Proceedings of the 9th APTE Conference
6th - 8th August 2014, Mount Lavinia Hotel, Sri Lanka

A STUDY OF ROAD NETWORK DEVELOPMENT PRIORITIZATION AT LEMBATA DISTRICT - EAST NUSA TENGGARA PROVINCE, INDONESIA

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ABSTRACT
The objective of the study was to prepare a recommendation on how to set up a road network construction programming in Lembata District, Indonesia given such constraints as budget, types of construction, and so on. There were eight road segments across Lembata District included in the road network under consideration. To achieve the objective, the Analytic Hierarchy Process (AHP) method was applied.
The process was initiated by brainstorming factors that may affect the selection and prioritization, called in the AHP analysis criteria. The factors were then evaluated using the Cut Off method to select the most suitable ones. From the analysis it was found that factors strongly influence in the selection were road condition, type of road surface, accessibility, mobility, population density, land use disparity, poverty alleviation program, and construction cost.
Using the above criteria, an AHP analysis was then conducted to set up a prioritization recommendation for the road construction sequences. It was found that the construction cost was the most important factor to be considered, followed by land use disparity and road condition.

Keyword : Analytic hierarchy process (AHP), cut off point, road network prioritization

1. BACKGROUND

District of Lembata is located in the East Nusa Tenggara Province, which is the southeastern part of Indonesia. The district is considered strategic by the central government due to its location, especially in the defense point of view since it is one of the outer islands bordering with Australia. Therefore, in recent years the government has developed a plan for infrastructure development in the area. The plan includes revitalizing about 570 km of the district roads. The total length of roads in the district is 680 km, consisting of 50 km provincial and 630 km of district road. Based on the recent road condition survey, as many as 67% are deteriorated (Central of Statistical Bureau, 2012).

The main problem of road maintenance in many districts in Indonesia is not just a matter of inadequate budget availability. It is also related to technical, social, and cultural problems (Djakfar, 2012). Therefore, in preparing a road maintenance and construction programming, it should not only be based on the road condition, but should also be based on the availability of fund, political, and overall government development program. In other words, the decision should not be based on the road condition only, but should also consider other aspects. Djakfar (2012) has studied the use of the Analytic Hierarchy Process (AHP) in preparing the prioritization program for road maintenance in Malang District, Indonesia. Other studies have also used this technique to determine the priorities of road constrution, such as those by Ardiyanti (2006), Farhan and Fwa (2009), Faiz (2009), and Moazami et al (2011),

One of the critical aspects to ensure the robustness of the analysis using the AHP method is in the criteria selection. Criteria can be defined as factors that determine how prioritization process should

be conducted. As such, the factor selection should be performed carefully and that they should be really representing the condition. Otherwise, it will come up to a bias solution. In this study, the researchers propose to use the cut off point method to select the criteria, as suggested by Tam and Tummala (2001).

2. OBJECTIVE OF STUDY

The objective of the study was to determine the prioritization schemes for the road network maintenance and reconstruction in Lembata District, Indonesia.

3. METHODS

The road prioritization depends on several factors. Therefore, in order to come up to the list, it can be done using the multi criteria analysis. Each factor should have its score and its degree of importance among the factors, expressed as the weighted score. The analysis can be expressed as follows:

$$Total\ Score\ for\ Each\ Road\ Segment = \sum AWF_i \times Individual\ Score_i \qquad (1)$$

where:

AWF_i = average weighted factor for each criterion
$Score_i$ = score for each individual factor

The AWF can be obtained from the AHP analysis, while the Score for each individual factor can be obtained from data office of statistical bureau or field collection.

The study, therefore, can be conducted using the following steps.

1. Prepare the list of roads to be included in the analysis
2. Prepare set of potential criteria regarding the road development scheme
3. Evaluate and select the criteria using the cut off methods
4. Prepare the AHP survey forms using questionnaire
5. Distribute survey forms to stakeholders
6. Evaluate and analyze the survey
7. Evaluate the condition of each road on the list based on the criteria
8. Select the prioritization scheme based on the highest value to the lowest.

3. RESULTS AND DISCUSSION

Based on the available data, there are eight road segments to be included in the study, as shown in Table 1. These segments were selected due to their strategic location in terms of economic and social development. Defense criterion was not included to avoid bias perception of the stakeholders.

