Multi-Criteria Analysis Method for Determining the Priority of Bridge Construction

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ABSTRACT

The bridge is one of the important infrastructure facilities which functioned to connect roads that support the development of social and economic in a region. In Indonesia, each year, the limited fund is available to accommodate all construction projects. In practice, the government of Aceh Besar District has limited District Revenue and Expenditure Budgets (APBK) to finance the entire project of bridge construction. Considering that many other sectors still require APBK funding, the priority rank of the bridge development needs to be determined. This study aims to identify the dominant criteria in determining the development of bridges and the priority rank of bridge development projects. This study used a mixed method approach which is a qualitative and quantitative method. The Qualitative method is related to respondent perception through distributing questionnaires and the qualitative method is related to numbers used through the perception score of respondents from the analysis. Respondents are stakeholders and policymakers as many as 8 people. The questionnaire contains some criteria, namely the length of the bridge, construction costs, land use, accessibility, population, and regional development. Based on the literature review, those criteria can be used to obtain which bridge needs to be prioritized. Multi-Criteria Analysis is used to analyze those criteria from respondent perception. The results show that the dominant criteria in determining the construction of bridges in the project were construction costs with a weight of 0.35. It is also obtained that the bridge development project at first rank is the Kr. Keumeuruek with a value of 7.56.

Key words: *multi-criteria method, bridge construction, priority, dominant criteria.*

ABSTRAK

Jembatan merupakan bagian dari infrastruktur transportasi darat untuk menghubungkan dua bagian jalan yang terputus. Dalam pelaksanaannya pemerintah Kabupaten Aceh Besar mempunyai keterbatasan Anggaran Pendapatan Belanja Kabupaten (APBK) untuk membiayai seluruh pembangunan jembatan yang diusulkan. Mengingat masih banyak sektor-sektor lainnya yang memerlukan pendanaan APBK, sehingga 5 usulan pembangunan jembatan perlu menentukan urutan prioritas. Penelitian ini bertujuan untuk mengidentifikasi kriteria yang dominan dalam menentukan pembangunan jembatan dan mengetahui jembatan yang menjadi urutan prioritas pembangunan. Penelitian ini menggunakan pendekatan *mixed method* (kualitatif dan kuantitatif), metode kualitatif berhubungan dengan persepsi responden melalui pengumpulan data kuesioner serta metode kuantitatif berhubungan dengan angka-angka yang digunakan melalui analisis skor persepsi responden. Responden ditujukan kepada pemangku kepentingan dan pengambil kebijakan (*stakeholders*) sebanyak 8 orang. Analisis data digunakan Analisis Multi Kriteria (AMK), dimana kriteria yang ditinjau adalah panjang jembatan, biaya pembangunan, tata guna lahan, aksesibilitas, jumlah penduduk, dan pengembangan wilayah. Hasil penelitian diperoleh bahwa kriteria yang dominan dalam menentukan pembangunan jembatan di Kabupaten Aceh Besar adalah kriteria biaya pembangunan dengan bobot sebesar 0,35. Selanjutnya kriteria lain dalam menentukan pembangunan jembatan adalah kriteria aksesibilitas dengan bobot sebesar 0,19, kriteria pengembangan wilayah dengan bobot sebesar 0,18, kriteria jumlah penduduk dengan bobot sebesar 0,13, kriteria tata guna lahan dengan bobot sebesar 0,10, dan kriteria panjang jembatan dengan bobot sebesar 0,04. Ruas jembatan yang menjadi urutan prioritas utama pembangunan adalah Jembatan Kr. Keumeuruek dengan nilai 7,56, kemudian Jembatan Siron II dengan nilai 3,88, Jembatan Blang Baro I dengan nilai 3,72, Jembatan Inong Balee dengan nilai 3,48, dan Jembatan Alue Jeumpung dengan nilai 2,46.

Kata Kunci: multi kiteria, jembatan, prioritas, kriteria dominan.

