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COMPARATIVE STUDY OF INTEGRATED MULTICRITERIA DECISION MAKING: AHP-TOPSIS VS ENTROPY-TOPSIS FOR PRIORITIZING ROAD DAMAGE REPAIR

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ABSTRACT

This study compares two integrated methods, specifically the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), to determine prioritized road sections for repair. The first method, AHP-TOPSIS, assigns weights to damage criteria based on the characteristics of road damage types. The second method, Entropy-TOPSIS, determines the weights of damage criteria using the Entropy formula. The accuracy of both methods is assessed by comparing their ranking results to the Pavement Condition Index (PCI) assessment based on the percentage of similarity. Based on the accuracy percentages, Entropy-TOPSIS demonstrates higher accuracy (27.5%) compared to AHP-TOPSIS (21.25%). Meanwhile, the road sections prioritized for repair yielded the same ranking results between AHP-TOPSIS and Entropy-TOPSIS, specifically the road sections on Jorong Beach, from STA 3+401 to 3+500 (Alternative 70). The results of this study support the development of more accurate and efficient decision-making models for infrastructure maintenance, which can be applied to broader transportation management systems.

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INTRODUCTION

Road construction is a key indicator of regional development. As a developing country, Indonesia, through the Ministry of Public Works and Housing, has established infrastructure development to enhance community mobility. High-quality road infrastructure is a vital asset for improving both social and economic productivity (Sutandi, 2023). Roads serve not only as transportation routes but also as means of socialization and access to various services. The identification of road damage at three beach locations highlights the need for targeted road maintenance programs (Sur, Dewi, and Adriana, 2024). Through the application of MCDM, this research contributes to improving the efficiency of infrastructure maintenance.

Several studies have applied MCDM methods to assess road damage. Previous studies (Beheshtinia dan Sayadinia 2021) employed hybrid MCDM approaches to rank hazardous road segments. The study used four hybrid methods, namely MDL-TOPSIS, MDL-VIKOR, AHP-TOPSIS, and AHP-VIKOR, to determine the ranking results of accident-prone locations. Entropy was applied to assign weights to the evaluation criteria. The results of the study, which employed different ranking methods but used the exact Entropy-based weighting, produced consistent outcomes, identifying the Zafaranieh residential area as the highest priority. Furthermore, (Fazri 2021) employed fuzzy TOPSIS and AHP methods to determine strategic priorities for reducing motor vehicle accidents. The integration of AHP-TOPSIS improves the reliability of the prioritization process and yields more conclusive results.

The study compares the AHP-TOPSIS and AHP-AHP methods, showing that the integration of AHP and TOPSIS aligns more closely with the decision maker's initial preference (Sharma, Sridhar, and Claudio 2020). Meanwhile, dos Santos, Godoy, and Campos (2019) argued that the Entropy weighting method in decision-making may fail to accurately reflect the true importance of the criteria, potentially leading to distorted results. Therefore, this study employed the integration of the AHP-TOPSIS method and the Entropy-TOPSIS method to determine the most effective method for assessing road damage on 80 road sections across three different beach locations.

HYPOTHESIS

This study assumes that there is a difference in the accuracy levels between the AHP-TOPSIS and Entropy-TOPSIS methods in determining road repair priorities based on Pavement Condition Index (PCI) assessments. It is hypothesized that the AHP-TOPSIS method yields higher accuracy as it aligns more closely with decision-makers initial preferences (Sharma, Sridhar, & Claudio, 2020). In contrast, the Entropy weighting method may fail to accurately reflect the true importance of the criteria, potentially leading to less reliable outcomes (dos Santos, Godoy, & Campos, 2019). Therefore, AHP-TOPSIS is expected to be more effective in supporting decision-making for prioritizing road infrastructure repairs.

RESEARCH METHOD

The data collection in this study was conducted through an investigation survey, which involved directly assessing the types of road damage and then measuring the extent of damage in each road section under study. A total of eighty (80) road sections were assessed based on seven common types of road observed in Tanah Laut Districts, namely: Cracking (X_1), Bumps and Sags (X_2), Depression (X_3), Patching and Potholes(X_4), Polished Aggregate (X_5), and Rutting (X_6), and Swell (X_7) (Sur, Dewi, dan Adriana 2024); (Sari et al. 2021). The three research locations (Swarangan, Jorong, and Turki) exhibited all seven types of road damage. In this case, the road sections served as the alternatives in the MCDM framework, and the types of road damage served as the criteria (Sur dan Machfiroh 2024). The damage type data used in the analysis were obtained from field assessments and processed using the MCDM method.

