

How to Determine Road Maintenance Priorities? An Analysis Using a Probabilistic Approach

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Keywords: Road Maintenance, Probabilistic Approach, Binary Logistic.

Abstract: The provision of limited maintenance budget for basic infrastructures often lead to unrepair and dilapidation of the untargeted roads, and this tends to be wasteful. Presently, treatment priority is one of the alternatives that have been carried out. This study aims to discuss determining road maintenance priorities based on a probabilistic approach, namely the probability of a road section being proposed in the maintenance program. The samples used were obtained from the Bakunase-Oenesu and Soe-Fatumnasi roads. The variables utilized were the pavement structure, average daily traffic, accessibility, economic benefits, time travel, and asphalt recycling technology. The binary logistic analysis showed that the condition of the pavement structure and the average daily traffic were variables that had significant effect on road maintenance. There is a greater chance for the Soe-Fatumnasi road section than the Bakunase-Oenesu being drafted for maintenance. A probabilistic approach can be applied in determining roads for maintenance programs. This method will be more appropriate if applied to planning at the first level. In making road maintenance decisions, policymakers need to pay attention to various factors to make their decisions right on target.

1 INTRODUCTION

In road maintenance planning, obstacles are often encountered while producing a predictive model for its conditions, mainly due to errors in the visual survey and lack of knowledge about essential factors affecting degradation (Zhao B, Soga K and Silva E 2019). When this continues, it affects the road's serviceability until it reaches its economical age and this increases costs for users (Salih J, Edum-Fotwe F and Price A 2016) (Mikolaj J, Remek L and Margorinova M 2019), also impacting the residents and the environment around the area negatively (Freitas E, Silva L and Vuye C 2019). Furthermore, highway repair is closely related to budget availability, and it is necessary to carry out an appropriate assessment (Muda A, Dumin L and Nahak P 2019), which include the deterioration of this area and its sections, such as inspection of the pavement, shoulders, drainage channels, and subgrade (Bhuva C R, Patel B and Kanam M 2019) (Tchemou G, Minsili L S, Mokotemapa A M, Eko R M and Manguelle J H 2011). This implies that there is need for right decision making when planning road maintenance (Siswanto H, Supriyanto B, Pranoto, Putra Y A M and Huda A S 2018). Consequently,

various efforts have been made by government both technically and managerially, these involved carrying out routine checks periodically, and conducting a priority analysis for sustainability. However, the sustenance budget is often not followed by useful methods, therefore, it does not produce a good result (Susanna A, Crispino M, Giustozzi F and Toraldo E, 2017). Maintenance is an essential part of traffic management (Ma J, Cheng L and Li D, 2018), and when planning, it is necessary to consider various aspects before making decisions, including the performance and strength of the pavement structure (Bazlamit S M, Ahmad H S and Al-Suleiman T I, 2017), traffic load, age, road level, and non-technical aspects, such as resources, disposition, and bureaucratic formation (Li H, Ni F, Dong Q and Zhu Y 2018) (Hayat E and Amaratunga D 2014). Besides, due to limited natural and financial resources, handling critical highways needs to be performed with a good strategy by relying on renewable materials and choosing the right construction method (Susanna A, Crispino M, Giustozzi F and Toraldo E 2017).

One of the techniques is planning a proper maintenance program. Studies on organizing have been carried out, with a priority approach in making

decisions using multicriteria analysis (Ahmed S, Marcelino P, Liem F, 2019), based on road structural data (Bazlamit S M, Ahmad H S and Al-Suleiman T I 2017). However, the use of a probabilistic approach in planning maintenance programs has never been carried out. To fill this gap, this paper aims to discuss determining road maintenance priorities based on the probability approach, namely the chance of a road section being included in the maintenance program. For this reason, the considerations that will be used in the analysis are not only on the structural aspects of roads but also considering the economic value of roads and the application of green construction principles.

