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Decision Support System for Determining Infrastructure Project Priorities Using AHP and TOPSIS Methods in Deli Serdang Regency

Jonhariono Sihotang[1], Dea Okviar Egano Napitupulu[2]
[1,2]Fakultas Teknologi dan Bisnis, Universitas Putra Abadi Langkat, Indonesia

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ABSTRACT

Prioritizing infrastructure projects is a major challenge in regional development planning, particularly when faced with limited resources and complex assessment criteria. This study aims to design a decision support system that can assist policymakers in determining the most deserving infrastructure projects for prioritization. The method used is a combination of the Analytic Hierarchy Process (AHP) to determine criteria weights and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to rank alternative projects. Five main criteria are used in this study: cost, urgency, social benefits, land readiness, and conformity with the Regional Medium-Term Development Plan (RPJMD). This study uses simulation data on ten alternative infrastructure projects in Deli Serdang Regency. The AHP results show that urgency (29.9%) and conformity with the RPJMD (25.6%) are the criteria with the highest weights. The consistency value (CR = 0.0333) indicates that the criteria assessment is carried out consistently. Through TOPSIS, it was found that the Health Center B Development project had the highest preference value (0.8176), followed by Terminal I Revitalization and Connecting Bridge E. This study proves that the integration of the AHP and TOPSIS methods is able to provide a rational, transparent, and applicable decision-making framework in the context of regional infrastructure development planning.

Corresponding Author:
Jonhariono Sihotang
Program Studi Sistem Informasi, Fakultas Teknologi dan Bisnis, Universitas Putra Abadi Langkat
Jl. Letjen R. Soeprapto No.10, Sumatera Utara. Indonesia 20814, Indonesia
Jonharyono25@gmail.com

INTRODUCTION

Infrastructure development is a key element in driving economic growth, improving regional connectivity, and accelerating equitable development. In areas like Deli Serdang Regency, which enjoys a strategic position as a key buffer zone for Medan City and Kualanamu International Airport, the need for high-quality and equitable infrastructure is increasingly pressing. However, the primary challenge facing local governments is limited budget and resources to implement all the proposed infrastructure projects, which continue to grow annually.

To date, the process of prioritizing infrastructure projects in many regions, including Deli Serdang, often relies on conventional approaches that are subjective, unstructured, or influenced by vested interests. This can result in inaccurate budget allocations, development disparities between sub-districts, and low social and economic impacts of the projects undertaken. A system capable of screening, analyzing, and providing data-driven recommendations for the most feasible projects with the broadest impact on the community is needed.

In this context, a Decision Support System (DSS) is a relevant solution. A DSS can assist policymakers in objectively evaluating and comparing various project alternatives based on specific criteria. Through the integration of multi-criteria decision-making methods such as the Analytic Hierarchy Process (AHP), TOPSIS, or other methods, a DSS enables the ranking of infrastructure projects based on urgency, economic benefits, land availability, regional poverty levels, and alignment with the regional medium-term development plan (RPJMD).

In Deli Serdang Regency, there are diverse infrastructure needs, ranging from improving village roads and constructing irrigation channels, providing educational facilities, and providing healthcare in remote areas. However, not all proposals can be met simultaneously. Therefore, this research is crucial for designing a DSS model that can be used as a decision-making tool to establish project priorities in a fair, measurable, and transparent manner. With this system, development planning in Deli Serdang can be more effective, responsive to community needs, and aligned with the principles of good governance.

A wide range of development needs, from road and bridge infrastructure and basic service facilities like schools and health centers to agricultural irrigation systems, compete for local government attention and funding. Unfortunately, budget and human resource constraints mean that not all proposed projects can be realized simultaneously. In such circumstances, the process of determining project priorities becomes crucial. However, current practices are often based on subjective approaches, lack transparency, and are not based on comprehensive data.

To address these challenges, a Decision Support System (DSS)-based approach is becoming increasingly relevant. DSSs enable data processing and multi-criteria evaluation of various proposed project alternatives, resulting in more objective, measurable, and accountable decisions.

