Analytical Network Process

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Analytical Network Process (ANP) for priority setting of strategic roads handling at Tebo Regency

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Abstract. Development of transportation infrastructure in the region aims to meet the needs of the community to facilitate mobility of people, goods, and services. However, the work of transportation infrastructure requires a large amount of cost while the development budget is limited. Therefore, a careful determination of the priority of road handling is urgently required. In this study, an analysis was conducted to determine the priority of handling strategic roads in Tebo Regency. This study uses the Analytic Network Process (ANP) method with 4 (four) criteria to determine the priority of road handling, namely: engineering, economics, regional potential, and policies. It was found that National Road - Pintas being the first priority with a weight of 0.252, then the second priority for National Road - Lubuk Mandarsah with a weight of 0.23.The third priority is Unit I Rimbo Bujang - Unit XI Rimbo Ulu Road with a weight of 0.211.

1. Introduction

In order to spur economic growth in the regions and central economic regions, the Tebo Regency government has carried out various efforts. One of them is by improving transportation infrastructure in the form of opening new roads, adding lengths of roads, widening roads, and road rehabilitation/maintenance programs. The transportation infrastructure improvement program is not easy for Tebo Regency as it requires a significant amount of money while the development budget is limited. This has made it impossible for the Tebo Regency government to fulfill all of the road construction needs in one budget year so that it must determine the priority of road handling appropriately.

Previous research has introduced the Multi-Criteria Decision Making (MCDM) approach in determining road handling priorities such as the Analytic Hierarchy Process (AHP) for example [1][2][3]. The AHP method assumed that the criteria are independent, even though the interdependence between criteria exists which could lead to a bias conclusion.

The Analytic Network Process (ANP) method is an approach which takes into account the existence of dependencies in one group (inner dependence) and between different groups (outer dependence) [4]. ANP method is able to overcome the shortcomings of AHP. In addition, the ANP method is more complete and scientific than AHP, and the network structure in ANP is more complicated than the hierarchical structure. Therefore, this research utilized the Analytic Network Process (ANP) method in reviewing and analyzing the priority of strategic road handling in TeboRegency.

2. Literature Review

2.1. Analytic Network Process (ANP)

Analytic Network Process or ANPis the first mathematical theory that provides the possibility of systematic dependency and feedback [5]. It is a new theory that extends the AHPwhich were both introduced by Thomas L. Saaty [6].One of the advantages of this method is the way of obtaining decisions and calculating the scale ratio. Priority as a scale of ratios is a fundamental element in carrying out necessary arithmetic calculations by adding them on the same scale and multiplying them with different scales that are meaningful to ANP [7].

Unlike the Analytic Hierarchy Process (AHP) method, ANP does not use hierarchies that are linear but in the form of networks without having to set the level as used in AHP. The basic principle of ANP is to include in the word of "influence" while in AHP is "a choice," where in this case the use of the word influence indeed requires more depth of meaning than the word choice [8].

Figure 1 shows that the linear hierarchy in AHP consists of the level of objectives, criteria, sub-criteria, and alternatives, where each level has elements. Whereas in the ANP network model, the level in AHP is called a cluster where it can contain criteria and alternatives called nodes.

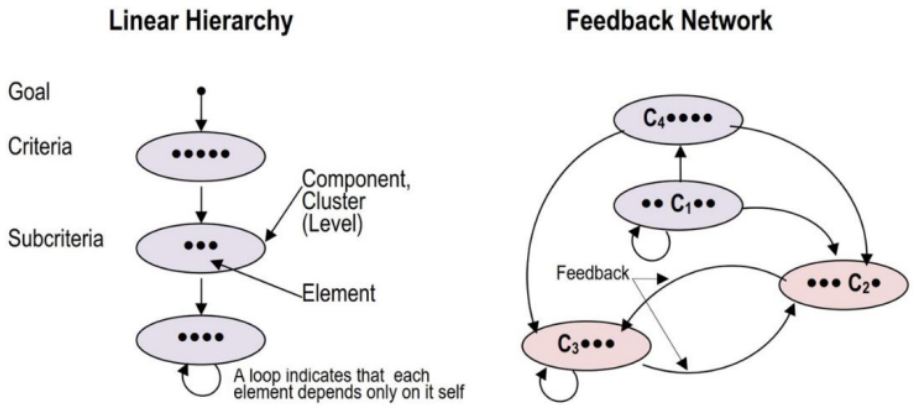

Figure 1. Comparisons of hierarchy and network [4]