Submitted:	Reviewed:	Revised	Published:
05 Des 2022	15 Jan 2023	01 Feb 2023	05 Feb 2023

INTRODUCTION

The increasing population and activity centres have implicated the increasing number of movements between regions in Aceh Besar District. Therefore, additional infrastructure such as bridges is needed. The bridge is one of the

important transportation infrastructures in the road network system to pass vehicle traffic from a disconnected path. The role of bridges is to spur economic growth in a region, balance development between regions, control the structure of regional development at the national level, and improve national defence and security (Zainuddin, 2010). Those roles are included in the Long-Term Development Plan (RPJP) and the Medium-Term Development Plan (RPJM), to lead to a just and prosperous Indonesian society based on Pancasila and the 1945 Constitution (Direktorat Jenderal Perimbangan Keuangan, 2020b).

The Special Allocation Fund (DAK) is a source of funding from the Indonesian Central Government which is allocated to certain regions that meet the requirements to fund special activities related to the public interest. Aceh Besar District Government through DAK 2020, proposed the construction of 5 bridge sections (Usulan DAK Tahun 2020 Bidang Jalan Dan Jembatan Kabupaten Aceh Besar, 2020). The bridge segments are Blang Baro Bridge I, Inong Balee Bridge, Siron II Bridge, Kr. Keumeuruek, and Alue Jeumpung Bridge. The total cost for the construction of them is Rp. 69,175,000,000 (Sixty Nine Billion One Hundred Seventy-Five Million Rupiah) (Direktorat Jenderal Perimbangan Keuangan, 2020b). Aceh Besar District Government must provide a companion fee of at least 10% of the total proposed cost which was proposed through DAK funding sources. These costs are allocated from the Regency Revenue and Expenditure Budget (APBK) (Direktorat Jenderal Perimbangan Keuangan, 2020a).

The limitations of the 2020 APBK have resulted in not all of the proposed bridges can be constructed at the same time, because many other sectors still require APBK funding. Therefore, it is essential to analyze the priorities scale for constructing the 5 proposed bridges through multi-criteria analysis. It is an analysis that can help decision-makers to solve problems by considering all existing criteria as comprehensively as possible in determining the priorities scale (Putra, 2012).

This study aims to identify the dominant criteria in determining the construction of bridges in Aceh Besar District and determine which bridges are in the priority scale of development in Aceh Besar District. The benefits of this research are expected to provide information for stakeholders regarding the dominant criteria in determining bridge development. Moreover, it can provide information for stakeholders on the priority of bridge development in Aceh Besar District.

METHODOLOGY

A mixed method approach was used in this research, namely qualitative dan quantitative method. The qualitative method is through distributing questionnaires and the quantitative method is related to numbers used through the perception score of respondents from the analysis. Multi-Criteria Analysis is used to determine bridge development's priority using respondent perception as decision-making (Thantawi et al., 2020).

Respondents are stakeholders and policymakers as many as 8 people. Their perceptions are an assessment of the influential determined criteria. The step of MCA starts with generating a pairwise comparison matrix, followed by scoring criteria performance and calculating alternative performance matrices to obtain the priority order of bridge development in Aceh Besar District.

Research Criteria

There were 6 research criteria taken from various literature reviews (Asrul & Azis, 2018) (Faqih, 2016) (Mahi, 2016)(Sudradjat et al., 2016). The criteria selected from the literature review which is considered can be used to obtain which bridge needs to be prioritized. Research criteria can be seen in the following table.

Table 1. Research Criteria

No.	Criteria	Notation
1	Bridge Length	A
2	Construction Cost	B
3	Land Use	C
4	Accessibility	D
5	Population	E
6	Regional Development	F

Each criteri**on** has its characteristics. The characteristics are different between the proposed bridge location. The bridge location can be seen in the table below:

Table 2. Bridge location

No.	Bridge	Location (District)
1	Blang Baro Bridge	Seulawah
2	Inong Balee Bridge	Kota Jantho
3	Siron II Bridge	Kuta Cot Glee
4	Krueng Keumeruk Bridge	Seulimum
5	Alue Jeumpung Bridge	Kota Jantho

