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A multi-criteria model approach for identifying priorities in road maintenance in the province of Lampung, Indonesia

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A B S T R A C T

The source of financing largely determines the implementation of road maintenance. Due to the limited funding capacity of the Regional Government, the performance of road maintenance cannot be handled throughout the provincial road network, so it is necessary to determine the priorities and types of maintenance that must be performed carefully and accurately following the conditions. Therefore, this article conducts a study to determine the priority scale in road maintenance in the province of Lampung (Indonesia), which is limited by the government's financial capacity to make comprehensive improvements through a multi-criteria analysis approach. The approach used is a survey method with purposive sampling, integrated with a multi-criteria analysis approach to find eigenvalues as a priority for improvement. There are at least eight groups with 238 respondents who provide input in determining the priority of road preservation in the province of Lampung. The results show that there are ten main parameter criteria to assess the implementation of road preservation in the Lampung province, including accessibility, social, regional development, economy, number of vehicles, security, congestion, road damage, road safety, and regional disparities. The results of the calculation of the multi-criteria analysis of the parameters found that the "road damage" parameter has the highest weight or eigenvalue. The following parameter that becomes the main consideration is the economic aspect and accessibility, with the second and third largest eigenvalues. The security parameter is a factor that is not considered because it is ranked the lowest.

1. Introduction

The economic growth of a region cannot be separated from the quantity and quality of its infrastructure-supporting activities. Roads play a role in the movement of people from one place to another and as an infrastructure for the distribution of goods and services, which are essential in daily activities (Cebro and Sitorus, 2019; Evans et al., 2018; Lemanski, 2020; Mattioli et al., 2020; Sitorus et al., 2018). The road is one of the transportation infrastructures that plays a vital role in economic growth, sociocultural, environment, politics, defense, and security. It is used for the greatest prosperity of the people. Rapid population growth, of course, affects the increasing need for the movement and distribution of goods and services. With the increasing physical and social mobility of the community, the role of roads will increase, so that currently the roads not only facilitate the flow of transportation of people, goods, and services. Instead, it is also related to social, economic, cultural and environmental life (Arcese et al., 2013; Benoît et al., 2010; Hamim et al., 2021). Developed through a regional development approach to achieve balance and equitable development between regions, establish and strengthen national unity to strengthen national defense and security, and form a spatial structure to realize national development goals, as written in Law Number 38 of 2004 concerning roads.

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Lampung Province, one of the provinces on the island of Sumatra, which is included in the province with a high GRDP, contributed the fourth largest (10.52%) (Lestari et al., 2022). In recent years, Lampung province has experienced rapid growth in infrastructure and land use. Based on Lampung Provincial Regulation Number 12 of 2019 concerning amendments to regional regulation number 1 of 2010 concerning regional spatial planning of Lampung Province from 2009 to 2029, Lampung has established strategic areas to further support regional development in Lampung Province. The activities in the area are necessary and generate a lot of movement involving various types and classes of vehicles. The increase in production levels raises the issue of overdimension overload, causing reduced road quality; of course, this will impact the areas and damage provincial roads (Mora et al., 2016; Persaud and Nguyen, 1998; Sartika et al., 2018). So it is important to develop strategic areas supported by a steady and integrated provincial road network.

The high level of road damage in Lampung Province is caused by the number of vehicles that pass more than the tonnage of the road class as a result of the operation of the Bakauheni-Terbanggi Besar-Simpang Pematang 252 km toll road. This encourages the movement of vehicles on land transport by provincial roads within and between districts/cities in Lampung Province. In general, movement is dominated by heavy transport modes. In essence, activities in several strategic areas, such as plantations and industries, which have a fairly high level of logistics distribution, greatly affect road durability.