Table 1. Road segments included in the study

No.	Segment No	Road Segments	Length (Km)	Sub-district
1	I	Tapobaran – Balurebong and Leragingga - Bobu	30.25	Lebatukan
2	II	Hingalamamengi – Wairiang, Balauring – Wairiang, and Wairiang 0 Tobotani	57.15	Omesuri - Buyasuri
3	III	Aramengi – Wowong and Peumole - Bean	17.8	Omesuri

4	IV	Waikomo – Kalikasa, Atadei – Lerek – Baoraja, Watuwawer - Atawolo	66.7	Nubatukan - Atadei
5	V	Lewoleba-Waijarang – Lamalera, . Belame - Riangdua	60.5	Nubatukan - Nagawutung - Wulandoni
6	VI	Lewoleba-Puor – Wulandoni - Lamalera	52.4	Nubatukan - Nagawutung - Wulandoni
7	VII	Waikomo-Uruor – Wulandoni - Mulandoro	36.1	Nubatukan - Wulandoni
8	VIII	Pasak Raja - Lamaau – Waiara, Baopukang - Kampung Lama, Riangbao - Kolipadan	53.1	Ile Ape – East Ile Ape

3.1. Selection of Criteria.

The criteria to be included in the AHP analysis were obtained by brainstorming factors that may influence in the prioritization process. They include: road condition, type of road surface, accessibility and mobility, population density, land use disparity, poverty alleviation, and construction cost.

Before being included in the AHP analysis, the above criteria need to be evaluated to ensure that they have significant effect on the prioritization analysis. It is done by the cut off method. Questionnaires consisting of those criteria were distributed to 9 stakeholders, 5 from Public Works Department and 4 from Department of Planning. They are asked to rate each criterion in terms of degree of importance, i.e., not important, somewhat important, and very important. Table 2 presents the result of the selection process. Note that the Total Score in column 6 of Table 2 is obtained by multiplying number of responds and value for each responds, while column 7 is obtained by dividing column 6 with the total number of respondents, which is 9.

Table 2. Selection of criteria based on cut off point

No	Criteria	No of Responds			Total Score	Average Score	Remarks
		NI* (=1)**	SI* (=2)**	VI* (=3)**			
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (6)/9	(8)
1	Road condition	0	3	6	24	2.67	
2	Type of road surface	0	4	5	23	2.56	
3	Accessibility	0	4	5	23	2.56	
4	Mobility	0	3	6	24	2.67	
5	Population density	2	3	4	20	2.22	Min
6	Land use disparity	0	4	5	23	2.56	
7	Poverty alleviation	1	2	6	23	2.56	
8	Construction cost	0	2	7	25	2.78	Max

Notes: *NI = not important, SI = somewhat important, VI = very important, ** = represents quantitative value for each choice

The next step is to calculate the cut off point, which is expressed as follows:

$$Cut\ Off\ Point = \frac{Max+Min}{2} = \frac{2.78+2.22}{2} = 2.5 \quad (2)$$

The cut off point is used as the basis for criteria selection. Only criteria having score more than the cut of point will be included in the analysis. Although all criteria seem to be important, criterion 5 was excluded in the AHP analysis. since it is well below the average.

3.2. Prepare and distribute AHP Questionnaire

An AHP questionnaire was prepared and distributed to the stakeholder using the above criteria. The objective of the analysis is to obtain the weighted score for each criterion, which represents the degree of importance among the criteria. Table 3 presents the result of the AHP analysis. As can be seen from Table 3, most respondents consider that construction cost is the most important factor to be considered, followed by road condition, and land use disparity. It does make sense since from their experience the respondents know that budget inadequacy is the most important factor that hinders the road maintenance in their region.