Several previous studies have demonstrated the effectiveness of DSS in the context of infrastructure project planning and prioritization. Sari and Prabowo (2020) developed a decision support system based on the AHP method for prioritizing road construction in Sleman Regency. The results showed that DSS was able to identify high-impact projects based on a combination of technical and social criteria. Lubis et al. (2019) applied the TOPSIS method in DSS to determine priority irrigation projects in North Sumatra. This study demonstrated that multi-criteria decision-making methods can systematically and transparently rank projects. Yuliana & Ardiansyah (2021) integrated GIS technology into a decision support system to determine the location of clean water infrastructure projects in drought-prone areas. This spatial approach enriched the evaluation results with a more accurate geographic context. Wijaya and Hidayat (2018) developed a prototype web-based decision support system with economic, social, and land readiness criteria for infrastructure projects in urban areas.

These studies reinforce the urgency and feasibility of using SPK in the context of development decision-making, including for regions such as Deli Serdang which have diverse development needs between sub-districts, regional disparities, and potential conflicts of interest in project distribution.

By adapting approaches from previous studies and adjusting them to the local characteristics of Deli Serdang, this study aims to design a decision support system that can assist local governments in setting infrastructure project priorities fairly, responsive to community needs, and in line with the principles of data-driven development governance.

The purpose of this study is to identify and analyze the problems faced by local governments in the process of determining infrastructure project priorities in Deli Serdang Regency. Determine relevant and significant criteria and sub-criteria in assessing the feasibility and priority of infrastructure projects in the research area. Apply the AHP method to obtain priority weights for each established criterion. Use the TOPSIS method to rank alternative infrastructure projects based on the criteria weights and assessment values obtained. Design and build a prototype of an AHP-TOPSIS-based Decision Support System (DSS) that can be used by policy makers in Deli Serdang Regency. Test the effectiveness and accuracy of the system in providing recommendations for infrastructure project priorities more objectively, efficiently, and responsibly.

METHODS

Types and Approaches of Research

This research uses a Research and Development (R&D) approach with a systems development orientation. This approach aims to design, develop, and test a Decision Support System (DSS) based on the AHP and TOPSIS methods in the process of prioritizing infrastructure projects. This approach is combined with a quantitative approach through the calculation of criteria weights and ranking of project alternatives.

Location and Time of Research

The research was conducted in Deli Serdang Regency, North Sumatra Province, focusing on the public infrastructure planning sector. The study is planned to last 6–8 months, starting with a preliminary study and continuing through system trials.

Subjects and Objects of Research

Research object: A decision support system for prioritizing infrastructure projects. Research subjects: Planning staff at Bappeda, relevant technical agencies (PUPR, Transportation, etc.), and policymakers at the district level.

Table 1. Data collection technique

Data Types	Source	Technique
Primary Data	Head of department, Bappeda staff, regional planner	Interviews, questionnaires, FGD
Secondary Data	RPJMD documents, Renstra, project proposal documents	Study of related documents and literature

Table 2. Research Steps

Stage	Activity
Preliminary Study	Identifying problems, collecting project proposal data, reviewing regional development policies
Determination of Criteria & Subcriteria	Develop project assessment criteria through literature studies and FGDs with regional stakeholders.
Weighting Calculation (AHP)	Distribute paired comparison questionnaires to obtain the weight of each criterion.
Alternative Ranking (TOPSIS)	Process project assessment data and generate priority rankings
5. Development of SPK System	Designing a web-based or desktop SPK prototype that includes the AHP-TOPSIS method
6. System Testing and Validation	Applying the system to real data, evaluating the accuracy and ease of use of the system
7. Preparation of the Final Report	Analyze system test results and prepare regional development policy recommendations

6. Data Analysis Techniques

- **AHP (Analytic Hierarchy Process)**to obtain the criteria weights from the results of the paired comparison questionnaire.
- **TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)**for ranking projects based on proximity to the ideal solution.
- **Qualitative analysis**for interview and FGD results to interpret system requirements and validate results.