The types of road damage caused by excess vehicle load capacity are shown, among others, by the presence of a bumpy road surface (deformation) so that cracks and holes in the road surface occur quickly (Singh et al., 2017; Vittorio et al., 2014; Yang and Sun, 2020). If the condition of the cracked and potholed road surface is not treated immediately, the road damage will increase relatively quickly. Damage caused by lack of road maintenance includes road shoulders being overgrown with grass and shrubs, as well as side drains that are not functioning, resulting in waterlogging, which accelerates the decline in the quality of road structures. Meanwhile, the economic potential of Lampung province in 2019 is supported by three main sectors, including the agricultural sector at 28.96%, the processing industry at 19.85%, and the repair of vehicles in trade at 11.75%. The three main sectors require a good infrastructure network so that production, distribution, and marketing activities can run well (Applegate et al., 1996; Clarke, 2001; Klein Woolthuis, 2010). The Trans Sumatera toll road network that has been present in Lampung has become a liaison between economic centers between provinces and islands and then should be supported by provincial roads as a connecting network between regencies that produce the main economic sector of Lampung. In addition, road maintenance includes routine maintenance, periodic maintenance, and road rehabilitation, including road complementary facilities and other equipment (Ganobjak et al., 2020; Li et al., 2019; Solla et al., 2021). Maintenance activities that are diverse and spread throughout the province are difficult to measure and control. However, they have not referred to specific policies to determine the priority of provincial road maintenance. The result is that maintenance work is often carried out inefficiently and with low productivity.

The management and financing of road maintenance are also determined by the organization or institution that handles certain types of maintenance, in this case, including the absence of local government policies specifically in continuously governing road maintenance. This is also related to regional financial procedures that regulate the use and distribution of less flexible road maintenance funds (Geng et al., 2009; Meyer, 1999; Xu & Yeh, 2005). The financing policy has not been oriented toward road maintenance but rather to support improving road quality which is related to the political interests and prestige of policy managers. However, the problem of budget constraints makes road maintenance not comprehensive. Therefore, it must be carried out as effectively as possible by supporting strategic areas to be on target. The regulation and distribution of funds for road maintenance continue to follow the normative pattern of financing and budgeting for regional development. Supposed that there are road damage that seriously disrupts community activities, not only strategic area activities, but also other activities connected by the provincial road network, in that case, well-planned and planned financing. Therefore, this study aims to analyze the priority of road maintenance with budget constraints in Lampung Province (Indonesia) through a multi-criteria analysis approach. It is expected that priority parameters in the road maintenance program can be sorted though in the limited budget conditions, and can obtain more efficient results.

2. Methodology

Data collection is carried out to obtain comprehensive information and opinions on aspects of road development. The information obtained is the perception of various stakeholders about the criteria or parameters that are compared in decision making. The stakeholders involved come from different elements, including regulators, operators, users, and experts.

The method of determining the sample uses the purposive sampling method (Campbell et al., 2020; Denieffe, 2020; Klar & Leeper, 2019), by selecting the criteria for the source or respondent and mapping the resource person based on the requirements and data that need to be obtained. In this study, eight groups of respondents were used, which were mapped according to the type of institution or their role in the development of transportation and road infrastructure.

The criteria assessment technique used is by distributing questionnaires to informants/respondents. The questionnaire was written concisely and distributed online to make it easier for the respondents. The questionnaire contains one main question about the considerations in determining the priority of road handling in Lampung province. Respondents were asked to prioritize road handling based on ten criteria or parameters provided, as shown in **Table 1**.

Table 1
The main priority parameters considered

Parameter codes	Priority parameters
A1	Accessibility
A2	Social
A3	Regional development
A4	Economy
A5	Traffic volume
A6	Security
A7	Congestion
A8	Road demage
A9	Road safety
A10	Regional disparities

Data analysis was carried out until the final stage where the research objectives were obtained. At the initial stage, an analysis of the validity of the data relevant to the research was conducted. In addition, an analysis of the road maintenance budgeting method is carried out so that later it can be used for road maintenance to formulate a priority policy for road maintenance budgets. Using multi-criteria analysis (Li et al., 2021; Santos et al., 2022; Tsigdinos and Vlastos, 2021), various financing alternatives for road maintenance are being signed to support strategic areas in Lampung province.