Table 3. Analysis of Weighted based on AHP Analysis

Criteria	Respondents									Average Weighted Factor (AWF)
	1	2	3	4	5	6	7	8	9	
Road condition	0.293	0.212	0.033	0.202	0.232	0.222	0.089	0.178	0.165	**0.1811**
Type of road surface	0.219	0.197	0.027	0.044	0.216	0.101	0.049	0.152	0.047	**0.1172**
Accessibility	0.076	0.077	0.165	0.100	0.072	0.052	0.222	0.130	0.208	**0.1229**
Mobility	0.059	0.166	0.245	0.043	0.030	0.026	0.269	0.208	0.062	**0.1235**
Land use disparity	0.037	0.056	0.201	0.267	0.216	0.248	0.029	0.163	0.235	**0.1619**
Poverty alleviation	0.024	0.061	0.099	0.106	0.047	0.046	0.047	0.041	0.027	**0.0558**
Construction cost	0.289	0.228	0.227	0.236	0.184	0.301	0.292	0.125	0.253	**0.2377**
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0000

3.3. Analyze Score for Each Criterion

The next step is to evaluate and score each of road segments based on each criterion. Each criterion has distinct evaluation methods as follows:

3.3.1. Road Condition.

The road condition (RC) is evaluated using the following formula (Achmad, 2009):

$$RC = \frac{\sum_1^4 Li \times RSi}{(\sum L) \times Index_{max}} \quad (3)$$

where:

L = length of road segment
RS = Road surface condition
= 1 (good), 2 (fair), 3 (poor), 4 (very poor)

To illustrate the calculation of Road Condition (RC), let us calculate the RC for Alternative I.

$$RC = \frac{0.75 \times 1 + 2.90 \times 2 \ + 4.65 \times 3 + \ 21.95 \times 4}{30.25 \times 4} = 0.91$$

Using similar procedure, RC for other alternatives can be seen in Table 4.

Table 4. Road condition (CSB, 2012)

No	Segment No	Length (Km)	Road Condition (in km)				RC
			Good	Fair	Poor	Very Poor	
1	Alternative I	30.25	0.75	2.90	4.65	21.95	0.91
2	Alternative II	57.15	5.00	15.10	21.85	15.20	0.71
3	Alternative III	17.80	1.50	3.82	4.50	7.98	0.77
4	Alternative IV	66.70	2.00	9.75	20.05	34.90	0.81
5	Alternative V	60.50	19.10	9.00	16.00	16.4	0.60
6	Alternative VI	52.40	11.68	9.50	4.10	27.12	0.59
7	Alternative VII	36.10	16.90	8.80	5.70	4.70	0.51
8	Alternative VIII	53.05	38.00	9.25	4.80	1.00	0.39

3.3.2. Surface Index

The surface index (SI) can be calculated as follows:

$$SI = \frac{L_1 \times ST_1 + L_2 \times ST_2 + L_3 \times ST_3 + L_4 \times ST_4}{L_{max} \times ST_{Max}} \qquad (4)$$

where:

SI = Surface index
$L_1 - L_4$ = length of segment based on the surface type
ST = road surface type (1 = asphalt, 2 = lean concrete, 3 = aggregate, and 4 = unpaved road)
L_{max} = the longest road segment
ST_{max} = surface type associated with the longest road segment

Using similar procedure such Road Condition, the surface index can be calculated, and the result is presented in Table 5.

Table 5. Surface Index (Central of Statistical Bureau, 2012)

No.	Segment No	Length (Km)	Surface Type				SI
			Asphalt (Km)	Lean Concrete (Km)	Aggregate (Km)	Unpaved (Km)	
1	Alternative I	30.25	8.65	1.05	3.10	17.45	0.71
2	Alternative II	57.15	42.95	0	7.0	7.20	0.42
3	Alternative III	17.80	3.02	0	0	14.78	0.88
4	Alternative IV	66.70	28.80	4.65	23.85	9.40	0.59

5	Alternative V	60.50	20.0	2.0	31.0	7.50	0.46
6	Alternative VI	52.40	38.72	0.18	13.5	0	0.33
7	Alternative VII	36.10	7.0	3.50	7.70	17.90	0.74
8	Alternative VIII	53.05	26.80	7.25	17.50	1.50	0.53

3.3.3. Accessibility.

The accessibility (A) is determined using the following formula:

$$A = \frac{L}{A_{sub-dist}} \quad (5)$$

Where:

A = Accessibility value
L = length of road segment
$A_{sub-dist}$ = area of sub-district of road under consideration

3.3.4. Mobility

The mobility (M) is expressed in the mobility index and can be determined as follows:

$$M = \frac{L}{fi} \times 1000 \quad (6)$$

where :

M = Mobility index
L = length of road segment
fi = population of the sub-district

Using the eq 5 and 6, the Accessibility and Mobility Index can be determined as shown in Table 6.

