Determination of the priority for arterial and collector road handling in Solok city, West Sumatra province

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Abstract. When handling roads, there should not be any roads that are neglected. Due to the limitation of funds, among the roads that have to be maintained, it is not necessarily possible to handle all of them with the same priority. It is necessary to prioritise road handling by considering the conditions and factors that influence its use. Roads that are used more often will be prioritised when it comes to maintenance. The data used in this study consisted of secondary and primary data. The secondary data was obtained from the Public Works Office of Solok City (Database of Solok City Roads, 2017) and Bappeda (RPJMD and RTRW). 8 segments of road were observed. Traffic volume surveys were conducted for 2 x 24 hours. Furthermore, questionnaires were distributed to support the secondary data, and 30 respondents answered. Six criteria were considered: Condition Factors (A), Traffic Volume Factors (B), Economic Factors (C), Policy Factors (D) Land Use Factors (E), and Side Building Factors and Road Complement (F). This study used the Analytic Hierarchy Process (AHP) method developed by Thomas L. Saaty. This method will simplify the complex multi-criteria problem into a priority scale hierarchy. The results of the AHP method analysis were included in a mathematical model as according to Brojonegoro (1991). The results showed that the priority for routine road maintenance was “Traffic Light Pandan - Tanjung Paku” road section (033), the priority for periodic road maintenance was “SMP 1 Simpang Damar” road section (047) and the priority for road improvement in general was “Simpang Sigege - Ampang Kualo” road section (051).^a

1 Introduction

Solok City has 170 roads with an overall length of 206.6 km, and the roads cross two (2) sub-districts and thirteen (13) urban village. There are thirteen (13) primary and collector roads with a total length of ± 27.2 km. Because of the limited amount of funds available, it is necessary to select the priority for handling the roads.

At present, many methods are used to determine the priority for road handling. What is most often used is the Analytic Hierarchy Process (AHP) method. Saaty [1] developed this

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method. This method was chosen in this research because this model can support the decision-making by simplifying complex multi-criteria problems into a hierarchy of priority scale. Thus, the issues will appear to be more structured and systematic [2]. The analysis of road handling from the AHP method were entered into mathematical model calculations as according to Brojonegoro [3].

There were eight arterial and collector road segments studied in this research, consisting of 4 secondary arterial and 4 collector roads. This study aimed to determine the priority sequence of road handling in Solok City based on the Analytical Hierarchy Process (AHP) method. The results of this study are expected to be taken into consideration by relevant agencies when determining the priority for road handling in Solok City.

2 Materials and methods

2.1 Data collection

The data used in the study consisted of secondary and primary data. The secondary data was obtained from the Public Works Office of Solok City [4] and Bappeda (RPJMD and RTRW) [5]. The primary data was in the form of the traffic volume of the eight segments selected, which was obtained by surveying the volume of vehicles and pedestrians. The surveys were conducted for 2 x 24 hours, on market days and non-market days. Solok City market day is on Tuesdays and Fridays. Furthermore, questionnaires were distributed to support the secondary data regarding the road conditions. The data of the arterial and collector road segments studied can be seen in Table 1.

Table 1. List of arterial and secondary roads in Solok City [4].

No	Segment number	Segment name	Width (m)	Length (km)
		Secondary Arteries		
1	033	Pandan Traffic Light Junction - Tj. Paku Road	8	1
2	046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road	8	4.1
3	047	SMP 1 –Damar Junction Road	8	5.4
4	051	Sigege Juction - Ampang Kualo Road	6	2.4
		Collectors Primary/Secondary		
5	034	BRI Junction - Tanjung Paku Junction Rd	7	1.2
6	054	Laing Junction- Batas Kota Damar Road	8	2.4
7	056	Laing Bridge - Laing Pasir Road	6	4
8	064	Lintasan KA - Lurah Lama Office Kp. Jawa Rd	8	0.4

2.2 Respondent perception survey

According to Hair [6], the minimum number of research samples with an unknown population number should be five times the variables analyzed. In this study, there were six variables or criteria used. Therefore the minimum number of samples required is 5 x 6 criteria = 30 samples. According to Singarimbun and Efendi [7], the minimum number of samples in the questionnaire trial was 30 respondents, which means that the distribution of values would be closer to the normal curve. In this research study, 30 respondents were involved, as can be seen in Table 2.