3. Results and Discussions

3.1 Respondent classification analysis

Altogether, 238 respondents were involved as resource persons and completed the questionnaire, divided into eight groups, as presented in Table 2. The results of the response to the assessment of the prioritized aspects or criteria in road handling are described in **Table 1**. Based on the data collected (Table 3) from all respondents, it is known that the road damage aspect is a parameter that is the primary consideration of stakeholders in the handling of roads. This is at least reflected in the dominance of the assessment of this aspect by 121 respondents (50.8%), making this parameter a priority 1. Then the economy and accessibility parameters look superior, and more respondents are chosen in the order of priority from 1 to priority 5. On the other hand, the security and regional disparities aspects are chosen more by respondents in the 8th to 10th priority order. This means that stakeholders do not consider these two parameters in the road maintenance program in Lampung Province. This is in line with the findings of Flint and Zhu (2019), who found that aspects of non-traditional security issues were not a top priority in road maintenance from a political aspect.

Table 2
Group and number of respondents

Respondent group	Total
Public works service	41
Department of transportation	11
Development planning agency at sub-national level	34
Academics and practitioners	57
Regional people's representative assembly	12
Corporate	30
Bureaucrat	41
Bank Indonesia and central bureau of statistics	12

Table 3
Priority distribution matrix of respondents

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
A1	30	7	15	28	4	3	8	121	18	4
A2	25	18	12	45	27	8	38	33	26	6
A3	32	28	20	51	29	6	21	19	21	11
A4	44	33	22	29	19	17	23	15	12	24
A5	28	30	33	40	20	13	28	11	13	22
A6	36	52	33	20	19	15	15	11	15	22
A7	15	29	44	16	22	27	18	8	21	38
A8	17	19	20	9	26	37	31	8	34	37
A9	5	15	24	2	28	59	35	6	28	36
A10	6	7	17	0	41	52	21	6	50	38

3.2 Weighting of Assessment Results

To provide a more quantitative and measurable assessment, the assessment results that the stakeholders have carried out are then given a weighting, as presented in **Table 4**. Weighting is carried out based on the order of priority chosen. For parameter values on priority 1, they are given a weight of 100% or a matter of 1. The values for the priorities below are given a lower 10% weight, successively decreasing until the last priority, namely priority ten, which has a weight of only 10% or a value of 0.1. The total value of each parameter is the sum of all the values in each priority order multiplied by its weight. This can be illustrated in Eq. (1).

$$W = \sum_{i=0}^{9} (1 - .1 \times i) A_{i+1} \tag{1}$$

Table 4
Priority weighting of parameters

Parameter codes	Parameters weighting
A8	36.1
A1	28.2
A4	28.1
A3	22.1
A2	21.1
A5	21
A9	20.6
A7	20.2
A10	15.3
A6	12.8

3.3 Value of Interest Clustering

As shown in the table above, the assessment results for each parameter are not directly used to construct a pairwise matrix. These values should be clustered into more straightforward classes to see their level of importance. Classes are divided on the basis of quartiles by dividing the data into 4 (four) parts with approximately the same amount. The first or lower quartile (Q1) is the middle value between the most minor and median values of the data group. The first quartile is a marker that the data in that quartile are 25% from the bottom in the data group. The second quartile (Q2) is the data median, marking 50% of the data (dividing the data into two). The third or upper quartile (Q3) is the middle value between the median and the highest value of the data set. The third quartile is a marker that the data in that quartile are 75% from the bottom in the data group. In **Table 5**, the minimum and maximum values are 81.1 and 195.9, respectively. The class boundaries in the first quartile (Q1) are 109.8, the second quartile (median) is 138.5, and the third quartile (Q3) is 167.2. Using the quartile class table (**Table 5**) the total value of each parameter will be grouped into interest groups following the existing range of values as presented in **Table 6**. The collection is built using four groups.