This study compares two integrated approaches using the MCDM method, specifically the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The comparison focuses on the integration of weighting methods, specifically the Analytical Hierarchy Process (AHP)-TOPSIS and Entropy-TOPSIS, which were compared using accuracy percentages calculated based on the Pavement Condition Index (PCI) assessment. This comparison aimed to determine which method provides a more accurate prioritization of road sections for repair based on the severity and type of road damage.

Before applying the MCDM method, the problem must be structured into a decision matrix $X_{m \times n}$where m denotes the number of alternatives or experts, n represents the number of decision criteria, and x_{ij} represents the evaluation value of an alternative i under the criterion j, with $i = 1,2,\dots,m$ and $j = 1,2,\dots,n$. The MCDM matrix is as follows.

$$X = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_m \end{array} \begin{array}{c} \begin{array}{ccccc} c_1 & c_2 & c_3 & \cdots & c_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad \ldots\ldots(1)$$

This study applied the MCDM methods, namely AHP-TOPSIS and Entropy-TOPSIS, following the steps and theoretical frameworks outlined below.

AHP-TOPSIS method

The integrated AHP-TOPSIS method combines the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank alternatives. In this approach, AHP is used to determine the weights of the criteria, which are then used to rank the alternatives using TOPSIS (Çalık, Çizmecioğlu, dan Akpınar 2019). A summary of AHP-TOPSIS is as follows: the stages of weighting the criteria and ranking the alternatives based on AHP-TOPSIS are as follows (Han et al. 2020; Sharma, Sridhar, dan Claudio 2020; Sindhu, Nehra, dan Luthra 2017):

Step 1**:** Conduct pairwise comparisons among the criteria using the fundamental scale developed by Saaty (Leal 2020). This process yields a comparison matrix of size $n \times n$, where n denotes the number of criteria. Each entry a_{ij} in the matrix represents the relative importance of criterion i compared to criterion j $i, j = 1,2,\dots,n$.

Step 2**:** Normalize the pairwise comparison matrix using Equation (2)

$$r_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \ldots\ldots(2)$$

Step 3**:** Calculate the eigenvector as the weighted value, the maximum eigenvalue, and the Consistency Index (CI) using Equation (3)

$$CI = \frac{\lambda_{maks} - n}{n-1} \quad \ldots\ldots(3)$$

where λ_{maks} is the eigenvalue of the pairwise comparison matrix, and n is the number of criteria.

Step 4: Compute and verify the Consistency Ratio (CR) using Equation (4)

$$CR = \frac{CI}{RI} \quad \ldots\ldots(4)$$

where RI stands for Random Index, computed based on reciprocal matrices as described by E.Forman (L.Saaty 2007). The values of RI with the matrix size n are shown in Table 1.

Table 1. Random Index with matrix size n

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.54	1.56	1.57	1.58

The acceptable range of CR value depends on the matrix size $n \times n$. For $n = 3$, the CR value is 0.05; for $n = 4$, the CR value is 0.08; and for $n \geq 5$, the CR value is 0.01. If the CR criterion is satisfied, it indicates that the eigenvalues obtained in Step 3 are consistent and can be used as criterion weights for the subsequent steps (L.Saaty 2007). However, if the CR criterion is not satisfied, improvements must be made to the pairwise comparison matrix, and the process should return to Step 1. The subsequent step involves ranking the alternatives using the TOPSIS method.

Step 5: Use the calculated eigenvector values as the weights of the criteria (w_j). Each eigenvector w_j is obtained by dividing the sum of each row in the normalized pairwise comparison matrix (Step 2) by the total number of criteria.

Step 6: Construct the normalized decision matrix $[R_{ij}]_{m\times n}$, where r_{ij} represents the normalized value for an alternative i under criterion j; $i = 1,2\ldots,m$ denotes the number of alternatives, and $j = 1,2,\ldots,n$ denotes the number of criteria. The following Equation obtains the elements of the matrix:

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

where x_{ij} represents the performance value of the alternative i concerning the criterion j.