Sampling Technique

Non-probability sampling through purposive sampling is used. Probability sampling is used to overcome the diversity or plurality of various populations so that more accurate samples can be obtained which resulted in more reliable research

ISSN: 3513-2615
e-ISSN: 2655-934X

results (Sugiyono, 2015). Respondents in this research were stakeholders and policymakers in Aceh Besar District. There were 8 stakeholders, namely as follows:

1. Head of Public Works and Housing Department (PUPR)
2. Head of Road and Bridge Division, PUPR Department.
3. Head of Program and Reporting Division, PUPR Department.
4. Head of Road and Bridge Development Sub Division
5. Head of Road and Bridge Maintenance Sub Division
6. Head of Road and Bridge Improvement Sub Division
7. Head of Infrastructure Development Division, Department of Regional Development (BAPPEDA).
8. Member of Commission D, Regional Development Sector, Sub District Legislative Assembly (DPRK) of Aceh Besar.

Sampling Technique

The research questionnaire is divided into two parts, namely as follows:

1. Questionnaire part A contains the characteristics of respondents ranging from gender, age, and last education.
2. Questionnaire part B contains the level of importance between criteria partially. The criteria reviewed are the length of the bridge, construction costs, land use, accessibility, population, and regional development

Data Analysis

- **Data Processing**

Data processing in this study was carried out from the tabulation of the recapitulation of the questionnaire answers. The data are grouped according to the need in a hierarchy that explains the relationship between criteria and alternatives for selecting bridge construction. The hierarchy of the relationship between each criterion and the alternatives can be seen in Figure 1 below.

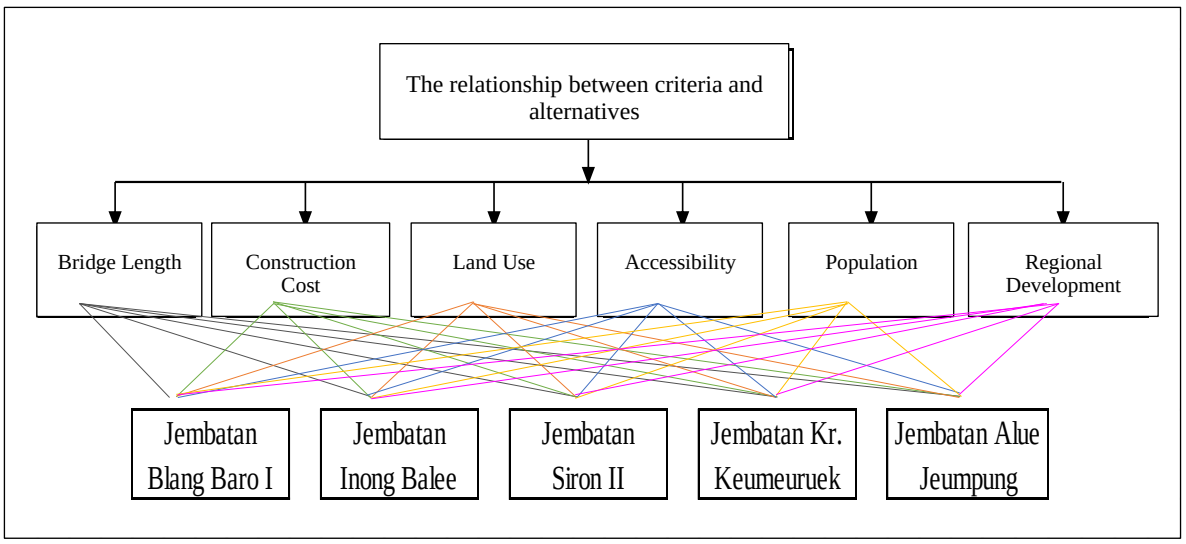

Figure 1. Relationship Between Criteria and Alternative

- **Criteria Weighting**

According to Saaty (1994) criteria were assessed through pairwise comparisons. For many problems, a scale of 1 to 9 is the best scale for expressing opinions. The value and definition of qualitative opinion from the comparison scale can be seen in the table below.

