Prioritizing District Road Maintenance Using AHP Method

Nindyo Cahyo Kresnanto

Abstract Efforts to extend the useful life of roads are carried out by routine, periodic maintenance, or reconstruction. In Indonesia, maintenance of district roads is carried out based on the Technical Guidelines for District Road Planning and Programming (SK No. 77 of the Directorate General of Highways, 1990). Road maintenance regarding these instructions prioritizes roads that are maintained by 5 criteria and 17 sub-criteria conditions that must be considered. Of course, it is not easy to prioritize with so many criteria and sub-criteria. This study will prioritize road maintenance based on the criteria/sub-criteria used by the Analytic Hierarchy Process (AHP) method. The research was conducted by interviewing respondents who are road maintenance experts. Furthermore, the results of respondents' assumptions as measured by a Likert scale were analyzed using the AHP method, which resulted in the weight of the influence of the criteria/sub-criteria on the priority of road maintenance. The results showed that the most important order of priority for road maintenance is the traffic volume factor, the road condition factor, the policy factor, the economic factor, and the last factor is land use.

Keywords Analytic hierarchy process (AHP) · Priority · Rehabilitation

1 Introduction

With age, the road will experience a decrease in the level of service. In addition to traffic loads, other factors that can damage roads are temperature, weather, air content, and road quality. To extend the life of the road, it is necessary to carry out routine or periodic maintenance so that the road is always in a state of high service level. The relationship between the level of road service, rehabilitation, and duration of road use can be seen in Fig. 1 [1].

N. C. Kresnanto (✉)
Civil Engineering, Janabadra University, Yogyakarta, Indonesia
e-mail: nindyo_ck@janabadra.ac.id

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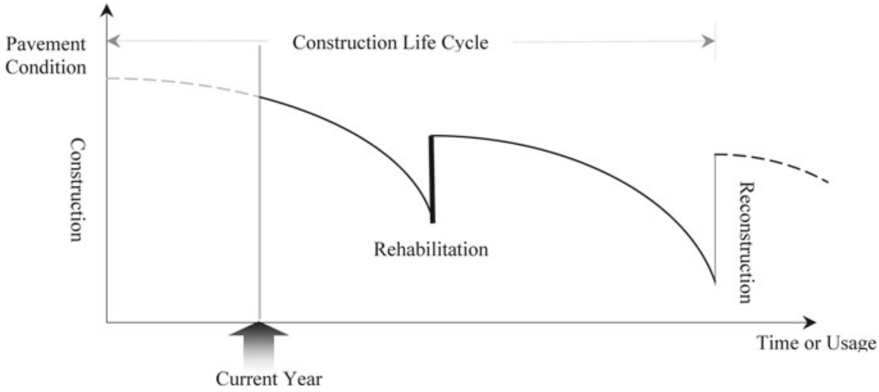

Fig. 1 Rehabilitation and construction life-cycles for new and existing pavements [1]

The maintenance/rehabilitation process must be carried out with priority by assessing road conditions based on specific criteria [2–4]. It was done because, especially for roads with the status of district roads, the amount of maintenance funds was not proportional to the number/length of roads that had to be handled [5, 6]. However, its condition was never reported. Thus, stakeholders who are authorized to carry out maintenance activities must assess the condition of roads and prioritize which roads should be rehabilitated. Prioritization is carried out by referring to Decree No. 77 of the Directorate General of Highways (1990). There are at least five criteria and 17 sub-criteria in this decree that must be considered in setting priorities.

In this condition, it is necessary to calculate the weight of the influence of each criterion/sub-criteria on the priority priorities. One of the tools used for this weighting is the Analytical Hierarchy Process (AHP) [7, 8]. AHP is a decision-making method developed by Thomas L Saaty in 1970 [9]. This method is part of the Multi Criteria Decision Making (MCDM) [10]. So, in terms of prioritizing which roads will be maintained, the question that must be resolved is the priority order of road handling at the maintenance stage using the AHP method. The explanation of these questions is the purpose of this study, namely determining the order of priority for road handling based on the AHP method.