2 METHOD

The research location was in West Timor, East Nusa Tenggara Province. The samples were the roads of Bakunase-Oenesu in Kupang Regency and Soe-Fatumnasi in South Central Timor. The main concept of this study was to identify the chances for a section to be included in the road maintenance program, because in one budget year, the available repair funds were very limited, below what was needed. Therefore, to strengthen the related technical agencies' proposals, the planning approach with this probability concept was used as a guide in proposing maintenance for a particular road section. The considerations used to measure how many opportunity was accepted or not were based on these main criteria, namely the condition of the pavement structure (X1), average daily traffic (X2), accessibility (X3), economic benefits (X4), time travel (X5) and use of asphalt recycling technology (X6). The dependent variable was the sustenance of the Bakunase-Oenesu and Soe-Fatumnasi roads.

The approach used to obtain the value of the formulas above was quantitative subjective; that is, the respondent made an assessment based on the information they had on the distributed questionnaires. Therefore, they understood the problems involved in road maintenance activities and were responsible for the problems, including budgeting. Summarily, they are the policymakers in relations to construction works. In this study, the number of respondents were 150 from technical agencies at the provincial to district levels.

The analytical method used to ascertain the probability of road maintenance was binary logistic, and because the questionnaire questions were qualitative, each response gave a certain nominal scale, as in Table 1.

Table 1: Variables and scales used.

No.	Variable	Response
1	The Pavement Structure	(0) slightly damaged, (1) moderate, (2) heavily damaged
2	Average daily traffic	(0) low, (1) moderate, (2) high
3	Accessibility	(0) low, (1) moderate, (2) high
4	Economic Benefits	(0) low, (1) moderate, (2) high
5	Travel Time	(0) slow, (1) moderate, (2) normal
6	Application of recycling technology	(0) is not urgent, (1) important and urgent
7	Maintenance of roads	(0) not yet feasible, (1) feasible

Based on the variables above, the following model was formed:

The basic form of binary logistics:

$$p = \frac{\exp(\beta_0 + \beta_1 X)}{1 + \exp(\beta_0 + \beta_1 X)} = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_1 x}}$$

From this basic form, then used as a binary logistic equation model tested in this study are:

$$\text{Log} [P/(1 - P)] = \beta_0 + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4) + \beta_5(X_5) + \beta_6(X_6)$$

β_0 is a constant; β_i is the regression coefficient of each variable; X_i is the independent variable. P is the probability that the road will be included in the maintenance program; (1-P) is the chance that the road is not included in the maintenance program.

The model evaluation included the following tests: (1) goodness of fit, concerning the level of significance 0.05; (2) simultaneous variable effect based on the chi-square significance value; (3) determination using the Negelkerke R-square criteria, and (4) the significance of the variables in the equation. Because two dependent quantities were compared, each section's analysis was carried out separately for the Bakunase-Oenesu and Soe-Fatumnasi roads.

3 RESULT AND DISCUSSION

In modeling the probability between two alternative options, using a discrete approach, the model needed to meet the test conditions. Table 2 describes the results of the model test in the form of the goodness

of fit test, simultaneous and determination test. The goodness of fit test and the simultaneous test are based on a significance value of $\alpha = 0.05$, while the determination test shows the magnitude of the influence of the independent variables in the model.

Table 2: Result of model test.

Model	The goodness of fit test	Model simultaneous test	Determination test
Y ₁ : Maintenance of Bakunase-Oenesu road	1. The chi-square significance value 0.211 > $\alpha = 0.05$	The chi-square significance value on the omnibus test is 0.000 < $\alpha = 0.05$	The Negelkerke R-square value is 0.406
	2. The percentage on the classification test is 80.2%.		
Y ₂ : Maintenance of Soe-Fatumnasi road	3. The chi-square significance value 0.912 > $\alpha = 0.05$	The chi-square significance value on the omnibus test is 0.000 < $\alpha = 0.05$.	Nilai Negelkerke R-square sebesar 0.564
	4. The percentage of the classification test is 81.7%.		

First, to assess the goodness of fit of the standard, the terms used were the chi-square significance value. From Table 2, it was observed that the two models met the requirements where the chi-square value of the Hosmer and Lemeshow test was more than 0.05. These indicated that the model was used to predict the observations made.

Secondly, the simultaneous results based on the omnibus test (Table 2) show that the chi-square significance level was less than 0.05 in both. These proved that all the variables that make up the model (X₁ - X₆) had a simultaneous influence on road maintenance. In other words, at least one of the quantities had a significant effect on road maintenance.