Table 2. List of interview respondents.

Respondents	Amount
Head of Department PUPR	1
Secretary of Development PUPR	1
Head of Highways Development PUPR	1
Head of Spatial Planning Development PUPR	1
Head of Program Development PUPR	1
Head of the Road Maintenance Section	1
Head of the Road Construction Section	1
Head of Lighting & Streetlights	1
PPTK/ Technical Team/ Supervisor	10
Camat	2
Lurah	6
Badan Legislature	2
Public figure	2
Total	30

2.3 Data processing

After the data was collected, the data processing stage was conducted using the AHP method, incorporating the criteria and sub-criteria that had been previously determined. This will be formulated in the form of a hierarchical structure (Fig. 1).

- The hierarchical levels in the AHP method consisted of 3 (three) levels, namely:
1. Level 1 (goal) - to determine the priority of roads road handling based on a routine and regular handling, road rehabilitation, and road improvement.
 2. Level II (criteria) - several criteria involved in determining road priority. The criteria are Road Condition Factors (A), Traffic Volume Factors (B), Economic Factors (C), Policy Factors (D) Land Use Factors (E), and Side Building Factors and Road Complement (F).
 3. Level III (sub-criteria) - factors that influence the criteria factors.

Fig. 1. Preparation of road maintenance level hierarchy.

2.4 Stages of the Analytical Hierarchy Process (AHP) method

2.4.1 The initial matrix calculation

Table 3. Matrix comparison paired element weight [1].

	A ₁	A ₂		A _n
A ₁	a ₁₁	a ₁₂		A _{1n}
A ₂	a ₂₁	a ₂₂		a _{2n}
.....				
A _n	a _{n1}	a _{n2}		a _{nn}

The matrix was used to calculate an element’s weight. Comparative results in the pairs of the elements will form a comparison matrix (Table 3).

$$(ij) = Ai / Aj, \text{ where : } i,j = 1,2,3,...n \tag{1}$$

The results of the pair-wise comparison has been expressed as vector W, with W = (W₁, W₂, W₃ W_n) and then the value of the intensity of the importance of the operating element. i.e. Ai against Aj was expressed equal to aij.

Table 4. Matrix comparison paired element weight [1].

	W ₁	W ₂		W _n
W ₁	W ₁ /W ₁	W ₁ /W ₂		W ₁ /W _n
W ₂	W ₂ /W ₁	W ₂ /W ₂		W ₂ /W _n
.....				
.....				
W _n	W _n /W ₁	W _n /W ₂		W _n /W _n

The preference comparison matrix was processed by calculating each row using Eq. 2:

$$Wi = n\sqrt{(ai1 \times ai2 \times ai3, ..., x ain)} \tag{2}$$

2.4.2 Vector Eigen calculation, maximum Eigenvalues, and control of Consistency Index

The obtained matrix was the eigen vector, which is also the criteria weight. The criteria weight or Eigen Vector is (Xi) in Eq. 3, maximum Eigenvalues in Eq. 4 and control of Consistency Index in Eq. 5.

$$Xi = (Wi / \Sigma Wi) \tag{3}$$

$$\lambda maks = \Sigma aij.Xj \tag{4}$$

$$CI = (\lambda maks -n/n-1) \tag{5}$$

where C₁ = Consistency index, λ maks = Value *eigen* maximum, n = matrix sizes.

Random matrix with a rating scale of 1 to 9 with its inverse as Random Index (RI). The Random Index (RI) of each matrix order is as shown in Table 5.

Table 5. Random index based on Matrix order [1].

