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The Determination of Development Priorities Road Infrastructure at "Dinas Pekerjaaan Umum dan Penataan Ruang Kabupaten Balangan" Using AHP and Bayes Methods

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Abstract

The construction industry is a significant part of the gross domestic product of any country, and its success can lead to the long-term economic and social development of lives in general. Many studies have found a positive link between public infrastructure and the economy. Infrastructure investment directly affects economic growth. Well-designed infrastructure will have long-term financial benefits. The Ministry of Public Works and Housing (Pekerjaan Umum dan Perumahan Rakyat / PUPR) has played an essential role in strengthening the monitoring and evaluation of the implementation of infrastructure development by local authorities, including making the right policies in determining infrastructure development priorities. The Analytical Hierarchy Process (AHP) and Bayes method were used in this study. First, we used AHP to derive independent weights for criteria. Then, we determined the closeness between priorities to produce a sequence of infrastructure development priorities. Based on the results, using Analytical Hierarchy Process (AHP) and Bayes Method showed that Lampihong-Panaitan, Halong-Tabuan, and Bihara-Tariwin roads are Priorities for development. Then the Wangkili-Pudak road, and finally, the Awayan-Bihara. Decision support systems using the AHP and Bayes methods can determine priorities for road infrastructure development at the Office of Public Works and Public Housing in Balangan Regency.

Keywords: *Analytic Hierarchy Process (AHP); Bayes* Method; Decision Support System

Abstrak

Industri konstruksi adalah bagian penting dari produk domestik bruto negara mana pun, dan keberhasilannya dapat mengarah pada perkembangan ekonomi dan sosial kehidupan secara umum dalam jangka panjang. Banyak penelitian telah menemukan hubungan positif antara infrastruktur publik dan ekonomi. Investasi infrastruktur secara langsung mempengaruhi pembangunan ekonomi. Infrastruktur yang dirancang dengan baik akan memiliki manfaat ekonomi jangka panjang. Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR) telah berperan penting dalam memperkuat pemantauan dan evaluasi pelaksanaan pembangunan infrastruktur oleh otoritas daerah, termasuk membuat kebijakan yang tepat dalam menentukan prioritas pembangunan infrastruktur. Metode Analytical Hierarchy Process (AHP) dan Bayes digunakan dalam penelitian ini. Pertama, kami menggunakan AHP untuk memperoleh bobot independen untuk kriteria. Kemudian, kami menetapkan menentukan kedekatan antar prioritas untuk menghasilkan urutan prioritas *pembangunan infrastruktur. Berdasarkan hasil analisis, menggunakan Analytical Hierarchy Process (AHP) dan Metode Bayes menunjukkan bahwa jalan Lampihong-Panaitan, Halong-Tabuan, dan Bihara-Tariwin menjadi prioritas untuk dikembangkan. Kemudian jalan Wangkili-Pudak dan terakhir jalan Awayan-Bihara. Sistem pendukung keputusan dengan metode AHP dan Bayes dapat menentukan prioritas pembangunan infrastruktur jalan pada Dinas Pekerjaan Umum dan Perumahan Rakyat Kabupaten Balangan.*

Kata Kunci : Analytic Hierarchy Process (AHP); Metode Bayes; Sistem Penunjang Keputusan;

INTRODUCTION

Infrastructure plays a vital role in a country's economic growth. The infrastructure system is the primary support for the functions of the social and economic system in the community's daily life (Warsilan & Noor, 2015). The construction industry is also a significant part of the gross domestic product of any country, and its success can lead to the long-term economic and social development of lives in general(Sarvari, Chan, Alaeos, Olawumi, & Abdalridah Aldaud, 2021).

The infrastructure system can be defined as basic facilities or structures, equipment, and installations built and required for the social and community economic systems (Endi Pratista & Gde Ariastita, 2013). A previous study revealed that infrastructure positively affected economic growth, whereas direct economic growth harmed income inequality. Infrastructure indirectly reduces income inequality. Thus, infrastructure development, fundamental infrastructure, and transportation could reduce income inequality in Indonesia (Nugraha, Prayitno, Situmorang, & Nasution, 2020).