Table 6. Accessibility and Mobility index

No.	Segment No	Length (Km)	Under Sub-district	Area (km2)	Population	Accessibility Index (A)	Mobility Index
1	Alternative I	30.25	Lebatukan	241.90	8,864	0.125	3.41
2	Alternative II	57.15	Omesuri & Buyasuri	266.17	35,714	0.215	1.60
3	Alternative III	17.80	Omesuri & Buyasuri	266.17	35,714	0.067	0.50
4	Alternative IV	66.70	Nubatukan & Atadei	316.06	41,908	0.211	1.59
5	Alternative V	60.50	Nubatukan, Nagawutung, & Wulandoni	472.78	51,664	0.128	1.17
6	Alternative VI	52.40	Nubatukan, Nagawutung, & Wulandoni	472.78	51,664	0.111	1.01
7	Alternative VII	36.10	Nubatukan & Wulandoni	287.08	42,723	0.126	0.85

8	Alternative VIII	53.05	Ile Ape & East Ile Ape	135.12	17,038	0.393	3.11

3.3.5. Land Use Disparity

The land use disparity is determined using the Williamson Index as follows (Muta'ali, 2000):

$$W = \sqrt{\frac{\sum(Y_i - Y)^2 \times (\frac{f_i}{N})}{Y}} \qquad (7)$$

Where :

W = Williamson index.
Yi = GDP for each sub-district
Y = GDP for district
f_i = population of sub-district
N = population of district

Using the eq 7, the Williamson Index can be determined as shown in Tabble 7.

Table 7. Williamson Index

No.	Segment No	Under Sub-district	GDP Subdistrict	Population	Williamson Index
1	Alternative I	Lebatukan	717,982	8,864	0.154
2	Alternative II	Omesuri & Buyasuri	1,877,245	35,714	0.100
3	Alternative III	Omesuri & Buyasuri	1,877,245	35,714	0.100
4	Alternative IV	Nubatukan & Atadei	2,788,530	41,908	0.032
5	Alternative V	Nubatukan, Nagawutung, & Wulandoni	4,984,656	51,664	0.090
6	Alternative VI	Nubatukan, Nagawutung, & Wulandoni	4,984,656	51,664	0.090
7	Alternative VII	Nubatukan & Wulandoni	2,993,858	42,723	0.055
8	Alternative VIII	Ile Ape & East Ile Ape	2,067,060	17,038	0.042

Notes: District GDP = IDR 1,374,505 , District Population = 121,012

3.3.6. Poverty Level

The poverty level is determined using the following formula:

$$K = \frac{q}{f_i} \times 100\% \qquad (8)$$

Where :

K = poverty level of sub-district.
q = population below poverty line of sub-district
f_i = population of sub-district

Using eq 8, the poverty level can be determined as shown in Table 8.

Table 8. Poverty Level

No	Segment No	Under Sub-district	Population	Poverty	K
1	Alternative I	Lebatukan	8,864	5,085	0.57
2	Alternative II	Omesuri & Buyasuri	35,714	17,733	0.50
3	Alternative III	Omesuri & Buyasuri	35,714	17,733	0.50
4	Alternative IV	Nubatukan & Atadei	41,908	9,840	0.23
5	Alternative V	Nubatukan, Nagawutung, & Wulandoni	51,664	16,527	0.32
6	Alternative VI	Nubatukan, Nagawutung, & Wulandoni	51,664	16,527	0.32
7	Alternative VII	Nubatukan & Wulandoni	42,723	11,622	0.27
8	Alternative VIII	Ile Ape & East Ile Ape	17,038	7,038	0.41

3.3.7. Construction Cost index

The construction cost index is determined using the following formula:

$$Ci = \frac{RB}{TB} \times L \qquad (9)$$

Where :

Ci = Construction Cost Index
RB = Budget allocated for road construction on the budget year
TB = total budget of the district
L = length of road

Using eq 9, the construction cost index can be determined as shown in Table 9.