Table 3. Pairwise Comparison Rating Scale

Intensity of Interest	Description
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is more absolutely important than the other elements
9	One element is the most important.
2,4,6,8	The values between the two values of adjacent considerations

Comparisons are made based on the maker's policy decision by assessing the level of importance of one element to another. The pairwise comparison process starts from the topmost hierarchical level aimed at selecting criteria, then the elements to be compared are taken. The pairwise comparison matrices can be seen in Table 4.

Table 4. Pairwise Comparison Matrices

No.	Criteria in Pairs	Information Intensity of Interest
1	A-B	Bridge length to construction cost
2	A-C	Bridge length to land use
3	A-D	Bridge length to accessibility
4	A-E	Bridge length to population
5	A-F	Bridge length to regional development
6	B-C	Construction cost to land use
7	B-D	Construction cost to accessibility
8	B-E	Construction cost to the population
9	B-F	Construction cost to regional development
10	C-D	Land use to accessibility
11	C-E	Land use to population
12	C-F	Land use for regional development
13	D-E	Accessibility to population
14	D-F	Accessibility to regional development
15	E-F	Population to regional development

Then the weights are calculated as elements of an eigenvector associated with the maximum eigenvector of a matrix. The eigenvector value can be obtained by Equation 1.

$$Wi = \sqrt[n]{ai1 \text{ x } ai2 \text{ x } ... \text{ x } aij} \quad \dots (1)$$

where:
Wi = *Eigenvektor* criteria i
$a\,i_1$ = Comparison of the importance level of criterion i to criterion 1
ai_2 = Comparison of the importance level of criterion i to criterion 2
a_{ij} = Comparison of the importance level of criterion i to criterion j
n = Number of criteria

The weight of the criteria (x_i) is calculated using Equation 2

$$X = \frac{Wi}{\sum Wi} \quad \dots (2)$$

The eigenvalue (λ_{max}) for each criterion is calculated using Equation 3.

$$\lambda_m = \sum (aij \text{ x } xij) \quad \dots (3)$$

where:
λ_{max} = Maximum Eigenvalue
a_{ij} = Comparison of the importance level of criterion i to criterion j
x_{ij} = *Eigenvector* on each criterion *i* to criteria *j*

Weighting Consistency

The measurement of the matrix consistency is based on a maximum eigenvalue, so that inconsistencies that are usually produced by comparison matrices can be minimized (Saaty, 1994). The consistency index measurement is shown in Equation 4.

$$CI = \frac{\lambda maks - n}{n - 1} \quad \dots (4)$$

where:
CI = Consistency index
λmaks = Eigenvalue
n = Matrix size

A matrix is considered consistent if the Consistency Ratio (CR) < 0.1. The consistency index is then converted into an inconsistency ratio and divided by a Random Index (RI). Random index values can be shown in Table 5.

Table 5. Random Index Values (Saaty, 1994)

Matrix Size	Random Index (RI)
1, 2	0
3	0.58
4	0.9
5	1.12
6	1.24
8	1.32
9	1.41
10	1.45
11	0.0
12	0.58
13	0.9
14	1.12
15	1.24

Alternative Performance Matrix

(Tamin, 2008) argues that the alternative performance scoring process can be carried out using the proportional method as a direct comparison of the value of the performance variable displayed by each proposal, where the score is assessed on a scale between 0 to 10.
The highest and the lowest value for the best variable:

$$\text{Weight scoring X} \frac{Variable\ X}{Best\ value\ of\ Variable}\ x\ 10 \quad \dots (5)$$

Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil ISSN: 3513-2615
Vol. 7 No. 1 (2023) pp. xx – xx e-ISSN: 2655-934X
DOI:

$$\text{Weight scoring X} = 10 - \text{x } 1 \frac{Variable\ X}{Best\ value\ of\ Variable} x\ 10 \quad ...(6)$$

(Saaty, 1994) argues that the alternative performance matrix is a representation of the level of fulfillment of the criteria for an alternative which is the result of multiplying the weight of the criteria with the alternative performance score. The alternative performance matrix can be seen in Table 6.