Step 7: Create the weighted normalized matrix $V = [v_{ij}]_{m\times n}$ where $i = 1,2\ldots,m$ is the number of alternatives and $j = 1,2,\ldots,n$ is the number of criteria, with entries v_{ij} obtained by (Sindhu, Nehra, dan Luthra 2017):

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

Step 8: Identify the positive and negative ideal solution matrix by the equations (Zhao, Ma, dan Lin 2022) :

$$A^+ = \{(\max V_{ij} | j \in J), (\min V_{ij} | j \in J'), i1,2,\ldots,m)\} \quad (7)$$

$$A^- = \{(\min V_{ij} | j \in J), (\max V_{ij} | j \in J'), i = 1,2,\ldots,m)\} \quad (8)$$

where J represents a standard related to profit or benefit, and J' represents a standard related to cost or loss.

Step 9: Determine distances between each alternative's positive and negative ideal solutions, respectively, using Equations

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, i = 1,2,\ldots,m \quad (9)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}\; i = 1,2,\ldots,m \quad (10)$$

Step 10: Compute the Closeness Coefficient (CCi) and rank the alternatives in descending order. CC_i obtained by Equation:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}; i = 1,2,\ldots,n \quad (11)$$

the most prioritized solution is the alternative one, having the most significant value of CC_i.

Entropy-TOPSIS method

Like AHP-TOPSIS, integrated Entropy-TOPSIS also combines Entropy methods to determine criteria weights, which are then used in alternative ranking using TOPSIS. The decision matrix used (1) A summary of Entropy-TOPSIS as follows the stages of weighting the criteria and ranking the alternatives based on Entropy-TOPSIS are as follows (dos Santos, Godoy, dan Campos 2019; Zhao, Ma, dan Lin 2022; Liu et al. 2021):
Step 1: Normalize the decision criteria values of the matrix (1) at each decision alternative with entries P_{ij} as follows (dos Santos, Godoy, dan Campos 2019):

$$P_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \quad (12)$$

where $i = 1,2,\ldots,m$ dan $j = 1,2,\ldots,n$, with i is the number of alternatives and j is the number of decision criteria.

Step 2: Set the Entropy weight E_j for each decision criterion based on (Liu et al. 2021). We used:

$$E_j = -\frac{\sum_{i=1}^{m} P_{ij} \ln P_{ij}}{\ln n}, \forall j \quad (13)$$

where n is the number of alternatives.

Step 3 Identify w_j as an Entropy weighting results as follows (Zhu, Tian, dan Yan 2020):

$$w_j = \frac{1}{\sum_{j=1}^{n} (1 - E_j)} \quad (14)$$

it is the final step of the Entropy weighting method; the next step follows Step 5 and subsequent AHP-TOPSIS, using w_j as the weighting criterion.

RESULT AND ANALYSIS

Results of Road Damage Assessment

Road damage investigation surveys at three beach locations were conducted on damaged road sections, with a distance between road sections of 100 m. At Swarangan Beach (Location Label S), the survey was conducted at STA 0+000 to STA 6+000, obtaining 15 damaged road sections and becoming the object of this study. At Turki Beach (Location Label T), the survey was conducted at STA 0+000 to STA 1+985, obtaining 20 damaged road sections and becoming the object of this study.

Furthermore, at Jorong Beach (Location Label J), the survey was conducted at STA 0+100 to STA 4+500, obtaining 45 damaged road sections and becoming the object of this study. The details of road damage data for the 80 road sections studied based on the type of damage are presented in Table 2.

Table 2. Summary of Road Damage Assessment

No	Location Labels	Road Sections	The extent of Damage Types $(\mathbf{m^2})$						
			X_1	X_2	X_3	X_4	X_5	X_6	X_7
1	S0	0+000 s.d 0+100	3.5	0.00	0.00	0.00	2	0.00	0.00
2	S1	0+101 s.d 0+200	17	0.00	0.00	3.2	19	0.00	0.00
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
15	S48	4+801 s/d 4+900	6.1	4.6	4	0.00	0.00	0.00	0.00
16	T0	0+000 s.d 0+100	15.5	1.5	9.4	29	1.9	1.7	37.6
17	T1	0+101 s.d 0+200	19.57	0	0	5.45	1	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
35	T19	1+901 s/d 1+985	102.25	0.00	0	161.68	0.00	20	0.00
36	J0	0+000 s.d 0+100	56	0.00	1.44	55.54	0.00	13.6	0.00
37	J1	0+101 s.d 0+200	0.00	0.00	0.00	25.55	0.00	0.00	0.00
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
80	45	4+401 s/d 4+500	52.36	0.00	0.00	0	0.00	0.00	0.00