Table 9. Construction Cost Index

No.	Segment No	Length (Km)	Under Sub-district	% Cost	CI
(1)	(2)	(3)	(4)	(5)	(6) = (3)*(5)
1	Alternative I	30.25	Lebatukan	0.164	4.961
2	Alternative II	57.15	Omesuri & Buyasuri	0.164	9.373

3	Alternative III	17.80	Omesuri & Buyasuri	0.164	2.919
4	Alternative IV	66.70	Nubatukan & Atadei	0.164	10.939
5	Alternative V	60.50	Nubatukan, Nagawutung, & Wulandoni	0.164	9.922
6	Alternative VI	52.40	Nubatukan, Nagawutung, & Wulandoni	0.164	8.594
7	Alternative VII	36.10	Nubatukan & Wulandoni	0.164	5.92
8	Alternative VIII	53.05	Ile Ape & East Ile Ape	0.164	8.70

3.4. Evaluate Total Score for Each Road Segments

The last step of the overall analysis is to evaluate score for each alternative. Using eq 1, the score can be determined as shown in Tables 10 and 11. Tables 10 and 11 also present the ranking of the Road segments. As can be seen from the tables, Alternative IV, which consists of Waikomo – Kalikasa, Atadei – Lerek – Baoraja, and Watuwawer – Atawolo road segments have the highest score. Therefore, it is recommended to be the first on the list in the prioritization program. The road maintenance dan reconstruction program should be based on the rank of each alternative.

Table 10. Score and Ranking for Each Road Segment

No	Criteria	AWF	Alt I		Alt II		Alt III		Alt IV	
			Score	AWF * Score	Score	AWF * Score	Score	AWF * Score	Score	AWF * Score
1	Road condition	**0.1811**	0.91	0.16	0.71	0.13	0.77	0.14	0.81	0.15
2	Type of road surface	**0.1172**	0.71	0.08	0.42	0.05	0.88	0.10	0.59	0.07
3	Accessibility	**0.1229**	0.13	0.02	0.22	0.03	0.07	0.01	0.21	0.03
4	Mobility	**0.1235**	3.41	0.42	1.60	0.20	0.50	0.06	1.59	0.20
5	Land use disparity	**0.1619**	0.15	0.02	0.10	0.02	0.10	0.02	0.03	0.01
6	Poverty alleviation	**0.0558**	0.57	0.03	0.50	0.03	0.50	0.03	0.23	0.01
7	Construction cost	**0.2377**	4.96	1.18	9.37	2.23	2.92	0.69	10.94	2.60
	Total			1.92		2.67		1.05		3.06
	Ranking			IV		II		VII		I

Table 10. Score and Ranking for Each Road Segment, continued

No	Criteria	AWF	Alt V		Alt VI		Alt VII		Alt VIII	
			Score	AWF * Score	Score	AWF * Score	Score	AWF * Score	Score	AWF * Score
1	Road	**0.1811**	0.60	0.11	0.59	0.02	0.51	0.09	0.39	0.07

	condition									
2	Type of road surface	**0.1172**	0.46	0.05	0.33	0.01	0.74	0.09	0.53	0.06
3	Accessibility	**0.1229**	0.13	0.02	0.11	0.00	0.13	0.02	0.39	0.05
4	Mobility	**0.1235**	1.17	0.14	1.01	0.02	0.85	0.10	3.11	0.38
5	Land use disparity	**0.1619**	0.09	0.01	0.09	0.00	0.06	0.01	0.04	0.01
6	Poverty alleviation	**0.0558**	0.32	0.02	0.32	0.00	0.27	0.02	0.41	0.02
7	Construction cost	**0.2377**	9.92	2.36	8.59	0.56	5.92	1.41	8.70	2.07
Total			1.51		0.61		1.73		2.66	
Ranking			VI		VIII		V		III	

4. CONCLUSION

Based on the analysis, the following conclusions can be drawn:

1. Using cut off point method in the beginning of the AHP analysis will help focusing on the criteria that contributes to the analysis, hence providing a better result.
2. Stakeholders in Lembata District consider that the most important criteria to be considered when setting up a highway construction programming is the construction cost, followed by road condition and land use disparity
3. Applying the AHP analysis to the road maintenance and reconstruction programming in Lembata District, it was suggested that the Alternative IV, which consists of 4 segment roads, Waikomo – Kalikasa, Atadei – Lerek – Baoraja, Watuwawer – Atawolo, be put in the first place when the road maintenance and reconstruction program is set up.

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