Matrix order	1	2	3	4	5	6	7	8	9	10
RI (Index Random)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

For the AHP model, the comparison matrix was accepted if the ratio value was consistent and no more than 10%, equal to 0.1.

$$CR = CI / RI < 0, I(OK) \tag{6}$$

where C_R = Consistency Ratio, R_I = Random Index.

2.4.3 Weighting the criteria

After obtaining the criteria weight from the comparison of the criteria matrix, a scoring process or priority assessment was carried out for each criteria for each road section, using the 2nd level criteria weight, 3rd level (respondent analysis weight), and secondary data analysis results. In the matrix below is an example of the Road Condition (A) criteria value (Table 6). The same has been done for other criteria. The Priority Value scoring results with AHP proceeded with equations according to Brodjonegoro [3]:

$$Y = A(a1 \times \text{weight } a1 + \dots + a6 \times \text{weight } a6) + F(f1 \times \text{weight } f1 + \dots + f3 \times \text{weight } f3) \quad (7)$$

Table 6. Weighting criteria.

Code criteria	Criteria	Weight (%)
A	Musrenbang DPRD	14.66
B	Field of Agriculture	31.30
C	Trade-Services	25.31
D	Education	30.11
E	Socio-cultural	13.28

3 Results and discussion

3.1 Application of weight criteria for handling roads

The AHP method is known as one of the structured approaches involved in making decisions. The choice between the criteria and sub-criteria in this model is considered to be capable of meeting the objectives in decision-making. The principle used was the principle of preparing the hierarchy, the setting priorities, and logical consistency. The AHP core was the weighting and scoring. The weighting was obtained from the pair-wise comparison matrix as a result of the respondent's perception (questionnaire). The scoring in this study used the Linear Model equation.

Table 7. Weighting criteria, 2nd level.

Code Criteria	Criteria	Weight (%)
A	Road condition factors	31.46
B	Volume of traffic factors	21.89
C	Economic factors	11.50
D	Policy factors	16.95
E	Land use factors	12.23
F	Building/supplementary road factors	5.97

Table 8. Weighting sub-criteria, 3rd level.

Code criteria	Criteria	Weight (%)
a1	Hole	22.15
a2	Collapsed	45.07
a3	Cracked	9.74
a4	Flow rut	7.67
a5	Road side	7.42
a6	Slope of the road	7.96
b1	Truck	25.27
b2	Car wheel 4	23.19
b3	Bus	22.99
b4	Motorcycle	12.32
b5	Pedestrian	16.24
c1	Benefits/appropriateness (NPV)	74.90
c2	Cost of activities	25.10
d1	Musrenbang Tingkat Kelurahan	42.98
d2	Musrenbang Tingkat Kecamatan	24.69
d3	Musrenbang Tingkat Kota	17.67
d4	Musrenbang DPRD	14.66
e1	Field of agriculture	31.30
e2	Trade-Services	25.31
e3	Education	30.11
e4	Socio-cultural	13.28
f1	Drainage	56.77
f2	Sidewalk	24.38
f3	Street lights	18.85

Table 9. Proposed election of maintenance work.

Grade 6-10 routine maintenance	Grade 11-16 periodic maintenance	Grade 16-24 other jobs
Light (R)	The thin asphaltting	Job buffer
Medium (S)	Asphalt coating/ retracting	Hard work
Hard (B)	Drainage work	-
	Bridge work	
	Mixed jobs	

3.2 Priority scale determination with the analytic hierarchy process (ahp)

Based on 30 respondents and the observed six criteria (A-F), the respondent's answers were varied, ranging from 1-9, aligned with the following meanings: 1) Equally important; 2) Between equally important and more important; 3) More important; 4) Between more important and important; 5) Important; 6) Between important and very important; 7) Very important; 8) Between the very important values is very important; and 9) Very important.

The weighting obtained was assessed using a criteria comparison scale. The value of the initial matrix criteria was obtained from the average comparison value by dividing the cumulative number of comparison scales by the number of respondents, simplified to calculate the vector values (X_i) and eigenvalues (λ_i).