Table 6. Alternatives Performance Matrices

	Criteria A	**Criteria B**	**.....**	**Criteria j**	**Kinerja**
Alternative 1	$S_{11} * W_1$	$S_{12} * W_2$	.....	$S_{1j} * W_j$	P_1
Alternative 2	$S_{21} * W_2$	$S_{22} * W_2$	.....	$S_{2j} * W_j$	P_2
.....	.....	.....	.....	.....	.....
Alternative i	$S_{i1} * W_1$	$S_{i2} * W_2$	.....	$S_{ij} * W_j$	P_i

Where:
S_{ij} = Alternative score I against criteria J
W_j = Criteria weighting
$S_{ij} * W_j$ = Weighted score
P_i = Alternative criteria i = Σ Sij * Wj

RESULTS AND DISCUSSION

Criteria Weighting

Based on respondent responses, the pairwise comparison matrix between criteria is calculated using equation 3. In the matrix, the eigenvalue (Xi). Wi value and eigenvalue max (λ_{max}) are obtained which can be seen in table 7, and the average weight value of the criteria from all stakeholders (respondents) can be seen in table 8.

Table 7. Pairwise Comparison Matrix of Criteria for Respondents Head of the Public Works and Housing Office of Aceh Besar District

Criteria	**Criteria**						**Eigen Vector (W_i)**	**Weight Criteria (x_i)**	**Eigen Value (λ_{max})**
	A	B	C	D	E	F			
A	1	0,14	0,50	0,20	0,20	0,20	0,29	0,04	0,22
B	7	1	7	1	3	3	2,76	0,34	2,18
C	2	0,14	1	0,33	0,14	0,20	0,37	0,05	0,30
D	5	1	3	1	1	3	1,89	0,23	1,48
E	5	0,33	7	1	1	3	1,81	0,22	1,44
F	5	0,33	5	0,33	0,33	1	0,99	0,12	0,80
							8,10	1,00	6,41
								CI	0,08
								CR	0,07

Table 8. The average weight of each criterion and respondent

No.	**Criteria**	**Criteria Weight (xi)**								**Average Criteria Weight (xi)**
		R-1	**R-2**	**R-3**	**R-4**	**R-5**	**R-6**	**R-7**	**R-8**	
1	Bridge Length	0,04	0,03	0,05	0,03	0,05	0,04	0,07	0,03	0,04
2	Construction Cost	0,34	0,37	0,24	0,36	0,25	0,45	0,36	0,39	0,35
3	Land Use	0,05	0,13	0,11	0,08	0,09	0,15	0,16	0,07	0,10
4	Accessibility	0,23	0,24	0,21	0,17	0,13	0,15	0,19	0,21	0,19
5	Population	0,22	0,09	0,08	0,19	0,23	0,03	0,04	0,18	0,13
6	Regional Development	0,12	0,13	0,31	0,17	0,25	0,19	0,17	0,11	0,18
Total		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Based on Table 7, it can be concluded that from the results of criteria weighting, the construction cost criteria have the highest weight with an average criteria weight of 0.35. This is shown that development cost gets the highest importance weight criteria from the respondents (stakeholders) in Aceh Besar. This can be interpreted that stakeholder tend to consider how large funds have to be spent on bridge construction due to limited funds. The second position is the accessibility criteria with a weight of 0.19, followed by regional development criteria with a weight of 0.18. The next is the criteria for the population with a weight of 0.13, the fifth criteria for land use with a weight of 0.10, and the last is the criterion of the length of the bridge with a weight of 0.04.

Bridge Alternative Performance Score Assessment

The scoring process for criteria was calculated based on equations 5 and 6. The recapitulation of the performance scores on each bridge alternative based on the assessment of each criterion can be seen in Table 9.