Descriptions:

X_1	:	Cracking	X_6	:	Rutting
X_2	:	Bumb and Sags	X_7	:	well
X_3	:	Depression	S	:	Label for Swarangan
X_4	:	Patching and Potholes	T	:	Label for Turki
X_5	:	Polished Agregat	J	:	Label for Jorong

The data of Table 2 in the decision matrix of the road damage assessment based on (1) obtained as:

$$
X = \begin{array}{c} \\ a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_{80} \end{array}
\begin{array}{c}
\begin{array}{ccccccc} c_1 & c_2 & c_3 & c_4 & c_5 & c_6 & c_7 \end{array} \\
\begin{bmatrix}
3,5 & 0.00001 & 0.00001 & 0.00001 & 2 & 0.00001 & 0.00001 \\
17 & 0.00001 & 0.00001 & 3,2 & 19 & 0.00001 & 0.00001 \\
58 & 0.00001 & 0.00001 & 0,8 & 3,9 & 0.00001 & 0.00001 \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
800 & 0.00001 & 0.00001 & 800 & 0.00001 & 0.00001 & 0.00001
\end{bmatrix}
\end{array} \quad \text{...(15)}
$$

there are 80 decision alternatives and seven decision criteria, with entries x_{ij} filled with data evaluating road damage levels at three locations.

Analysis of AHP-TOPSIS

The weighting results using the AHP method based on road damage data with seven criteria for types of road damage obtained are as follows:

Table 3. Road Damage Type Criteria Comparison Matrix

Criteria	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	1	3	2	3	2	3	4
X_2	0.33	1	3	4	3	3	2
X_3	0.50	0.33	1	3	2	3	3
X_4	0.33	0.25	0.33	1	3	3	2
X_5	0.20	0.33	0.50	0.33	1	3	3
X_6	0.33	0.33	0.33	0.33	0.33	1	3
X_7	0.25	0.50	0.33	0.50	0.33	0.33	1
Total Weight	2.95	5.74	7.49	12.16	11.66	16.33	18

The formed pairwise comparison matrix is normalized based on the Equation (2) as follows:

Table 4. Pairwise Normalization and Vector Eigen

Criteria	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Total	Vector Eigen
X_1	0.34	0.52	0.27	0.25	0.17	0.18	0.22	1.95	0.28
X_2	0.11	0.17	0.40	0.33	0.26	0.18	0.11	1.57	0.22
X_3	0.17	0.06	0.13	0.25	0.17	0.18	0.17	1.13	0.16
X_4	0.11	0.04	0.04	0.08	0.26	0.18	0.11	0.83	0.12
X_5	0.07	0.06	0.07	0.03	0.09	0.18	0.17	0.66	0.09
X_6	0.11	0.06	0.04	0.03	0.03	0.06	0.17	0.50	0.07
X_7	0.08	0.09	0.04	0.04	0.03	0.02	0.06	0.36	0.05

The eigenvector value is the total score normalization of rows divided by the number of criteria. The eigenvector is obtained as the weighted results of the criteria, with a consistent ratio CR = $\frac{0.14}{1}35 = 0.10$. Because CR = 0.01, it can be seen that the weights of each criterion are $w1 = 0.28$, $w_2 = 0.22$, $w3 = 0.16$, $w_4 = 0.12$, $w_5 = 0.09$, $w_6 = 0.07$, and $w7 = 0.05$, which have been consistent. The weight of each criterion will be used to rank using

TOPSIS. The normalization matrix $\left[R_{ij}\right]_{m\times n}$of road damage case obtained:

$$R = \begin{bmatrix} 0.0023847 & 0.00000 & 0.00373 & 0.00000 & 0.00186 & 0.00000 & 0.00000 \\ 0.0115828 & 0.00000 & 0.00373 & 0.00190 & 0.01770 & 0.00000 & 0.00000 \\ 0.0395180 & 0.00000 & 0.00373 & 0.00048 & 0.00364 & 0.00000 & 0.00000 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0.1520713 & 0.00000 & 0.00061 & 0.05665 & 0.00000 & 0.00000 & 0.00000 \end{bmatrix} .(16)$$