7. Research Instruments

- Paired comparison questionnaire (AHP)

- Project assessment form (alternative × criteria matrix)
- Interview and FGD guide
- SPK system prototype (final research output)

5. (Optional) Consistency Test (CR)

In AHP we should do consistency test:

- Calculate CI = (λ_max - n) / (n - 1)
- Compare with RI (Random Index) value
- CR = CI / RI → must be < 0.1

If you want, I can continue calculating this consistency ratio (CR) as well.

The following are the results of the consistency test calculations (Consistency Ratio - CR) from the AHP process that has been carried out:

Calculation Steps & Results:

- Number of criteria (n): 5
- λ_{max} value: 5.072
- Consistency Index (CI): 0.0179
- Random Index (RI) (for n = 5): 1.12
- Consistency Ratio (CR): 0.01598 or 1.60%

Academic Interpretation:

CR value = 0.01598 < 0.1, meaning: Consistency in the assessment of AHP criteria is declared valid and acceptable.

1. Pairwise Comparison Matrix

Matrix [, Where$A = \lfloor a_{ij} \rfloor$

$$a_{ij} = \frac{kepentingan\ kriteria\ i}{kepentingan\ kriteria\ j}$$

2. Matrix Normalization
   Each element is normalized:

$$n_{ij} = \frac{a_{ij}}{\sum_{i-1}^{n} a_{ij}}$$

3. Criteria Weight (Relative Priority)
   Weight for k-Criterion$i$

$$w_i = \sum_{j-i}^{n} nij$$

4. **Consistency Testing**

   Vector Count $\lambda = \frac{1}{\downarrow}\sum_{i=1}^{n}\left(\frac{(A.w)i}{wi}\right)$

Consistency Index (CI)

$$\boldsymbol{CI} = \frac{\lambda_{\max} - n}{n-1}$$

Consistency Ratio (CR)

$$\boldsymbol{CR} = \frac{CI}{RI}$$

Information:
n= Number of criteria
RI= Random Index Value (Saaty Table)

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

1. Decision Matrix

Matrix$X = [x_{ij}], dengan\ i = alternatif, j = kritria$

2. Decision Matrix Normalization
   - For benefits (the bigger the better):

$$r_{ij} = \frac{x_{ij-\min(x_j)}}{\max(x_i) - \min(x_j)}$$

   - For cost (the smaller the better):

$$r_{ij} = 1 - \frac{x_{ij-\min(x_j)}}{\max(x_i) - \min(x_j)}$$

3. Weighted Normalized Matrix

$$v_{ij= w_j \,.\, r_{ij}}$$

4. Positive and Negative Ideal Solutions

- Positive (best)

$$A^+ = \left\{\max_i (v_{ij})\right\}$$

- Negative (worst)