Table 9. Recapitulation of Performance Scores for each bridge based on each criterion

No.	Alternative (Bridge Name)	Recapitulation of Performance Scores					
		Bridge Length	Development Cost	Land Use	Accessibility	Population	Regional Development
1	Blang Baro I Bridge	2,50	5,59	7,78	0,00	4,98	1,17
2	Inong Balee Bridge	0,00	0,00	4,02	6,62	3,91	7,00
3	Siron II Bridge	1,67	3,14	5,64	5,88	5,72	1,38
4	Kr. Keumeuruek Bridge	6,42	7,37	8,37	6,05	10,00	7,55
5	Alue Jeumpung Bridge	0,00	0,00	4,02	6,62	3,91	1,38

Determination of Performance Matrix

Priority determination for each alternative for bridge construction in Aceh Besar District is determined by the sum of the alternative performance values (Pi), with a higher Pi value will be the first order of priority in determining bridge construction. The results of the multiplication of each alternative performance score with each criterion weight can be seen in Table 10.

Table 10. Alternative Performance Matrix

No.	Alternative (Bridge Name)	Bridge Length		Development Cost		Land Use		Accessibility		Population		Regional Development		Alternative Performance (Pi)
		Criteria Weight		Criteria Weight		Criteria Weight		Criteria Weight		Criteria Weight		Criteria Weight		
		0.04		0.35		0.10		0.19		0.13		0.18		
		Performance score	Result	Performance score	Result	Performance score	Result	Performance score	Result	Performance score	Result	Performance score	Result	
1	BlangBaro I Bridge	2.50	0.11	5.59	1.94	7.78	0.80	0.00	0.00	4.98	0.66	1.17	0.21	3.72
2	Inong Balee Bridge	0.00	0.00	0.00	0.00	4.02	0.42	6.62	1.27	3.91	0.52	7.00	1.27	3.48
3	Siron II Bridge	1.67	0.07	3.14	1.09	5.64	0.58	5.88	1.13	5.72	0.76	1.38	0.25	3.88
4	Kr. Keumeuruek Bridge	6.42	0.28	7.37	2.55	8.37	0.87	6.05	1.16	10.00	1.33	7.55	1.37	7.56
5	Alue Jeumpung Bridge	0.00	0.00	0.00	0.00	4.02	0.42	6.62	1.27	3.91	0.52	1.38	0.25	2.46

It can be concluded that the construction of the Krueng Keumeureuk bridge obtained the highest alternative performance score of 7.56 which was the highest priority for bridge construction in Aceh Besar. It is the shortest bridge which in terms of the construction cost criteria has the lowest cost compared to other bridges. This result agrees with the result of the highest criteria weighting that showed that development cost influences the stakeholder's decision. Moreover, based on Badan Pusat Statistik (2019), the land where Krueng Keumeureuk Bridge is located has a potential area for agriculture, plantation, and fishery sector. It is also closer to the district and provincial capital. In addition, the population of the Seulimum Sub District where Krueng Keumeureuk is located has the densest population, where the denser the population, the more influential the regional development.

CONCLUSION

The dominant criterion in determining bridge construction in Aceh Besar District is construction cost with the highest criteria weight of 0.35. It is followed by the accessibility criteria with a weight of 0.19, the criteria for regional development with a criterion weight of 0.18, the population criteria with a criterion weight of 0.13, land use criteria with a criterion weight of 0.10, and the criteria for the length of the bridge with a weight of 0.04 criteria.

The bridge section which is the main priority for construction in Aceh Besar Regency is the Kr.

ISSN: 3513-2615
e-ISSN: 2655-934X

Keumeuruek bridge with a value of 7.56, followed by Siron II Bridge with a value of 3.88. Blang Baro Bridge I with a value of 3.72 is in the third position and Inong Balee Bridge with a value of 3.48is the fourth priority. The last bridge priority to be constructed is the Alue Jeumpung Bridge with a value of 2.46.

ACKNOWLEDGEMENT

The authors wish to thank the colleagues who provided insight and expertise to assist this research.

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