Entropy Weighting Method, so the assessment is carried out objectively according to the level of data variation for each indicator.

Vector Normalization

The initial stage of TOPSIS is vector normalization of the decision matrix to remove differences in scale across indicators thereby enabling proportional comparison among the alternatives. For example, for the indicator Estimated Service Life, Alternative 1 (A1) with a value of 3.11 produces a vector normalization value of 0.441. This value indicates the relative contribution of A1 to the service life indicator after the normalization process.

The vector normalization results for all alternatives subsequently form the weighted decision matrix in the next stage. A summary of the vector normalization results appears in Table 11.

Table 11
Vector Normalization

No	Variable	Indicator	Lapen Alternatives			
			Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)
1	Function	F1. Suitability of road function	0.457	0.513	0.475	0.549
		F2. Road layer stability	0.455	0.507	0.474	0.558
		F3. Surface durability	0.444	0.518	0.466	0.563
		F4. Estimated service life	0.441	0.501	0.457	0.588
		F5. Resistance to weather influence based on implementation experience	0.441	0.513	0.467	0.569
		F6. Ease of implementation	0.459	0.505	0.481	0.551
		F7. Material availability	0.467	0.512	0.480	0.538
		F8. Labor availability	0.457	0.510	0.481	0.547
		F9. Environmental impact	0.455	0.500	0.484	0.555
		F10. Use of local materials	0.458	0.507	0.471	0.558
2	Cost	C1. Initial construction cost	0.456	0.515	0.474	0.550
		C2. Maintenance cost	0.449	0.520	0.477	0.548
		C3. Cost efficiency	0.452	0.504	0.480	0.558

Source: Author's Analysis Results, 2026

As indicated in Table 11, the Vector Normalization results show that the performance values of each Lapen alternative have been standardized so that they can be compared proportionally between indicators. The differences in values that appear reflect the relative performance variations of each alternative, where higher values indicate a more dominant contribution to a specific indicator. In general, Alternative 2 (A2) and Alternative 4 (A4) tend to have higher values for several specific indicators, such as Alternative 2 (A2) relating to maintenance costs and Alternative 4 (A4) relating to Estimated Service Life, while Alternative 1 (A1) shows relatively lower values for several function indicators, specifically the estimated service life indicator and Resistance to weather influence based on implementation experience. This variation forms the basis for the weighting process and determination of ideal solutions in the subsequent stages of the TOPSIS method.

Formation of the Weighted Decision Matrix

The weighted decision matrix is produced by multiplying the vector normalization values by the Entropy weights for each indicator. This stage demonstrates the contribution of each indicator to the alternative's performance based on its level of importance. For example, for the indicator Estimated Service Life, the vector normalization value for Alternative 1 (A1) of 0.441 multiplied by the Entropy weight of 0.156 produces a weighted decision matrix value of 0.069.

Table 12
Weighted Decision Matrix

No	Variable	Indicator	Lapen Alternatives			
			Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)
1	Function	F1. Suitability of road function	0.028	0.031	0.029	0.033
		F2. Road layer stability	0.034	0.038	0.035	0.041
		F3. Surface durability	0.046	0.054	0.049	0.059
		F4. Estimated service life	0.069	0.078	0.071	0.092
		F5. Resistance to weather influence based on implementation experience	0.050	0.058	0.053	0.065
		F6. Ease of implementation	0.026	0.029	0.027	0.031
		F7. Material availability	0.017	0.019	0.018	0.020
		F8. Labor availability	0.025	0.028	0.026	0.030
		F9. Environmental impact	0.029	0.032	0.031	0.035
		F10. Use of local materials	0.033	0.036	0.034	0.040
2	Cost	C1. Initial construction cost	0.029	0.033	0.031	0.035
		C2. Maintenance cost	0.032	0.036	0.033	0.038
		C3. Cost efficiency	0.033	0.037	0.035	0.041

Source: Author's Analysis Results, 2026

As indicated in Table 12, the weighted decision matrix shows that the value of each Lapen alternative reflects not only its relative performance but also the importance of each indicator. Larger values indicate that an alternative performs well on high-weight indicators, so its contribution to the final assessment is more significant. It appears that Alternative 2 (A2) and Alternative 4 (A4) have relatively higher weighted values for several key indicators, especially Estimated Service Life and Resistance to Weather Influence Based on Implementation Experience, demonstrating their comparative advantage in supporting the sustainability functions of Lapen road infrastructure. Conversely, Alternative 1 (A1) and Alternative 3 (A3) tend to have lower weighted values for several indicators, indicating that the limitations of the existing Lapen conditions affect their overall contribution to the analysis. This matrix subsequently provides the basis for identifying the positive and negative ideal solutions in the next stage.

CONCLUSION

This research successfully employed a Value Engineering (VE) approach integrated with the Entropy Weighting Method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to evaluate four alternatives for Macadam Penetration (Lapen) work under the Provision of Infrastructure, Facilities, and Utilities (PPSU) Program in East Lombok Regency. The weighting results obtained using the Entropy Weighting Method showed that the criteria prioritization process was carried out objectively based on data variation, while the TOPSIS method identified Alternative

4 (A4) as the best alternative, with the highest preference value of 0.5677. The Value Engineering analysis further reinforced this finding by showing that Alternative 4 (A4) has the highest function value (0.441) and the largest function-to-cost ratio (value) of 1.7332, thus providing the best balance between functional improvement and cost efficiency.

The methodological contribution of this research lies in the integration of Entropy Weighting, TOPSIS, and Value Engineering into the decision-making process for selecting Lapen work alternatives. This approach not only provides objective weighting and ranking but also evaluates the balance between functional performance and cost, ensuring that the selected alternative provides the best overall value. Practically, the findings of this study can inform local governments and agencies implementing the PPSU Program in determining more effective, efficient, and site-appropriate Lapen work alternatives. Furthermore, several advantages of Alternative 2 (A2), particularly in aggregate configuration optimization, can be incorporated into Alternative 4 (A4) to further improve implementation quality without reducing cost efficiency. This research is limited to evaluating initial construction functions and costs and uses data representing conditions in East Lombok Regency. Therefore, further research is recommended to develop the model by incorporating aspects such as Life Cycle Cost, construction risk analysis, and sustainability indicators to make the decision-making process more comprehensive. Additionally, applying the integrated Entropy-TOPSIS-Value Engineering approach to other types of infrastructure is necessary to test the model's consistency and validity under different project conditions and characteristics.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the relevant agencies and stakeholders in East Lombok Regency for their cooperation and support during the collection of data related to the Provision of Infrastructure, Facilities, and Utilities (PPSU) Program. The authors also express their appreciation to Universitas Mataram for the academic support provided during the completion of this research.

AUTHOR CONTRIBUTION STATEMENT

Okti Indayani, I Dewa Made Alit Karyawan, and Ngudiyono contributed to the conceptualization, methodology, data analysis, interpretation, and manuscript preparation. All authors approved the final manuscript and accept responsibility for the integrity of the work.

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