In this study, w_j represents the weight of the j^{th} criterion calculated from the eigenvector value in the AHP method weighting. Referring to Table 5, it can be seen that the weight of each criterion is $w_1 = 0.28$, $w_2 = 0{,}22$, $w_3 = 0.16$, $w_4 = 0.12$, $w_5 = 0.09$, $w_6 = 0.07$, $w_7 = 0.05$. The weighted normalized decision matrix $\left[V_{ij}\right]_{m\times n}$ can be presented in the following table

$$V = \begin{bmatrix} 0.000665 & 0.00000 & 0.00060 & 0.00000 & 0.00186 & 0.00000 & 0.00000 \\ 0.003232 & 0.00000 & 0.00060 & 0.00227 & 0.01770 & 0.00000 & 0.00000 \\ 0.011025 & 0.00000 & 0.00060 & 0.00048 & 0.00034 & 0.00000 & 0.00000 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0.1520713 & 0.00000 & 0.00061 & 0.05665 & 0.00000 & 0.00000 & 0.00000 \end{bmatrix} (17)$$

In this study, because all the criteria are types of damage where, the greater the area of damage in each type, the more excellent the opportunity for the road to be prioritized for repair. So that, critera $C_1, C_2, C_3, C_4, C_5, C_6,$ and C_7 are categorized as benefit criteria. Matrix Ideal obtained as follows:

$$A^{+} = \\ [0.15207 \quad 0.22269 \quad 18029.5 \quad 0.08620 \quad 0.06775 \quad 0.043975 \quad 0.047103] \ldots\ldots(18)$$

$$A^{-} = \\ [0.00000 \quad 0.00000 \quad 0.00061 \quad 0.00000 \quad 0.00000 \quad 0.000000 \quad 0.000000] \ldots\ldots(19)$$

The separation between each alternative is calculated using the Euclidean distance, with Closeness Coefficient based on (11) is obtained as:

Table 5. Summary of Ideal Solution & CC_i

Alternatives	d_i^{+}	d_i^{-}	CC_i
A1	18029.4857	0.000688	0.0000000381
A2	18029.4857	0.003639	0.0000002018
:	⋮	⋮	⋮
A79	18029.4857	0.013932	0.000000773
A80	18029.4857	0.162281	0.000009000

Alternative locations of the assessed road sections are sorted based on the C_i^{+}. The largest C_i^{+} becomes the road section most prioritized for repair. The results are as follows:

Table 6. Summary of AHP-TOPSIS Ranking Results

Ranking	Road Section Labels	Alternatives (i)	C_i^{+}
1	J34	A70	0.9999863613
2	J5	A41	0.482733316
3	J23	A59	0.2549999751
⋮	⋮	⋮	⋮
78	S0	A1	0.0000000381495
79	J10	A46	0.0000000241979
80	J24	A60	0.0000000222788

Based on the results of the alternative ranking, it can be seen that the road sections that are most prioritized for repair are the road sections on alternative A70, namely the road sections on Jorong Beach STA 3+401 to STA 3+500, STA +501 to 0+600, STA 2+301 to STA 2+3100. The following prioritized road sections are the road sections on Swarangan Beach: STA 0+000 to 0+100, Jorong Beach at STA 1+001 to STA 1+100, and STA 2+401 to STA 2+500.

Analysis of Entropy-TOPSIS

The criteria weighting value is obtained using the Entropy method (Zhao, Ma, dan Lin, 2022). The decision matrix, based on 80 alternatives and seven road damage criteria derived from the assessment data, is presented as a matrix $\left[X_{ij}\right]_{m\times n}$, as in (15), which has been previously written.