Many studies have found a positive link between public infrastructure and the economy. Infrastructure investment directly affects economic development. Well-designed infrastructure will have long-term economic benefits. It can raise economic growth, productivity, land values, and significant positive spillovers. (Srinivasu & Srinivasa Rao, 2013).

To support strategic areas, economic growth needs to be supported by providing adequate infrastructure, especially roads, to encourage regional economic development (Kartikasari, Sitorus, & Soma, 2017).

The infrastructure budget is increasing yearly, but the competitiveness of Indonesian infrastructure in the world still needs attention. The targets of the 9th SDGs in line with the 2020-2024 policy are the development of information and communication technology infrastructure, increased productivity, and the strength of economic infrastructure through roads, railways, ships, air, and terrestrial connections. However, they were not achieved. (Sulistyowati & Wibowo, 2022). The Ministry of Public Works and Housing (Pekerjaan Umum dan Perumahan Rakyat / PUPR) has played an essential role in strengthening the monitoring and evaluation of the implementation of infrastructure development by local authorities, including making the right policies in determining infrastructure development priorities.

Many methods in the academic literature deal with decision-making (MCDM) problems, including the Analytical Hierarchy Process (AHP). AHP has gained popularity in various fields due to its simple nature and ability to break down complex decision problems into systematic processes. However, AHP assumes that the criteria are independent, which may not be accurate in many real-world situations (Chen & Huang, 2023).

To solve the independence hypothesis in AHP, it can use probabilities obtained with the Bayesian formula to improve the accuracy of the AHP model's data input (Mimović, Stanković, & Milić, 2015).

Previous studies used the Analytic Hierarchy Process (AHP) method to analyze and prioritize critical success factors in construction projects in Ethiopia. After the survey data was collected, an AHP analysis was performed to calculate the relative weight of each success factor. This method used normalization to calculate the relative importance of each criterion. The results of the AHP analysis showed that the top success factors in construction projects in Ethiopia, such as Adequate Objectives/Aims, Competence of the Consultant, Prior Experience of the Consulting Firm, Willingness and Cooperation of the Consulting Firm, and Contractor's Financial Condition (Belay, Goedert, Woldesenbet, & Rokooei, 2022).

Other research used AHP (Analytical Hierarchy Process) to determine the Priority of infrastructure development for agrotourism in Karo Regency. This research indicates that the Priority for infrastructure development in supporting agrotourism in Karo Regency was complex infrastructure, focusing on clean water development. The AHP analysis showed that complex infrastructure has the highest Priority, with a value of 0.750, while clean water development within the hard infrastructure category had a priority value of 0.389 (Tonny & Wulan, 2020).

A study about assessing flood risks on road infrastructures using Bayesian networks was done in Santarem, Portugal. The study found that 61% of sub-basins in Santarem have a low flood risk, 30% have a medium flood risk, and 9% have a high flood risk. The most influential factors on high flood risk were identified as the EPSI factor, light traffic vehicles, and soil type (Arango, Santamaria, Nogal, Sousa, & Matos, 2022).

However, to our knowledge, no studies have explored applying the AHP and Bayesian methods (BM) to determine infrastructure priorities. This study analyzes and prioritizes road infrastructure development using AHP and Bayes Method to help decision-makers in public works and public housing agencies determine priorities.

RESEARCH METHODS

Leaders decide to solve their problems by starting one of the best problem-solving alternatives based on specific considerations (criteria). Decision-making must be carried out systematically, then collect facts, thoroughly determine the alternatives faced, and then take action which, according to calculations, is the most appropriate (Pratiwi, 2016).

The Analytical Hierarchy Process (AHP) and Bayes method were used in this study. First, we used AHP to derive independent weights for criteria. Then, we determined the closeness between priorities to produce a sequence of infrastructure development priorities. This can help the head of the service in making policies in determining infrastructure priorities.

The data collection process used in this study, i.e., road data and several criteria that support priority decisions for road infrastructure development.

Decision Model with AHP

The decision model with AHP is carried out through the following steps:

1. Create a Hierarchy (Decomposition)

Complex systems can be understood by dividing them into minor and understandable elements, as shown in Figure 1. The figure shows the Priority of road infrastructure based on several criteria. Determination of measures obtained from the existing standards in The Department of Public Works and Housing of Balangan Regency.