In the ANP network, alternatives have a dependency on criteria and also have interdependencies. Likewise, the criteria in the ANP can be interdependent with other criteria as well as on alternatives. The feedback is able to provide more accurate predictions than AHP because it can increase priorities so that the results of ANP become more stable [9].

2.2. Ratter Agreement

Rater agreement is a measure that describes the level of agreement (approval) of the respondent (R_1-R_n) on a problem in one cluster. One of the tools used to measure the rater agreement is Kendall's Coefficient of Concordance ($W; 0 < W \leq 1$).

To calculate Kendall's (W), for example, if there are raters (respondents) as much as m and the subject as many as n will be given a rating from 1 to n, where rij is ranked on rater j against subject i, then the following steps are taken [9]:

$$R_i = \sum_{j=1}^{m} r_{ij} \quad (1)$$

Calculate the average of the total ranking:

$$R = \frac{1}{2} m(n+1) \tag{2}$$

Calculate the square of the deviation (S):

$$S = \sum_{i=1}^{n} \left(R_i - \bar{R}\right)^2 \tag{3}$$

So Kendall's (W) is obtained as:

$$W = \frac{12S}{m^2\left(n^3 - n\right)} \tag{4}$$

The W value equal to 1 (W = 1) means that the respondents have perfect similarities in giving an assessment or opinion. Whereas the W value equal to 0 or closer to 0indicates that the respondents provide different responses [9].

2.3. Geometric Mean

When respondents more than one, an individual assessment of the respondents is needed, and then the opinions of all respondents are grouped into one group using geometric mean calculations [4]. Questions in the form of pairwise comparison of all respondents will be combined to form a consensus. Mean geometry is one of the average calculations that produce specific values with the following formula [9]:

$$g = \sqrt[n]{\prod_{i=1}^{n} a_i} = \sqrt[n]{a_1 a_2 \ldots a_n} \tag{5}$$

3. Research methods

3.1. Determination of the studied Road

The road sections reviewed in this study are strategic regency roads which are the authority of the regency government. This road segment is generally inter-city and connects cities in sub-regencies with government administration centers, centers of economic activity, and other growth centers including roads that connect between regency. The strategic road segment chosen is the road that has been damaged and needs immediate handling. Based on some of these criteria and secondary data obtained from the Office of Public Works and Spatial Planning of Tebo Regency, 5 (five) roads were obtained with a total length of 61.4 km spread in 6 sub-regency in Tebo Regency as shown in Table 1.

Table 1. Strategic roads that need to be handled in Tebo Regency

No.	No. Link	Code	Link Name	Long (km)
1	025	Road 1	National Road – Pintas	11.9
2	026	Road 2	National Road – Paninjau	13.9
3	121	Road 3	National Road – Lubuk Mandarsah	18.5
4	067	Road 4	Block E Alai Ilir Road – Block C Alai Ilir	9.8
5	054	Road 5	The unit I Rimbo Bujang Road – Unit XI Rimbo Ulu	7.6

*Analysed from secondary sources

3.2. Data Collection

Data for this study was collected from interviews and questionnaires to respondents who are experts and understand the road handling activities. The respondents consisted of 8 experts from the TeboRegency government and 3 experts from the Tebo Regency House of Representative who were in charge of infrastructure.Interviews and questionnaires were conducted by visiting respondents at their offices, where the distribution and filling out of the questionnaire took approximately 2 months.