The normalization matrix is determined based on (dos Santos, Godoy, dan Campos 2019) entry P_{ij} as explained in Eq.(12). The normalization matrix of the road damage in this study obtained:

$$P = \begin{bmatrix} 0{,}8682 & 0.000002 & 0.000002 & 0.00002 & 0{,}4961 & 0.000002 & 0.000002 \\ 0{,}6616 & 0.0000004 & 0.0000004 & 3{,}2 & 19 & 0.0000004 & 0.0000004 \\ 0{,}9976 & 0.00000002 & 0.00000002 & 0{,}0138 & 0{,}0670 & 0.00000002 & 0.00000002 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0{,}7071 & 0.000000008 & 0.000000008 & 0{,}7071 & 0.000000008 & 0.000000008 & 0.000000008 \end{bmatrix} \ldots\ldots\ldots(20)$$

To set the Entropy weight E_j for each decision criterion, based on (Liu et al. 2021), we used Equation (13). The weighting results, Wj, were obtained using Equation (14) as follows (Zhu, Tian, dan Yan 2020). The Entropy weighting result of the road damage case was obtained as follows:

Table 7. The Weighting Results of Entropy

j	1	2	3	4	5	6	7
Ej	-3.792612	-1.145082	-2.402272	-3.705311	-1.956804	-0.512273	-0.396555
1-E_j	4.792612	2.145082	3.402272	4.705311	2.956804	1.512273	1.396555
wj	0.229192	0.102582	0.162703	0.225017	0.141400	0.072320	0.066786

It can be seen that the weight of each criterion is $w_1 = 0.229192, w_2 = 0.102582$, $w_3 = 0.162703$, $w_4 = 0.225017$, $w_5 = 0.141400$, $w_6 = 0.072320$, $w_7 = 0.066786$. The weight of each criterion is used for ranking the alternatives with TOPSIS. The normalization matrix $[R_{ij}]_{m\times n}$ of road damage follows matrix (16). Then, the normalized weighted decision matrix $[V_{ij}]_{m\times n}$ can be presented as:

$$V = \begin{bmatrix} 0.0005466 & 0.0000 & 0.0000 & 0.0000 & 0.00043 & 0.000 & 0.0000 \\ 0.0002655 & 0.0000 & 0.0000 & 0.0004 & 0.00406 & 0.000 & 0.0000 \\ 0.0090572 & 0.0000 & 0.0000 & 0.0001 & 0.00083 & 0.000 & 0.0000 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0.1249271 & 0.0000 & 0.0000 & 0.1090 & 0.0000 & 0.0000 & 0.0000 \end{bmatrix} \ldots\ldots\ldots (21)$$

The normalized weighted matrix is formed into a positive ideal solution matrix A^+ and a negative ideal solution matrix A^- based on Eqs. (10) and (11). Similar to AHP-TOPSIS, in Entropy-TOPSIS, critera $C_1, C_2, C_3, C_4, C_5, C_6$, and C_7 are categorised as profit criteria. The ideal solution matrix of Entropy-TOPSIS is obtained as follows:

$$A^+ = [0.124927 \quad 0.227772 \quad 0.184539 \quad 0.165863 \quad 0.165856 \quad 0.141472 \quad 0.208965] \ldots\ldots (22)$$

$$A^- = [16\times10^{-11} \quad 41\times10^{-11} \quad 62\times10^{-11} \quad 1\times10^{-10} \quad 2\times10^{-10} \quad 7\times10^{-8} \quad 5.6\times10^{-8}] (23)$$

The separation between each alternative is calculated using the Euclidean distance, with Closeness Coefficient based on (11) is obtained as:

Table 8. Summary of Entropy-TOPSIS CC_i

Alternatives	d_i^+	d_i^-	CC_i
A1	0.4690022632	0.0006937296245	0.001476975821
A2	0.4670228299	0.00486947898	0.01031904714
A3	0.4666349289	0.009096107019	0.01912027245
⋮	⋮	⋮	⋮
A78	0.4671882389	0.008176480261	0.01720043565
A79	0.4655553268	0.01164354654	0.02439977794
A80	0.4246836164	0.1657997259	0.2807864575

Alternative locations of the assessed road sections are sorted based on the C_i^+. The largest C_i^+ becomes the road section most prioritized for repair. The results are as follows:

Table 9. Summary of Entropy-TOPSIS Ranking

Ranking	**Road Section Labels**	**Alternatives (i)**	CC_i
1	J34	A70	0.4236447078
2	J28	A64	0.382401086
3	J23	A59	0.3375781585
⋮	⋮	⋮	⋮
78	S0	A1	0.00166171491
79	J10	A46	0.001476975821
80	J24	A60	0.0007502021168

Based on the results of the alternative ranking, it can be seen that the road sections that are most prioritized for repair are, respectively, the road sections on alternative A70, namely the road sections on Jorong Beach STA 3+401 to STA 3+500, alternative 64, road sections on Jorong STA 2+801 to 2+900, alternative A16, road sections on Turki Beach STA +000 to STA 0+100. The following prioritized road sections are Alternative 1, the road sections on Swarangan: STA 0+000 to 0+100, and Alternative 60, the road sections on Jorong: STA 2+401 to STA 21+500.