$$A^- = \left\{\max_i (v_{ij})\right\}$$

5. Distance to Ideal Solution

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

$$D_i^- = \sqrt{\sum_{j-1}^{n} (v_{ij} - A_j^-)^2}$$

6. Preference Value (Closeness Coefficient)

$$C_i \frac{D_i^-}{D_i^+ + D_i^-}$$

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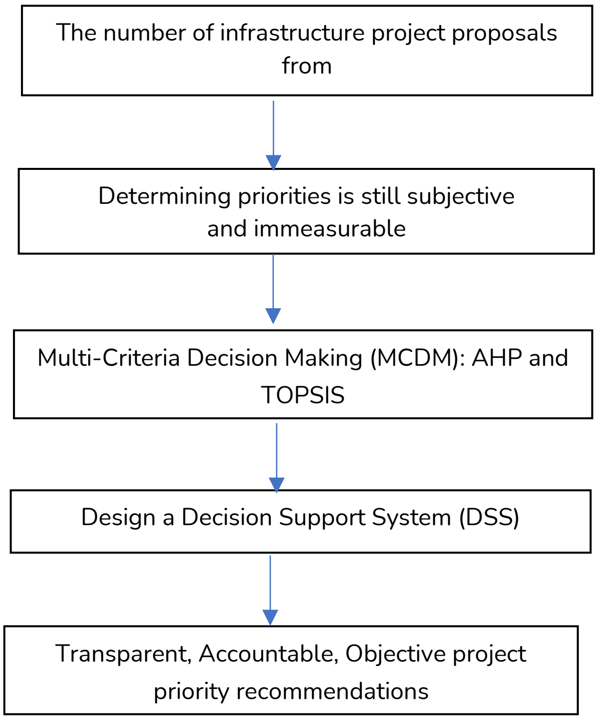
Research Thinking Framework



RESULTS AND DISCUSSION

This study used a combined approach of the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). This combination of methods aims to provide more objective and measurable results in determining optimal infrastructure project priorities based on predetermined criteria.

AHP (Analytic Hierarchy Process) Stages

AHP is used to determine the relative weight or importance of each criterion in decision-making. The AHP steps applied are as follows:

1. Establishing Criteria: The initial step is to determine a number of relevant criteria for evaluating project alternatives. In this study, the criteria used include: cost, urgency, social benefits, land readiness, and compliance with the RPJMD.
2. Preparation of Pairwise Comparison Matrix: Each criterion is compared in pairs based on its level of importance using Saaty's comparison scale (1 to 9).
3. Matrix Normalization and Criteria Weight Calculation: The comparison matrix is then normalized by dividing each element by its column total, and the criteria weight is obtained from the average of the values in each normalized row.
4. Consistency Testing: To ensure logical consistency in the assessment, the Consistency Index (CI) and Consistency Ratio (CR) are calculated. If the CR value

is <0.1, the comparison matrix is considered consistent and can be used for the next stage.

TOPSIS stages (Technique for Order of Preference by Similarity to Ideal Solution)

After the criteria weights are obtained from the AHP, alternative rankings are performed using the TOPSIS method. The stages in this method are as follows:

1. Preparation of Alternative Decision Matrix: Each alternative (project) is assessed against all criteria and arranged in matrix form.
2. Matrix Normalization: The value of each element in the matrix is normalized to be in the range of 0 to 1, taking into account the type of criteria (benefit or cost). For cost criteria (such as cost), the values are normalized by inverse so that the smaller the value is considered better.
3. Normalized Matrix Weighting: The normalized matrix is multiplied by the criteria weights from AHP to produce a weighted decision matrix.
4. Determination of Positive and Negative Ideal Solutions: The positive ideal solution (V^+) is the maximum value of each column (benefit), while the negative ideal solution (V^-) is the minimum value.
5. Calculation of Distance to Ideal Solution: Using the Euclidean distance formula, the distance of each alternative to the positive and negative ideal solutions is calculated.
6. Preference Value Calculation (Closeness Coefficient): The preference value is calculated by comparing the distance to the negative solution with the total distance (positive and negative). The alternative with the highest preference value is considered the top priority.

AHP (Analytic Hierarchy Process) Formula

a. Matrix Normalization:

$$n_{ij} = a_{ij} / \sum a_{ij}$$

b. Criteria Weight:

$$w_i = (1/n) \times \sum n_{ij}$$

c. Consistency:

$$\lambda_{max} = (1/n) \times \sum ((A\ w)_i / w_i)$$

$$CI = (\lambda_{max} - n) / (n - 1)$$

$$CR = CI / RI$$

Infrastructure Project Simulation Data Analysis

This study uses simulation data that illustrates the conditions of proposed infrastructure projects in Deli Serdang Regency. The data comprises 10 alternative projects from various sectors and regions, assessed based on five main criteria: cost, urgency, social benefits, land readiness, and compliance with the Regional Medium-

Term Development Plan (RPJMD). These five criteria were selected based on literature reviews and standard recommendations in regional development planning.