Table 10. Proposed selection of maintenance work in determining factors road condition.

No. segment	Segment name	Rekapitulasi sub-criteria of the road condition						Total value	Condition	Type maintenance
		Hole (x1)	Collapsed (x2)	Cracked (x3)	Flow rut (x4)	Road side (x5)	The slope of the road (x6)			
033	Pandan Traffic Light Junction - Tj. Paku Road	2	0	2	1	2	2	9	Good	Routine
046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road	2	1	4	2	2	1	12	Medium	Periodic
047	SMP 1 – Damar Junction Road	2	1	8	2	2	1	16	Medium	Periodic
051	Sigege Junction - Ampang Kualo Road	3	8	8	1	3	1	24	Light Damage	Enhancement
034	BRI Junction - Tanjung Paku Junction Road	2	0	2	1	2	2	9	Good	Routine
054	Laing Junction- Batas Kota Damar Road	5	1	3	3	2	2	16	Medium	Periodic
056	Laing Bridge - Laing Pasir Road	5	2	8	3	3	3	24	Light Damage	Enhancement
064	Lintasan KA - Lurah Lama Office Kp. Jawa Road	1	0	2	1	2	2	8	Good	Routine

3.3 Results of the weighting criteria (2nd level) and sub criteria (3rd level)

After the interviews and calculations by using AHP method were conducted, the results obtained were shown to have weighted levels that were recapitulated based on the criteria and levels as shown in Tables 7 and 8.

3.4 Proposed road maintenance works

After determining and assessing the level of damage, the category of maintenance work was determined with the values listed in Table 9.

Each segment's assessment was grouped into the handling that it required, including routine maintenance, periodic maintenance, improvement or development work. The weighting was obtained by dividing the sub-criteria value into the existing road conditions by four (4). For example, the condition of there being a road hole (x1) on the segment Simpang Lampu Merah Pandan - Tanjung Paku road (033) was 2. The weight of the sub-criteria of the hole was therefore $2/4 = 0.50$, as shown in Table 14 column a.

Tabel 11. Daily traffic average in relation to the factors determining traffic volume.

No. segment	Segment name	Traffic types				
		Truck (x7)	Cars 4 (x8)	Bus (x9)	Motorcycle (x10)	Pedestrian (x11)
033	Pandan Traffic Light Junction - Tj. Paku Road	148	807	13	9923	200
046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road	58	1160	15	10,209	119
047	SMP 1 –Damar Junction Road	99	730	0	2782	102
051	Sigege Junction - Ampang Kualo Road	29	631	2	6766	334
034	BRI Junction - Tanjung Paku Junction Road	31	716	3	9732	479
054	Laing Junction- Batas Kota Damar Road	139	483	11	3233	31
056	Laing Bridge - Laing Pasir Road	276	75	3	1106	79
064	Lintasan KA - Lurah Lama Office Kp. Jawa Road	26	296	0	1211	45

The traffic volume data in Table 11 was obtained from the average survey results: 2 x 24 hours on the market days and non-market days. Weighting the LHR of each type of vehicle was done by comparing the LHR with the highest LHR of the same kind of handling group. For example, the truck traffic (x7) on the Simpang Lampu Merah Pandan - Tanjung Paku Road (033) was 148, divided by the highest LHR with the same handling group, which was a motorcycle (incidentally the same section), which were 9923. Therefore the weight of the sub-criteria of the truck was $148/9923 = 0.015$, as in Table 14, column b.

Table 12. Value benefits based on the traffic data analysis in determining the economic factor values.