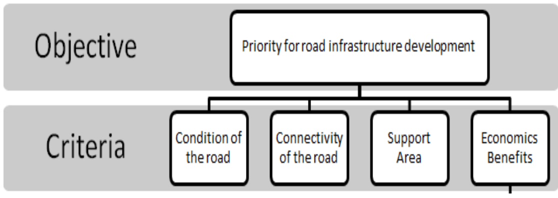

Figure 1. Hierarchical Structure

2. Evaluation of criteria and alternatives (Comparative Judgment)

Bars and options were done through pairwise comparisons. The value of the pairwise comparison table is based on the policy of the decision maker by looking at the level of importance between one element and another.

Comparison values between criteria for calculating AHP were obtained from interviews with the Head of the Department of Public Works and Housing of Balangan Regency.

The number of questions was obtained using n(n-1)/2 (Taherdoost, 2018), where n is the number of criteria. The results of the interviews are as follows:

1. Road conditions are 3 (three) times more critical than road connectivity.
2. Road conditions are 5 (five) times more important than supporting areas.
3. Road conditions are 9 (nine) times more important than economic benefits.
4. Road connectivity is 4 (four) times more important than supporting areas.
5. Road connectivity is 8 (eight) times more important than economic benefits
6. Supporting areas are 6 (six) times more important than financial benefits.

3. Determining Priority (synthesis of Priority)

Determine the Priority of the criteria elements considered as weight/contribution of factors to decision-making. AHP performs element priority analysis using the pairwise comparison method between two parts to meet all aspects. This Priority is determined based on the views of experts and interested parties in decision-making, either directly or indirectly.

4. Logical Consistency

Consistency has two meanings. First, similar objects can be grouped according to similarity and relevance. Second, regarding the level of relationship between objects based on specific criteria. To calculate and generate priorities, the calculation formula is as follows:

$$CI = \frac{\lambda max - n}{n-1} \quad (1)$$

Explanation:
CI: consistency index
λ max : the largest eigenvalue of matrix
n: Number of criteria

$$CR = \frac{CI}{RI} \quad (2)$$

Explanation:
CR: Consistency Ratio
CI: consistency index
RI: Random Index

Table 1. Random Index Value

n	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41
n	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
RI	1.45	1.49	1.51	1.48	1.56	1.57	1.59	

The comparison matrix is acceptable if the consistency ratio (CR) value ≤ 0.1.(Shyamprasad & Kousalya, 2020)

Decision Model With Bayes Method

The Bayes method is a technique that can be used to perform analysis in making the best decision from several alternatives to produce optimal results (Marimin, 2004). To have an optimal decision, it is necessary to consider various criteria. An example of the Bayes method was carried out in previous Research by Sigalingging, Handiwidjojo, & Oslan (2013). The focus of this research is how to categorize eligible students to participate in Community Service Programs. From the criteria it is compiled into a system capable of producing programs that will help find prospective Community Service Program participants who meet the requirements of administration and recommend prospective Community Service Program participants according to type. The Community Service Program used the Naïve Bayes method. However, the Bayesian method can only solve classification problems with supervised learning and categorical data. Therefore, using the Bayesian approach requires prior knowledge in making decisions. In this study, the authors combined two methods, namely the AHP and Bayes methods, to set priorities, to obtain higher results and accuracy. The Bayes equation used to calculate the value of each alternative is often simplified to:

$$Total\ Score_i = \sum_{j=1}^{M} Score_{ij}\left(Criteria_j\right) \quad (3)$$

Explanation:
Total score: total final score of the 1st alternative
ij value: the value of I alternative on the j-criteria
Criteria j: level of importance (weight) of the j criteria
i : 1,2,3,...n; n=number of alternatives
j : 1,2,3,...m; m=number of criteria

Table 2. Decision Matrix of Bayes

Alternative (ALT)	Criteria				A score of Decision Alternatives	The Rank of Decision Alternatives
	K_1	K_1	......	K_n		
ALT_1	V_{11}	V_{12}	......	V_{1n}	NK_1	
ALT_2	V_{21}	V_{22}	......	V_{2n}	NK_2	
ALT_3					:	
:	:					
ALT_m	V_{m1}	V_{m2}	......	V_{mn}	NK_m	
Weight	B_1	B_2	.....	B_n		

Model Suitability Testing According to Experts

Model suitability testing involved six respondents selected according to their influential fields in determining road infrastructure development plans.