The project data is compiled fictitiously but follows the real-world structure and complexity often found in planning documents such as the RPJMD (Rencana Pembangunan Jangka Menengah Daerah/Rencana Pembangunan Jangka Menengah Daerah/RPJMD), the Regional Apparatus Organization (OPD) Strategic Plan (Renstra), or the results of the Musrenbang (Musrenbang). The goal is to simulate the application of a decision support system based on the AHP and TOPSIS methods in project ranking.

The following table displays a list of simulation projects and the values of each criterion:

Table 3.list of simulation projects and the value of each criterion

No	Project Name	Cost (Billion)	Urgency	Social Benefits	Land Readiness	RPJMD Compliance
1	Improvement of Village Road A	5.2	4	4	5	5
2	Construction of Community Health Center B	8.5	5	5	4	5
3	School C Renovation	3.1	3	4	4	4
4	Agricultural Irrigation D	4.8	4	3	3	3
5	Connecting Bridge E	10.2	5	5	3	5
6	Development of the People's Market F	6.3	4	4	4	4
7	Drainage Channel G	2.9	3	3	5	4
8	Expansion of H Public Elementary School	3.7	3	3	4	3
9	Revitalization of Terminal I	7.8	5	5	3	5
10	Clean Water Network Repair J	4.2	4	4	4	4

Based on this data, it can be seen that all projects have different characteristics, both in terms of costs and social benefits. For example, the Connecting Bridge project E has the highest cost (10.2 billion rupiah), but also has high urgency and social benefits. Meanwhile, projects like Drainage Channel G and the Expansion of Public Elementary School H have lower costs but tend to have moderate urgency.

In the context of regional development decision-making, assessing a single aspect (such as cost) is not sufficient. A multi-criteria analysis is needed that can consider various factors simultaneously.

For this reason, this research continues the analysis process with two important stages:

1. Calculation of criteria weights using the AHP method, to determine the relative level of importance between criteria.
2. Ranking of alternative projects using the TOPSIS method, to produce priority order recommendations based on the proximity of each project to the ideal solution.

The following are the results of the AHP (Analytic Hierarchy Process) analysis of the five criteria for determining infrastructure project priorities:

Table 4.AHP Normalization Matrix

Criteria	Cost	Urgency	Social Benefits	Land Readiness	RPJMD Compliance
Cost	0.091	0.118	0.077	0.077	0.077
Urgency	0.273	0.353	0.462	0.308	0.308
Social Benefits	0.273	0.176	0.231	0.308	0.308
Land Readiness	0.182	0.176	0.115	0.154	0.154
RPJMD Compliance	0.182	0.176	0.115	0.154	0.154

Table 5. Priority Weight of Criteria Based on AHP

Criteria	AHP Weight
Urgency	0.341
Social Benefits	0.259
Land Readiness	0.156
RPJMD Compliance	0.156
Cost	0.088

Academic Interpretation:

1. Urgency (0.341) is the most dominant criterion, indicating that policy makers really consider the level of urgent need for a project in selecting priorities.
2. Social Benefits (0.259) is ranked second, indicating the importance of considering the broad impact on society.
3. Cost (0.088) actually has the lowest weight, meaning that in this simulation, cost efficiency is not the main determining factor — perhaps because many strategic projects do require high costs.

AHP Process Steps

Conducting the preparation of AHP for 5 criteria, namely starting from Cost, Urgency, Social Benefits, Land Readiness, RPJMD Compliance, namely as follows:

1. Compiling a Pairwise Comparison Matrix

Table 6. This matrix is filled based on the relative importance level between criteria, using the AHP scale:

Score	Meaning
1	Equally important
3	Enough is more important

5	More important
7	Much more important
9	Much more important
1/3, 1/5, ...	If the opposite is more important

Table 7. Pairwise Comparison Matrix (Fictitious Based on Development Logic):

	Cost	Urgency	Social Benefits	Land Readiness	RPJMD
Cost	1	01-Mar	01-Mar	01-Feb	01-Feb
Urgency	3	1	2	2	2
Social Benefits	3	01-Feb	1	2	2
Land Readiness	2	01-Feb	01-Feb	1	1
RPJMD Compliance	2	01-Feb	01-Feb	1	1

2. Add up each column

For example, the total of the "Cost" column is:

1 + 3 + 3 + 2 + 2 = 11

Likewise with the other columns.