No. segment	Segment name	Benefit Value based on Traffic Data Analysis				Condition
		Routine maintenance	Periodic maintenance	Enhancement	Development	
033	Pandan Traffic Light Junction - Tj. Paku Road	3872				Good
046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road		2608			Medium
047	SMP 1 –Damar Junction Road		2035			Medium
051	Sigege Junction - Ampang Kualo Road			2630		Light Damage
034	BRI Junction - Tanjung Paku Junction Road	3200				Good
054	Laing Junction- Batas Kota Damar Road		1644			Medium
056	Laing Bridge - Laing Pasir Road			770		Light Damage
064	Lintasan KA - Lurah Lama Office Kp. Jawa Road	771				Good

The value of the benefits toward the road conditions was gain from the total of the equivalent LHR road user value, found in the LHR survey results using the Traffic Data Analysis Sheet form (A2) SK 77/KPTS/Db/1990. The weighting of the economic benefits based on the traffic data were obtained by comparing the value of the benefits with the highest benefit value of the same type of handling group (see Table 14, column c).

Road handling costs for routine/ periodic maintenance and improvement were taken from the standardization of the DAK 2018 activities and then adjusted to the road conditions that are to be handled. The weighting estimated costs were found by comparing the estimated costs associated with the highest estimated costs of the same type of handling

group. If the road was proposed, then it was given a value of one (1). If it was not proposed, then it was given a value of zero (0).

Regarding the land use factor, the same assessment was also carried out. That is if the construction of a road would affect the productivity of that type of land use, such as agricultural/ trade/ education and social-cultural factors. These were marked by giving it a value of one (1). However, if the road built would not affect the products directly, then it was given a zero value (0). For more details, see Table 14, column E.

Table 13. Condition assessment of the drainage/ side channels in determining the building/ supplementary road factors.

No. segment	Segment name	Sub drainage/side channel criteria value						Value (x22)
		No need 0	Good 1	Medium 2	Broken 3	Heavily damaged 4	There is no, but necessary 5	
033	Pandan Traffic Light Junction - Tj. Paku Road			2				2
046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road		1					1
047	SMP 1 –Damar Junction Road			2				2
051	Sigege Junction - Ampang Kualo Road				3			3
034	BRI Junction - Tanjung Paku Junction Road			2				2
054	Laing Junction- Batas Kota Damar Road			2				2
056	Laing Bridge - Laing Pasir Road						5	5
064	Lintasan KA - Lurah Lama Office Kp. Jawa Road			2				2

The drainage condition was divided into five (5) assessments, starting from zero (0) to five (5). Thus an evaluation could be given based on the condition of the existing road drainage, as exposed in Table 13. The assessment of the sidewalk condition was divided into three (3), namely good condition - 1 point, medium condition - 2 points, and if there were no sidewalks on the road, then the specified point was 3. For the assessment of the street lights, an evaluation was made that if there was a street light on the section, then 1 was given, whereas if there was no street light, then zero points were given (0). For more details, see Table 14, column F.

Table 14. Value of the secondary data analysis results.

Segment code	a						b			
	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
033	0.50	0.00	0.50	0.25	0.50	0.50	0.015	0.081	0.001	1.000
046	0.50	0.25	1.00	0.50	0.50	0.25	0.006	0.114	0.001	1.000
047	0.50	0.25	2.50	0.50	0.50	0.25	0.010	0.072	0.000	0.273
051	0.75	2.25	2.00	0.25	0.75	0.25	0.004	0.093	0.000	1.000
034	0.50	0.00	0.50	0.25	0.50	0.50	0.003	0.072	0.000	0.981
054	1.25	0.25	0.75	0.75	0.50	0.50	0.014	0.047	0.001	0.317
056	1.25	0.50	2.50	0.75	0.75	0.75	0.041	0.011	0.000	0.163
064	0.25	0.00	0.50	0.25	0.50	0.50	0.003	0.030	0.000	0.122

Segment code	b	c		d				
	x11	x12	x13	x14	x15	x16	x17	x18
033	0.020	1.00	1.00	1.00	1.00	1.00	1.00	1.00
046	0.012	1.00	1.00	1.00	1.00	1.00	1.00	1.00
047	0.010	0.78	1.00	1.00	1.00	1.00	1.00	1.00
051	0.049	1.00	1.00	1.00	1.00	1.00	1.00	1.00
034	0.048	0.83	1.00	1.00	1.00	0.00	0.00	0.00
054	0.003	0.63	1.00	1.00	1.00	1.00	1.00	1.00
056	0.012	0.29	1.00	1.00	0.00	0.00	0.00	1.00
064	0.005	0.20	0.94	1.00	1.00	1.00	1.00	1.00