3.3. Identification of Criteria and Sub-Criteria

Based on the literature, the criteria and sub-criteria were identified and shown in Table 2. In the ANP model, the criteria can also be referred to as a cluster while sub-criteria are defined as elements.

Table 2. Criteria and sub criteria for selection of alternative strategic roads.

Criteria/ Cluster	Sub Criteria/ Element
A. Engineering	a.1 Road Condition
	a.2 Traffic Volume
B. Economy	b.1 Investment Cost
	b.2 Maintenance and Rehabilitation Cost
C. Regional Potential	c.1 Agriculture
	c.2 Trading and Services
	c.3 Central Government
	c.4 Education
	c.5 Population Density
D. Policy	d.1 Community Proposal
	d.2 Government Program

3.4. Design of ANP Structure Model

Analytic Network Process (ANP) is the advancement of the Analytic Hierarchy Process (AHP) which has a network structure model that is spread in all directions and involves cycles between groups and linkages/dependencies on the same group. Determining the interrelationship/dependency relationship was done by making a questionnaire with a voting method, based on research conducted by Kasirian and Yusuff [10].

The questionnaire was given to three respondents, namely two (Head of Division or *Kabid* in the TeboRegency Public Works and Spatial Planning Office and one in the Regional Development Planning and Research Agency of TeboRegency. The number of respondents involved in determining the relationship between these elements (N) is three people, so that if in a cell the number of respondents who choose (Vij) is more or equal to Q, where Q is N/2 = 3/2 = 1.5, then the element that

connects the cell is declared to have a relationship. Recapitulation of the results of the questionnaire regarding the interconnected relationships between elements can be seen in Figure 2. Then based on the dependency relationship between these elements, an ANP structure model was made for priority handling of the regency strategic roads as shown in Figure 3.

Criteria			Be Influenced										
			Engineering		Economy		Regional Potential					Policy	
			RC	TV	IC	MC	AG	TS	CG	ED	PD	CP	GP
Influence	Engineering	RC		3	3	3	2	3	2	2	1	3	3
		TV	3		3	3	0	2	1	1	0	3	3
	Economy	IC	3	0		3	0	0	0	0	0	2	2
		MC	3	0	3		0	0	0	0	0	2	2
	Regional Potential	AG	2	2	0	0		3	0	0	1	3	3
		TS	3	3	0	0	0		0	0	2	3	3
		CG	2	3	0	0	0	0		0	1	3	3
		ED	2	3	0	0	0	0	0		1	3	3
		PD	2	2	0	0	1	2	0	2		3	3
	Policy	CP	1	1	3	3	0	0	0	0	0		1
		GP	1	1	3	3	0	0	0	0	0	1	

Figure 2. Recapitulation of questionnaire results regarding the relationship between relationships between elements.

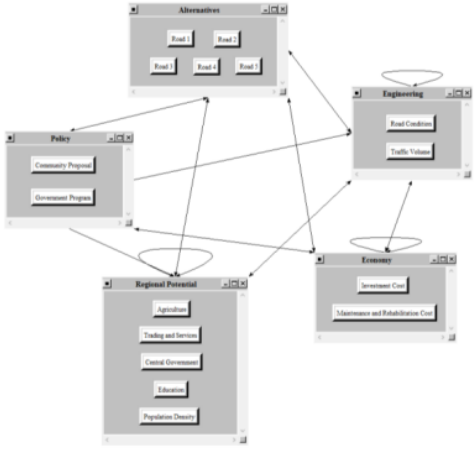

Figure 3. Alternative selection model of road section with ANP

4. Result and Discussion

4.1. Survey

The questionnaires were handed to respondents at their offices and taken back a few days later or by agreement. Maximum allocated time for the respondents to complete the questionnaires was two months starting from the day of the questionnaires were handed.