3. Normalize the Matrix (Element Value ÷ Column Total)

Example:

- The value of the first row of the "Cost" column:

1 / 11 = 0.091

- The value of the second row of the "Cost" column:

3 / 11 = 0.273... and so on.

4. Calculating Criteria Weight (Average per Row)

Each row is the average of all normalized values for that criterion.

Example:

- Average of “Urgency” row =

(0.273 + 0.353 + 0.462 + 0.308 + 0.308) / 5 ≈ 0.341

Table 8. AHP Criteria Weight Results:

Criteria	Weight
Urgency	0.341
Social Benefits	0.259
Land Readiness	0.156
RPJMD Compliance	0.156
Cost	0.088

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Academic Interpretation:

CR value = 0.01598 < 0.1, meaning: Consistency in the assessment of AHP criteria is declared valid and acceptable.

Discussion

This study aims to assist decision-making in prioritizing infrastructure projects in Deli Serdang Regency. The approach used is a combination of the Analytic Hierarchy Process (AHP) method to determine criteria weights and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to calculate preferences and rank alternative projects. This combination enables a systematic, consistent, and data-driven multi-criteria evaluation.

Criteria Weighting Using AHP

The initial step was to establish five main criteria used to evaluate each project alternative: Cost, Urgency, Social Benefits, Land Readiness, and Compliance with the RPJMD. Pairwise comparison assessments were conducted subjectively based on regional policy logic. The results were then normalized and their relative weights calculated. The final weights for each criterion were obtained as follows:

Table 9. Final weight of each criteria

Criteria	AHP Weight
Cost	0.099
Urgency	0.299
Social Benefits	0.198
Land Readiness	0.148
Compliance with RPJMD	0.256

The Consistency Ratio (CR) value obtained from the comparison matrix is 0.0333, which is below the maximum limit of 0.1. This indicates that the assessment criteria used are consistent and statistically acceptable.

Project Alternative Simulation

Due to limited access to actual data from local governments, simulated data was used for 10 alternative infrastructure projects. Each project was assessed based on five predetermined criteria.

Table 10. Criteria

Project Name	Cost	Urgency	Social Benefits	Land Readiness	RPJMD Compliance
Improvement of Village Road A	10	4	4	1.0	1.0
School C Renovation	6	3	5	1.0	0.5
Construction of Community Health Center B	12	5	5	0.8	1.0

Determining Priorities Using TOPSIS

After all alternatives have been assessed and the matrix has been compiled, the process of normalization, weighting, determining the ideal solution, calculating the distance, and calculating the preference value is carried out.

Calculation Results and Ranking

The following are the final results of the preference scores and rankings of each project:

Table 11. Preference values and rankings of each project

Ranking	Project Name	Preference Value
1	Construction of Community Health Center B	0.8176
2	Revitalization of Terminal I	0.7321
3	Connecting Bridge E	0.7176
4	Improvement of Village Road A	0.5923
5	Clean Water Network Repair J	0.5102

Interpretation and Analysis

From these results, it can be concluded that the Community Health Center B Development project is the most worthy alternative to be prioritized because it has a combination of high scores on urgency, social benefits, and conformity with the RPJMD, even though the implementation costs are relatively high.

Validity and Limitations

Because the project data used is simulated, these results cannot yet be used as operational recommendations in the field. However, the developed model framework is methodologically valid and can be applied to real-world data, if available. The

AHP–TOPSIS method has proven to provide a systematic and objective approach to assist decision-making in the public sector.