Table 5
Quartile class of criteria

Criteria	Value	Percentage	Commulative percentage
Min	81.1	0	0
Q1	109.8	25%	25%
Q2	138.5	25%	50%
Q3	167.2	25%	75%
Max	195.9	25%	100%

Table 6
Clustering the importance of parameters

Parameter codes	Parameters priority	Clustering
A8	Road demage	4
A4	Economy	3
A1	Accessibility	3
A2	Social	2
A3	Regional development	2
A5	Traffic volume	2
A7	Congestion	2
A9	Road safety	2
A10	Regional disparities	1
A6	Security	1

3.4 Pairwise analysis

Pairwise comparison matrices are used to compare various criteria/parameters to be weighted to show how necessary one parameter is to another. After compiling the average pairwise matrix, proceed to collect the normalization matrix. Matrix normalization is done to unify each element of the matrix so that the details in the matrix have a uniform value scale (**Table 7**).

Table 7
Pairwise normal matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0.13	0.15	0.15	0.13	0.15	0.14	0.15	0.14	0.14	0.14
A2	0.08	0.08	0.09	0.08	0.09	0.10	0.09	0.08	0.10	0.10
A3	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.08	0.08
A4	0.19	0.19	0.18	0.18	0.18	0.16	0.19	0.18	0.17	0.16
A5	0.07	0.06	0.07	0.07	0.06	0.08	0.06	0.07	0.07	0.08
A6	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.05	0.04
A7	0.10	0.09	0.10	0.09	0.09	0.10	0.08	0.08	0.09	0.10
A8	0.22	0.21	0.20	0.22	0.19	0.17	0.21	0.21	0.19	0.17
A9	0.07	0.07	0.07	0.06	0.07	0.07	0.06	0.07	0.06	0.08
A10	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.06	0.05	0.05

Eigenvalues are values that show how much influence a parameter has on the formation of the characteristics of a vector or matrix. Eigenvalue parameters are formed by averaging the row values for each parameter in the matrix normalization results obtained previously. The eigenvalue of the parameters in this discussion becomes the final weight value of each parameter and will be compared with other parameters, so that differences and ranking sequences emerge. The ranking of the eigenvalues shows which aspects are the priority in the road maintenance program. The final results of the calculation of the eigenvalues for the parameters are shown in **Table 8**.

The parameter road damage has the highest weight or eigenvalue of 0.199. This shows that the aspect of road damage is the main consideration of stakeholders when determining priority of the road maintenance program. The following parameter that becomes the main consideration is the economic and accessibility aspects with eigenvalues of 0.178 and 0.142, respectively. The parameter security is a factor that is not considered because it is in the lowest rank with a value of 0.044.

Table 8
Matrix eigenvalue dari setiap paramater

Parameter codes	Priority parameters	Eigenvalue	Priority ranking
A1	Accessibility	0.142	3
A2	Social	0.089	5
A3	Regional development	0.073	6
A4	Economy	0.178	2
A5	Number of vehicles	0.069	7
A6	Security	0.044	10
A7	Congestion	0.092	4
A8	Demage to roads	0.199	1
A9	Road safety	0.066	8
A10	Regional disparities	0.047	9

4. Conclusions

From the data collection results, ten criteria were analyzed, including accessibility, social, regional development, economy, number of vehicles, security, congestion, damage to roads, road safety, and regional disparities. The results of the calculation of the multi-criteria analysis of the parameters found that the road damage parameter has the highest weight or eigenvalue with a value of 0.199. This shows that the aspect of road damage is the main consideration for stakeholders when determining priority of the road maintenance program. The following parameter that becomes the primary consideration is the economic mix and accessibility aspects with eigenvalues of 0.178 and 0.142, respectively. The parameter security is a factor that is not considered because it is in the lowest rank with a value of 0.044.

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