Questionnaire Filling

Six experts selected according to their fields in determining priorities for road infrastructure development at the Public Works and Spatial Planning Office of Balangan Regency filled out the questionnaire. The total number of experts were six male.

Table 3. Expertise Data

No	Name	Position
1.	Budi Ansari, SE	Head of Planning and Finance Subdivision
2.	Cecep Ruswantoro, MT	Head of Highways
3.	Resto Rahwanto, ST	Head of Road and Bridge Construction
4.	Dony Wahyusi, ST	Head of Road and Bridge Maintenance
5.	Arif Musrifin, S.Sos	Treasurer
6.	Muhammad Haziqi	Staff

Conformance Meter

The Likert scale measurements are used for weighting in the final evaluation. As has been done in the Research by Sutrisno & Budiyanto (2019) by giving a weighting scale to the questionnaire. On the Likert scale, the calculation of the percentage of the suitability of the model uses an ideal score (criteria) with the following counts:

Likert scale was used to measure the suitability of the developed model. On the Likert

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scale, the calculation of the percentage of the usefulness of the model used an ideal score (criteria) with the following measures:

Criteria Score = Weight of Answer Scale x Number of Respondent

The criteria score is the highest score used to calculate the score in determining the rating scale and the total number of answers. In this study, a scale of 1 to 4 was used for solutions, and the number of respondents was 6, so the criteria score formed can be seen in Table 4.

Table 4 The criteria score

Formula	Scale
4 x 6 = 24	VS
3 x 6 = 18	S
2 x 6 = 12	LS
1 x 6 = 6	NS

Table 4 shows that the scale values given for the criteria scores are Very Satisfied (VS), Satisfied (S), Less Satisfied (LS), and Not Satisfied (NS)—the highest scores for VS=24, S=18, LS=12, and NS=6.

RESULTS AND DISCUSSION

Decision model with AHP

1. Create a pairwise comparison matrix.

Pairwise comparison matrices are used to assess comparisons between one criterion and another. The following is a pairwise comparison matrix Table 5 for selecting road construction priorities.

Table 5. Pairwise comparison matrix

Criteria	Condition of road	Connectivity of road	Area of supporting	Benefit of economic
Condition of the road	1	3	5	9
Connectivity of the road	1/3	1	4	8
Support Area	1/5	1/4	1	6
Economics Benefits	1/9	1/8	1/6	1

2. Determine the eigenvalues

The first step to calculating the eigenvalues for each criterion is to change the criteria matrix in Table 5 to a decimal number. The following is the criteria matrix table 6 after being converted to decimal numbers.

Table 6. Criteria Matrix

Criteria	Condition of road	Connectivity of road	Area of supporting	Benefit of economic
Condition of the road	1	3	5	9
Connectivity of the road	0.33	1	4	8
Support Area	0.2	0.25	1	6
Economics Benefits	0.11	0.125	0.166	1

Next, add up each column for each criterion. The criteria for the condition of the road column are as follows: 1+0.333+0.20+0.11. Likewise, with other measures. The result is shown in the following Table 7.

Table 7 The sum of the criteria comparison Matrix

Criteria	Condition of road	Connectivity of road	Area of supporting	Benefit of economic
Condition of the road	1	3	5	9
Connectivity of the road	0.33	1	4	8
Support Area	0.2	0.25	1	6
Economics Benefits	0.11	0.125	0.166	1
Total	1.644	4.375	10.166	24.00

Then, divide the value of each criterion by the sum. For example, the value 0.6081 was obtained from 1.0000 divided by 1.6444. The value of 2.1606 was obtained from the sum of the matrix rows.