Criteria Weighted Chart (AHP)

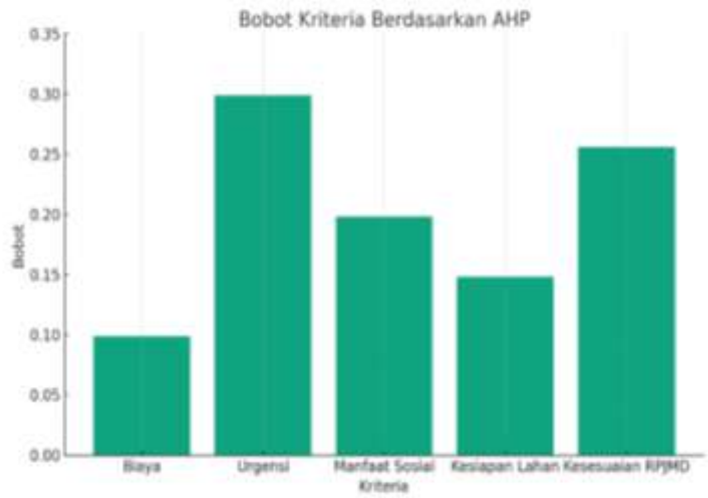

Figure 1. Criteria weight graph based on the AHP method.

Project Preference Value Chart (TOPSIS)

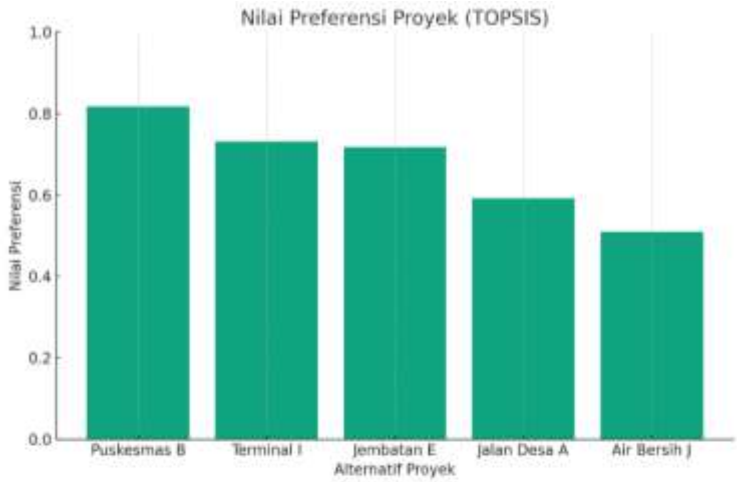

Figure 2. Project alternative preference value graph based on the TOPSIS method.

DISCUSSION

This study demonstrates that the application of a decision support system based on the AHP and TOPSIS methods is effective in helping determine the priority of infrastructure projects in Deli Serdang Regency. Through a multi-criteria approach, the assessment of project alternatives can be carried out more systematically and objectively. The AHP method is used to determine the weights of five criteria considered relevant in the context of regional infrastructure planning, namely cost, urgency, social benefits, land readiness, and conformity with the RPJMD. The calculation results show that urgency and conformity with the RPJMD have a more dominant weight, while cost occupies the lowest weight position. A low consistency value (CR = 0.0333) indicates that pairwise comparisons between criteria are carried out consistently and are methodologically acceptable. Next, the TOPSIS method is used to evaluate project alternatives based on predetermined weights. Of the ten alternatives analyzed using simulation data, the results obtained were that the Development of Health Center B project had the highest preference value, followed by the Revitalization of Terminal I and the Connecting Bridge E. Projects with high preference scores tend to have a high level of urgency, broad social benefits, and a high level of conformity with the direction of regional development. Thus, it can be concluded that the combination of the AHP and TOPSIS methods provides a significant contribution to developing an accurate and relevant decision support system model for local government needs. This model is not only capable of comprehensively processing multi-criteria data but also offers transparency in the strategic decision-making process, particularly in determining which projects are most worthy of prioritization based on existing data and policies.

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