At the end of the allocated time, from 11 questionnaires distributed, 1 respondent failed to return the questionnaire. Therefore, the number of returned questionnaires was 10. This was analyzed to determine the priority road to be handled.

4.2. Data Analysis

Data were analyzed using the Analytic Network Process (ANP) method which was assisted by Super Decisions 2.8.0 software. The data analysis stage was divided into 2. The first stage aims to process the opinions and judgments of each respondent based on the weighting questionnaire they have filled in to see the respondent's rater agreement on one problem in one cluster. In the second stage, the consistency was tested, responses were put together using a geometric mean to obtain the results of shared opinions and assessments which will become the final results for determining strategic road handling regency in TeboRegency.

4.3. Priority Analysis for Cluster

Priority analysis for the cluster was based on rater agreement between individual and expert consensus values or geometric mean values of 10 respondents. Figure 4 and Figure 5 show the results.

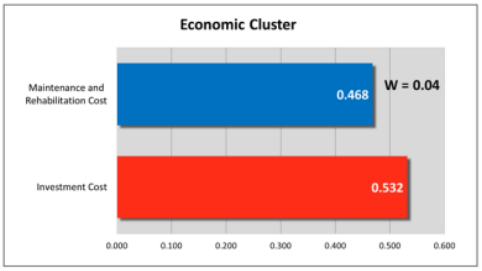

Figure 4. Economic cluster priority.

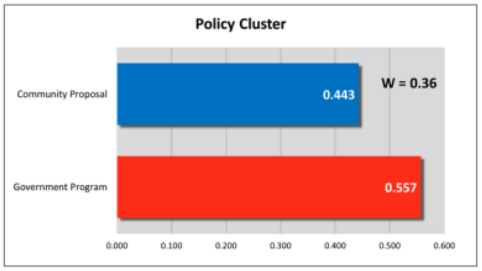

Figure 5. Policy cluster priority.

Figure 4 shows that the investment costs and maintenance and rehabilitation costs almost had the same effect in determining which regency strategic roads were prioritized to be handled with weights of 0.532 and 0.468, respectively. Respondents' opinion on the priority assessment of these two aspects is very diverse which can be seen from the rater agreement which is quite low, that is equal to (W = 0.04). With the W value almost close to 0, it can be concluded that the number of respondents who choose investment costs as a priority in the economic cluster is almost the same as respondents who choose maintenance and rehabilitation costs.

In the policy cluster, as shown in Figure 5, the collective agreement of the experts revealed that roadworks a program of the government are aspects that have a more significant influence in determining the priority of regency strategic road handling with a weight of 0.557 compared to roadworks derived from community proposals (weight is equal to 0.443. Even though the difference in assessment given to these two aspects is not so significant, the agreement on the two aspects is quite high, as indicated by the rater agreement value of (W = 0.36).

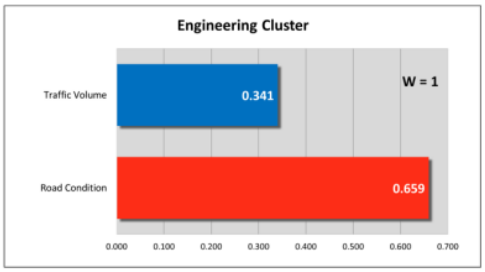

Figure 6. Engineering cluster priority.

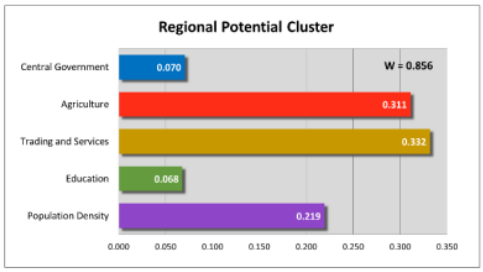

Figure 7. Regional potential cluster priority

Unlike the economic clusters and policy clusters where the two elements have similar priority weights, the respondents' assessment of the elements in the engineering cluster has a different priority weight as shown in Figure 6. The combined opinion of the respondents gives priority weight to aspects of the road condition is 0.659, almost double compared to the priority weight given to the aspect of traffic volume that is only 0.341. The assessment of the priorities of these two aspects is also strengthened by the perfect rater agreement (W = 1). This means that all respondents agree that road conditions are the most influential aspect in determining the priority of handling strategic roads when viewed in terms of technique compared to aspects of traffic volume.