Table 8 The Quotient Matrix

Criteria	Condition of road	Connectivity of road	Area of supporting	Benefit of economic	Total
Condition of the road	0.608	0.685	0.491	0.375	2.160
Connectivity of the road	0.202	0.228	0.393	0.333	1.156
Support Area	0.121	0.057	0.098	0.250	0.526
Economics Benefits	0.067	0.028	0.016	0.041	0.152
					3.994

Then, find the eigenvalues by dividing the number of rows by the number of criteria (n=4). For example, 2.0160 divided by 4 gives 0.540. The following table shows the eigenvalues for each criterion:

Table 9 EigenValue

Criteria	Eigen Value
Condition of the road	0.540
Connectivity of the road	0.289
Support Area	0.131
Economics Benefits	0.038

The eigenvalues will be used as weights for each criterion.

Decision Model with Bayesian Methods

The Bayes method is used to calculate the alternative's final value. The assessment model used an ordinal scale. Assessment can be seen in the following Table 10.

Table 10 Assessment criteria based on the classification

Criteria	Classification	Value
Condition of the road	Heavily damaged	3
	Lightly damaged	2
	Good	1
Connectivity of the road	National	3
	Province	2
	Regency	1
Support Area	settlement	3
	Agriculture	2
	Industry	1
Economics Benefits	Market	3
	Education	2
	Tourist attraction	1

In the case of the priority analysis of road infrastructure development on the Public Works and Public Housing Office of Balangan Regency, will be taken five road sections for determining the Priority of road infrastructure development using the AHP and Bayes methods. The five road sections have the following data:

Table 11 Road Segment Assessment Data

Name of Road	Criteria			
	Condition of road	Connectivity of road	Area of supporting	Benefit of economic
Lampihong-Panaitan	3	2	3	1
Halong-Tabuan	2	2	2	2
Wangkili-Pudak	2	1	3	2
Awayan-Bihara	1	1	2	3
Bihara-Tariwin	2	1	3	3

We calculate the alternative value by multiplying the Bayes and AHP weights.
1. Lampihong-Panaitan = 2,6335
2. Halong-Tabuan = 2
3. Wangkili-Pudak = 1,8423
4.Awayan-Bihara = 1,2089
5. Bihara-Tariwin = 1,8808

Table 12 Decision Matrix With Bayes Method

Name of Road	Alternative value	Priority Order
Lampihong-Panaitan	2.633	1
Halong-Tabuan	2.000	2
Wangkili-Pudak	1.842	4
Awayan-Bihara	1.208	5
Bihara-Tariwin	1.880	3

Table 12 shows that based on the calculation of the Bayes method, the Lampihong-Panaitan road is priority 1 for infrastructure development, followed by the Halong-Tabuan, Bihara-Tariwin, Wangkili-Pudak and finally Awayan-Bihara.

Model Suitability Testing According to Experts

Table 13 Conformity Test Result

No	Question	Total Answer				Total Score	%
		VS	S	LS	NS		
1.	Question 1	5	1	0	0	23	95.8
2.	Question 2	3	3	0	0	21	87.5
3.	Question 3	3	3	0	0	21	87.5
4.	Question 4	2	4	0	0	20	83.3
5.	Question 5	2	4	0	0	20	83.3
	Average					21	87.5

The Question Column is the questions given in the questionnaire. VS column is the number of experts who answered very satisfied. Column S is the number of experts who answered satisfied. Column LS is the number of experts who answered less comfortably. The NS column is the number of experts who responded that they were unhappy. The Total Score column is the sum of the weight of the value of each answer multiplied by the Number of Answers (VS, S, LS, NS).
Table 5 shows that the results of the completed questionnaires yield an average of 21 (twenty-one) or 87.5% (eighty-seven point five percent). That means the average score got VS or a Very Satisfied rating on the rating scale.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results, using Analytical Hierarchy Process (AHP) and Bayes Method showed that Lampihong-Panaitan, Halong-Tabuan, and Bihara-Tariwin roads are Priorities for development. Then the Wangkili-Pudak road, and finally, the Awayan-Bihara. Decision support systems using the AHP and Bayes methods can determine priorities for road infrastructure development at the Office of Public Works and Public Housing in Balangan Regency.

Suggestion

The following research can try to use other methods of decision support systems by comparing each technique. The following study can use data sets from this research and test the result using different testing methods.

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