DISCUSSION

Based on the AHP-TOPSIS and Entropy-TOPSIS ranking results of 80 road sections, which were derived from the Closeness Coefficient values, it was found that the highest and lowest priority road section was consistently identified as road section J34. Similarly, the lowest priority road section was consistently identified as road section J24. The results indicate that both methods produced identical highest and lowest priority rankings. A comparison of the road section rankings is illustrated in Figure 2.

Table 10. PCI Values and Pavement Conditions

PCI Value	Pavement Conditions	PCI Value	Pavement Conditions
0 - 10	Failed	56 - 70	Good
11 - 25	Very Poor	71 - 85	Very Good
26 - 40	Poor	86 - 100	Excellent
41 - 55	Fair	56 - 70	Good

Furthermore, the ranking results obtained from the AHP-TOPSIS and ENTROPY-TOPSIS methods were evaluated against the Pavement Condition Index (PCI) assessment. The PCI is a numerical index ranging from 0 to 100 that represents the overall surface condition of a pavement section, with 100 representing the best possible condition and 0 representing the worst possible condition (Elhadidy, El-Badawy, dan Elbeltagi 2021).

The pavement condition is assessed based on the type and extent of damage, which serves as a guide for maintenance efforts. The PCI ranges from 0 (worst) to 100 (best) and is classified into the following categories: excellent, excellent, good, fair, poor, very poor, and failed. The pavement condition classification, as recommended by the FAA (1982) and Shahin (1994), is shown in Table 10 (Beheshtinia and Sayadinia 2021).

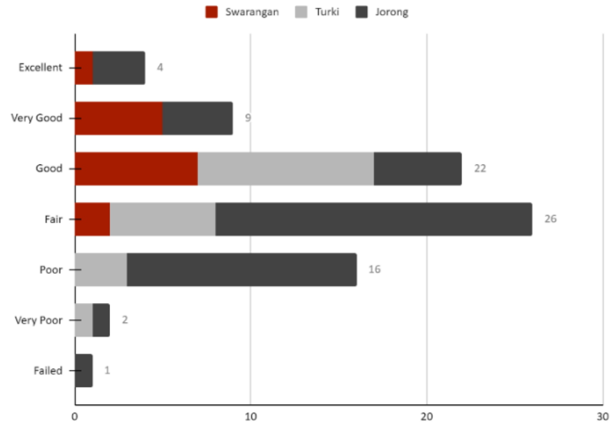

Figure 1. PCI of Road Damages at 3 Observed Locations

Based on the PCI results, it was observed that out of the 80 road sections studied across three locations—Swarangan, Turki, and Jorong—the majority of roads were categorized as having a fair condition, with 26 road sections identified as such. Additionally, one road section was classified as failed, two as having deplorable condition, and 16 as having poor condition. The remaining 35 road sections were categorized as good and have not yet been recommended for repair, including 22 road sections classified as good, nine as very good, and four as excellent.

The ranking results based on pavement conditions, as determined by the PCI values, along with those from AHP-TOPSIS and ENTROPY-TOPSIS, are presented in Figure 2.

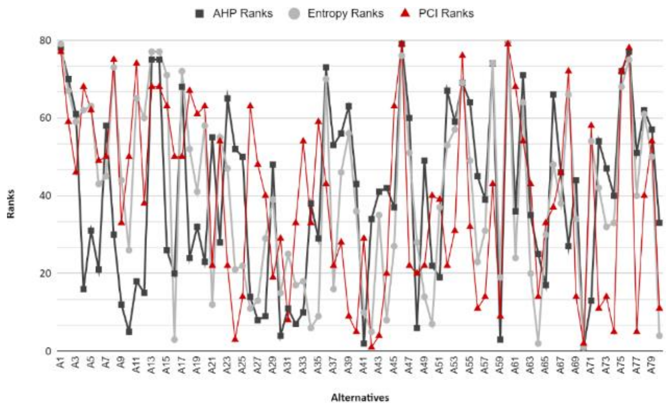

Figure 2 Summary of Ranking Comparison of AHP, Entropy, and PCI Methods

Based on the PCI results, a ranking order that aligns between the AHP-TOPSIS and Entropy-TOPSIS methods was determined for each road section. The comparison results were analyzed using the accuracy based on ranking similarity (percentage of similarity), as referenced by (Firgiawan, Zulkarnaim, dan Cokrowibowo 2020):

$$\text{Accuracy} = \frac{\textit{same amount of data}}{\textit{lots of data}} \times 100\% \quad (24)$$