The next priority is a cluster of potential areas consisting of 5 elements. Figure 6 shows that the aspects of trade and services and aspects of agriculture have a higher priority weight than other aspects with almost the same value of 0.332 and 0.311 followed by aspects of population density with a priority weight of 0.219. Whereas the other 2 aspects, namely the aspect of the central government and aspects of education received very low voting. The weight is 0.07 and 0.068 respectively in the potential regional cluster. The results of the assessment of the respondents were also supported by

their high agreement on the weighting of each aspect in the potential cluster area with the rater agreement (W = 0.856). The W value which is almost close to 1 indicates that the answers given by the respondents are very homogeneous.

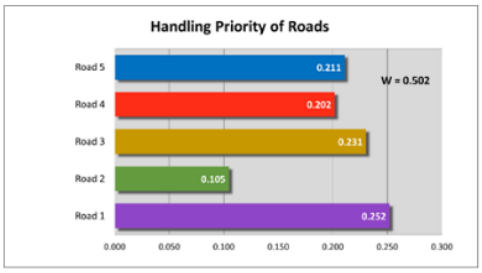

Figure 8. Handling priority of the strategic road.

The final goal of this study was to determine the priority sequence for handling the regency's strategic road in Tebo Regency. From the results of the consensus of the opinions of all respondents who were processed using the Analytic Network Process (ANP) method, priority was given to handling strategic roads as shown in Figure 8.

Based on the weighting results in Figure 8, it can be seen that the experts chose Road 1 as the first priority in the order of handling strategic roads with a weight of 0.252. Then The second order is road 3 with a weight of 0.231, then road 5 with a weight of 0.211 is in the third priority. Road 4 with a weight of 0.202 becomes the fourth priority, while the last sequence with a weight that is much lower than the other priority is 0.105 is the Road 2.

From the rater agreement value (W = 0.502), it can be seen that the agreement in giving priority to strategic road handling by experts consisting of 10 respondents classified as high. This means that the respondents did not differ in opinion on the determination of the strategic road handling sequence.

Based on the analysis above, the final priority sequence for handling the Regency Strategic Roads in Tebo Regency as follows:

- Priority 1: Road1 (National Road – Pintas)
- Priority 2:Road 3 (National Road – Lubuk Mandarsah)
- Priority 3:Road 5 (Unit I Rimbo Bujang Road – Unit XI Rimbo Ulu)
- Priority 4:Road 4 (Blok E Alai Ilir Road – Blok C Alai Ilir)
- Priority 5:Road 2 (National Road – Paninjau)

5. Conclusion

In determining the priority handling of roads, the selection of criteria and sub-criteria dramatically influences the final results. The selection of criteria and sub-criteria must consider many aspects and be adapted to geographical conditions and socio-cultural conditions in the area to be studied. The results of the analysis of the priority of each cluster show that there are four elements that are most dominant in influencing the selection of regency strategic road handling, namely the agricultural aspects, trade and service aspects and aspects of road conditions. This can be seen from the magnitude of the priority given to the element compared to other elements in a cluster.

The final result of the priority sequence for handling the regency's strategic road in Tebo Regency is the National Road - Pintas, National Road - Lubuk Mandarsah, Unit I Rimbo Bujang Road - Unit XI Rimbo Ulu, Blok E Alai Ilir Road - Blok C Alai Ilir, and National Road - Paninjau. The respondent's agreement in determining the priority order for handling the road is quite high as indicated by the rater agreement value (W = 0.502).

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