2 Literature Review

2.1 Priority Scale Based on Decree No. 77 Director General of Highways 1990

The procedure for SK No. 77/KPTS/Db/1990 from the Director General of Highways is a district road planning guide issued by the Director General of

Highways as a reference in determining the priority order of district road handling. However, the procedure does not provide how much weight value the influence of the criteria on priority determination. In general, the priority criteria for road handling according to the procedure are as follows:

1. The primary criterion for priority selection is to prioritize the project with the highest Net Present Value (NPV)/Km.
2. A project evaluation code is also provided for projects marked with an NPV/Km range to guide their selection, with the following selection instructions.
3. Give priority to the project group that has the highest feasibility.
4. Give the lowest priority to the project group with the most insufficient feasibility.
5. Prioritizing rollout projects, especially the completion of projects whose implementation is divided or in stages.
6. Completion of the project according to the initial plan or according to the initial design will provide full benefits for the investment.
7. Avoid very long projects (generally projects longer than 15 km) should be avoided at the project determination stage.
8. Prioritizing the strategic road network sections that have been determined.
9. Give priority to projects that meet district development objectives.

2.2 Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a complex decision-making technique with a pairwise comparison approach between criteria and results in an assessment of the weight of the influence of the criteria on the decision-making objectives. This method was first developed by Thomas L Saaty in 1970. The use of the AHP method for decision-making in the transportation sector has been widely used, among others: to evaluate the performance of public transportation [8, 11–13], for decision making on road safety [14], including to prioritize road maintenance [15–17]. Several researchers have also prioritized roads with certain statuses, such as: prioritizing the handling of district roads with four criteria (road conditions, traffic, land use, and economy) [18], and priority one level with five criteria in district road (road condition, traffic volume, accessibility, policy, and land use) [19, 20]. Some researchers have also done something similar with case studies on roads with national road status [21, 22].

3 Methodology

The processes carried out in the AHP method are as follows:

1. Step 1. Define the issue and decide on the best remedy. In this study, the problem to be solved is determining the priority of road maintenance based on various criteria.
2. Step 2. Create a hierarchical structure starting with a general goal followed by criteria and possible alternatives at the lowest criteria level. A hierarchy is formed with five criteria and 17 sub-criteria to prioritize road maintenance. In this study, the hierarchical level arrangement used in the Analytical Hierarchy Process (AHP) method is as follows:
   - Level I (Goal) is the purpose of determining the priority of road maintenance.
   - Level II (Criteria) consists of criteria in determining road priorities, namely: Road Conditions (A), Road Hierarchy (B), Social Aspects (C), Economic Aspects (D), Land Use Aspects (E)
   - Level III (Sub Criteria), Sub Criteria for Road Condition Aspects, Road Class, Economic Aspects, Road Hierarchy Aspects, Social Aspects, and Land Use Aspects. The hierarchy chart from level I to level III can be seen in Fig. 2.
3. Step 3. Create a pairwise comparison matrix that describes the contribution or influence of each element on the criteria specified in it.

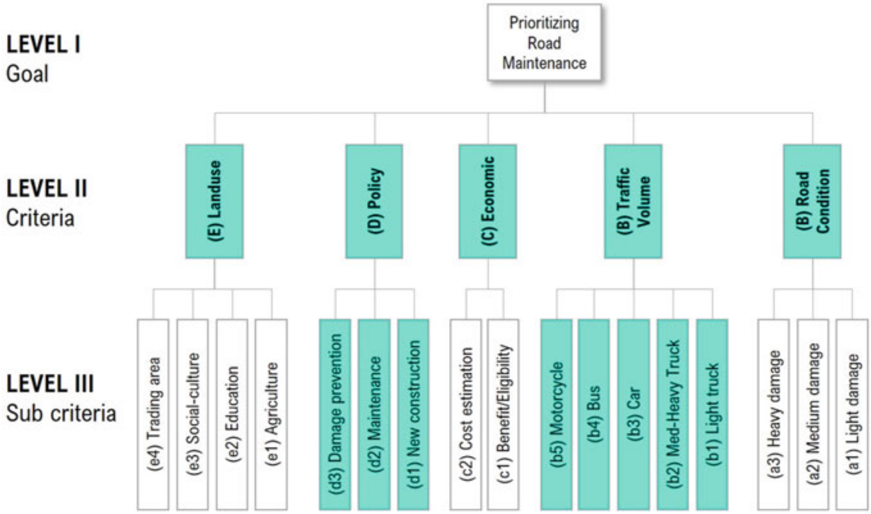

Fig. 2 AHP hierarchy to prioritize road maintenance

Table 1 Pairwise comparison matrix scale [23]

Intensity of importance	Definition
1	Elements that are equally significant to others
3	One factor is slightly more significant than the others
5	The importance of one over the other is moderate
7	Very strong important
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate value between two adjacent value