In the AHP-TOPSIS method, 17 road segments had the same pavement condition ranking as the PCI. Meanwhile, in the Entropy-TOPSIS method, 22 road segments have the same pavement condition ranking as the PCI. The accuracy of each method, based on PCI results, is as follows:

$$\text{AHP-TOPSIS} = \frac{17}{80} \times 100\% = 21{,}25\% \quad (25)$$

$$\text{ENTROPY-TOPSIS} = \frac{22}{80} \times 100\% = 27{,}5\% \quad (26)$$

Based on the accuracy percentages of the AHP-TOPSIS and Entropy-TOPSIS methods, and considering the similarities in pavement conditions identified through the PCI analysis, it can be concluded that the Entropy-TOPSIS method is more accurate than the AHP-TOPSIS method.

These results reveal a noteworthy gap in the existing literature, where AHP-TOPSIS has often been regarded as more accurate due to its alignment with expert judgment. However, the results of this study demonstrate that Entropy-TOPSIS, which employs objective, data-driven weighting, can yield higher accuracy in the context of road repair prioritization. This indicates that Entropy-based approaches offer a more reliable alternative in cases where expert preferences are limited or potentially biased.

However, the accuracy levels of both methods remain relatively low when compared to the rankings derived from the road pavement damage results.

This low accuracy can be attributed to the fact that the Pavement Condition Index (PCI) analysis relies solely on the extent of road damage to categorize its severity. In contrast, MCDM methods, such as AHP-TOPSIS and Entropy-TOPSIS, determine priority rankings for damage not only based on the extent of damage but also the characteristics of the criteria associated with each type of road damage. These criteria are established through the weighting of the criteria for each type of damage.

The use of MCDM approaches in prioritizing road repair can serve as a relevant alternative to conventional methods such as the Pavement Condition Index (PCI), which primarily reflects the severity and extent of surface damage. MCDM facilitates the integration of multiple factors that influence decision-making, leading to a more comprehensive assessment. Moreover, its systematic steps allow for a transparent review of the scoring process and facilitate easier integration into decision support systems.

Although AHP-TOPSIS and Entropy-TOPSIS are considered practical and systematic in determining road repair priorities, both approaches present several challenges. In AHP-TOPSIS, the pairwise comparison of criteria relies on expert judgment, which may introduce an inconsistency in the weighting process. On the other hand, Entropy-TOPSIS, while more objective and data-driven, tends to overlook contextual considerations or local policy priorities that are critical in practical road maintenance planning. Although MCDM-based prioritization results often align with technical assessments, such as PCI scores, the actual implementation must still be adjusted to accommodate budget planning, network urgency, and agreements among stakeholders.

CONCLUSION AND RECOMMENDATION

Conclusion

The results of our comparative study on AHP-TOPSIS and Entropy-TOPSIS are significant. We found that Entropy-TOPSIS (27.5%) provides more accurate results than AHP-TOPSIS (21.25%) based on PCI assessment results. Among the 80 road sections studied, the section prioritized for repair (ranked first) according to both AHP and Entropy-TOPSIS is the road along Jorong Beach from STA 3+401 to 3+500 (Alternative 70), which is rated as 'Very Poor' according to the PCI assessment. Meanwhile, the last road section prioritized for repair is the same road along Jorong Beach from STA 2+401 to 2+500 (Alternative 60). These findings demonstrate that both AHP-TOPSIS and Entropy-TOPSIS are viable alternatives for supporting decision-making in road repair prioritization, as they allow for a more nuanced evaluation of not only the extent of damage but also the characteristics and contextual importance of each road section.

Recommendation

It is recommended that road maintenance planning integrate MCDM approaches with conventional indices, such as PCI, to enable more systematic and flexible prioritization. Among these, the Entropy-TOPSIS method offers higher accuracy in reflecting actual pavement conditions, making it a valuable tool for improving repair decisions.

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