Segment code	e			f		
	x19	x20	x21	x22	x23	x24
033	1.00	1.00	1.00	1.00	0.67	0.50
046	1.00	1.00	1.00	0.50	1.00	0.50
047	1.00	1.00	1.00	1.00	1.00	0.50
051	1.00	1.00	1.00	0.40	1.00	0.50
034	1.00	1.00	1.00	1.00	0.33	0.50
054	1.00	1.00	1.00	1.00	1.00	0.50
056	1.00	1.00	1.00	1.00	1.00	0.50
064	1.00	1.00	1.00	1.00	1.00	0.50

We then calculated the amount of Y using formula from Brodjonegoro [3] or Eq. 7:
 $Y = \text{weight criteria} \times (\text{sub criteria weight} \times \text{secondary analysis weight})$, or
 $Y = A(a1.x1 + a2.x2 + a3.x3 + a4.x4 + a5.x5 + a6.x6) + B(b1.x7 + b2.x8 + b3.x9 + b4.x10 + b5.x11) + C(c1.x12 + c2.x13) + D(d1.x14 + d2.x15 + d3.x16 + d4.x17) + E(e1.x18 + e2.x19 + e3.x20 + e4.x21) + F(f1.x22 + f2.x23 + f3.x24)$

In order to get the value of each segment (Y), the value of the criteria in the 2nd level (Table 7) was multiplied by each sub-criteria value in the 3rd level (Table 8). This data had been multiplied and added to the value of the secondary data criteria (Table 14). The value obtained would determine the order of the top priorities for handling.

3.5 Proposed road maintenance works - the analysis using the AHP method

The first priority road for the secondary arterial and collector roads in Solok City was the Sigege Junction - Ampang Kualo Road section (0.907), with the type of handling being road improvement. The second priority was SMP 1 Damar Junction Road (0.602), to the kind of handling being periodic maintenance while the last priority was BRI Junction - Tanjung Paku Junction Road (of 0.427), and the type of road handling was routine maintenance, as shown in Table 15.

Table 15. Assessment using the AHP Method.

Segment code	Segment name	Value	Maintenance	Priority
033	Pandan Traffic Light Juction - Tj. Paku Road	0.541	Routine	6
046	Mesjid Kp. Jawa Mosque- Jemb Laing Taluk Bridge Road	0.580	Medium	4
047	SMP 1–Damar Junction Road	0.602	Medium	2
051	Sigege Juction - Ampang Kualo Road	0.907	Enhancement	1
034	BRI Junction - Tanjung Paku Junction Road	0.427	Routine	8
054	Laing Juction- Batas Kota Damar Road	0.583	Medium	3
056	Laing Bridge - Laing Pasir Road	0.570	Enhancement	5
064	Lintasan KA - Lurah Lama Office Kp. Jawa Road	0.432	Routine	7

4. Conclusions

From this study, the following conclusions can be drawn. The priority for road handling was determined using the AHP method, considering specific aspects/criteria and combining various criteria and sub-criteria carried out by weighting based on the level of importance. AHP consolidates broad and unstructured problems into a model that is flexible and easy to understand. Consider logical consistency in the assessment. In this case, for the criteria, the

level 2 Road Condition Factor got the highest rating in road handling with a weight of 31.46%. The Traffic Volume Factor had the second priority place, with a weight of 21.89%. In the top three in the priority list for road handling was Sigege Junction - Ampang Kualo Road section (0.907), and the type of handling was road improvement. The second priority was SMP 1 Damar Junction Road (0.602), and the kind of handling was periodic maintenance while the last priority was BRI Junction-Tanjung Paku Junction Road (0.427), and the type of road handling was routine maintenance.

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