Table 2 Random index value

Ordo matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

4. Step 4. Perform pairwise comparisons so that n[(n − 1)/2] scores are obtained, where n is the number of elements being compared, with five criteria elements, 5 [(5 − 1)/2] = 10 pairwise comparisons at the criterion level. At the sub-criteria level, there will be a total of 17[(17 − 1)/2] = 136. Pairwise comparisons are graded using a scale, as shown in Table 1.
5. Step 5. Calculate eigenvalues and assess each respondent's consistency. Data retrieval is repeated if it is not consistent, or inconsistent data is discarded. The basic principle in this consistency test is that if A is more important than B, B is more important than C, so there is no way C is more important than A. The benchmark used is CI (Consistency Index) versus RI (Ratio Index) or CR (Consistency Ratio). RI is determined based on previous studies [24], as shown in Table 2.
6. Step 6. Repeat steps 3, 4, and 5 for each hierarchy.
7. Step 7. Determine each pairwise comparison matrix's eigenvector.
8. Step 8. Verify the hierarchy's consistency. The judgment data assessment must be modified if the value is greater than 10%.

4 Discussion and Result

Respondents in this study were experts in the field of road maintenance/rehabilitation. The number of respondents was 29 people, consisting of eight people from the Public Works Department's Binamarga Expert Staff, six people from Sleman Regency, five people from Kulon Progo Regency, seven people from Bantul Regency, and three people from Gunung Kidul Regency.

Initial assessment of pairwise comparisons between criteria A (Road Conditions), B (Traffic Volume), C (Policy), D (Economic) and E (Land Use), Wi values, eigenvector values (E), and λmax can be seen in Table 3.

The consistency value as a measure of the control model is calculated using the consistency ratio (CR) by first calculating the consistency index (CI) = (λmax − n)/(n − 1) = (5.100 − 5)/(5 − 1) = 0.025 (where n denotes the matrix's size 5 × 5. CR = CI/RI, the value of RI is taken from Table 2, so CR = 0.025/1.12 = 0.02223 < 0.1 (meaning that the answers from respondents can be accounted for because they are consistent).

After analyzing the calculations using the AHP for each criterion and sub-criteria according to the calculation flow as above, the influence weight of each criterion and sub-criteria is obtained as shown in Table 4.

Table 3 Average original judgment matrix, Wi, E, and λmax

	A	B	C	D	E	$\sum A_i$	Wi = $\sqrt[n]{\sum A_i}$	Eigen vector $E = Wi/\Sigma Wi$	λmax = $Ei/\Sigma A_j$
A	1.000	0.949	1.138	1.805	2.457	4.790	1.368	0.257	0.999
B	1.054	1.000	2.375	1.754	2.149	9.433	1.567	0.294	1.000
C	0.879	0.421	1.000	1.485	1.724	0.947	0.989	0.185	1.070
D	0.554	0.570	0.673	1.000	2.235	0.475	0.862	0.162	1.049
E	0.407	0.465	0.580	0.447	1.000	0.049	0.547	0.103	0.982
$\sum A_j$	3.893	3.406	5.766	6.491	9.565	15.695	5.333	1.000	
								λmax	5.100

Table 4 Aggregated priority weights and rankings of criteria

Criteria		Subcriteria	
Factor	Weight against criteria (%)	Factor	Weight against sub-criteria (%)
(A) Road condition	25.70	Light damage	33.90
		Medium damage	44.70
		Heavy damage	21.40
(B) Traffic volume	29.40	Light truck	26.80
		Medium-heavy truck	35.80
		Car	12.80
		Bus	17.80
		Motorcycle	6.86
(C) Economic	16.20	Benefits/Eligibility	66.30
		Construction cost estimation	33.70
(D) Policy	18.50	New road construction	13.90
		Maintenance	55.60
		Damage prevention	30.50
(E) Landuse	10.30	Agriculture	26.40
		Education	34.01
		Socio-cultural	14.85
		Trading area	24.74

5 Conclusions

From the research results that have been described in the discussion, conclusions can be drawn, as follows:

1. The application of the AHP method can help provide alternative decision-making in road maintenance, according to several aspects of the criteria that are considered to affect road maintenance.
2. The results of the priority order of road handling criteria (level I) indicate that the Traffic Volume factor is preferred, with a weight of 0.294 (29.4%), then followed by the Road Condition factor of 0.257 (25.7%), the policy factor is 0.185 (18.5%), economic factors 0.162 (16.2%) and finally land-use factors 0.103 (10.3%).

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