Thirdly, from Table 2, it was also observed that the negelkerke R-square value of the two was far above 0.05. These results proved that the independent explain the dependent variable's instability by 40.6% in the Y₁ model and 56.4% in the Y₂ model.

Fourth is a partial effect test to see the effect of each variable. In Table 3, there are constant values for each variable (β) and significance (Sig) as well as the odd ratio value (Exp (β)) of the Y₁ model. The results showed that in the Bakunase-Oenesu road

maintenance model, there were two quantities that partially have a significant effect, namely X₁ and X₂ because the value was <0.05. Variable X₁, which was positive, indicated that the greater the pavement structure's damage, the greater the chance for the Bakunase-Oenesu road section to be included in the road maintenance program. The magnitude of this opportunity, observed from the odds ratio, was 8,425 times higher than if the damage does not increase. Likewise, with average daily traffic, it has 1,923 chances of being included in the program when it increases than when constant or depreciates.

Table 3: Result of Y₁ Model: maintenance of the Bakunase-Oenesu road.

Variable	β	S.E.	Wald	Df	Sig.	Exp(β)
X ₁	2.131	.561	14.430	1	.000	8.425
X ₂	.654	.290	5.097	1	.024	1.923
X ₃	.150	.309	.235	1	.628	1.162
X ₄	.126	.304	.172	1	.678	1.134
X ₅	.096	.407	.056	1	.814	1.101
X ₆	.439	.449	.955	1	.328	1.551
Constant	-4.385	1.354	10.496	1	.001	.012

Similar to Table 3, Table 4 also describes the constants of each variable in the Y₂ model, the significance value and the odd ratio value of each variable. In contrast to the Y₁ model, it was observed that the magnitude of the influence of the X₁ on the Y₂ was positive by 20,980, greater than if the road section does not experience additional damage. For X₂, it also had a positive effect with an odds ratio of 2.475.

Table 4: Result of Y₂ model: maintenance of Soe-Fatumnasi road.

Variable	B	S.E.	Wald	df	Sig.	Exp (β)
X ₁	3.044	.702	18.811	1	.000	20.980
X ₂	.906	.340	7.093	1	.008	2.475
X ₃	.291	.353	.680	1	.410	1.338
X ₄	.597	.385	2.407	1	.121	1.817
X ₅	.797	.489	2.663	1	.103	2.220
X ₆	-.442	.457	.934	1	.334	.643
Constant	-6.161	1.714	12.917	1	.000	.002

The analysis results showed that in the Y₁ and Y₂ models, the variables that had significant effect are the condition of the pavement structure and average daily traffic. These results confirmed the general trend that had occurred, where pavement conditions are the major basis for making road maintenance

decisions (Bazlamit S M, Ahmad H S and Al-Suleiman T I 2017, Li H, Ni F, Dong Q and Zhu Y 2018). It means that policymakers have not fully developed various criteria in assessing the feasibility of a road section being included in the repair program. Economic benefits and accessibility have not yet received attention. It becomes a serious problem when faced with the choice where many roads are in the same condition, and such decision are not easy to make. In this study, two roads were assessed since they have a strategic role as a route to a tourist area. On the Soe-Fatumnasi road, apart from this function, it is also the only access from the interior to urban areas. However, this study showed that the large probability of this road segment compared to Bakunase-Oenesu is only affected by pavement damage and average daily traffic. Therefore, policymakers need to determine the direction of the maintenance program, in order to pay attention to various criteria, and to obtain the best decision from the several alternatives. Besides, sustainability issues need to be considered, for example, by rewiring asphalt pavements (Liem F, Nenobais O, Bria M and Mata A 2019) in maintenance work.

However, in this study, the assumption of respondents was that they fully understand the maintenance and condition of the two sample roads. This certainly has weaknesses because respondents did not fully understand these problems. Moreover, data collection was carried out by distributing questionnaires and there was no dialogue. Therefore, the data obtained did not completely reflect the actual conditions.

4 CONCLUSION

Determining road maintenance priorities based on a probability approach using the logistic regression model, results in a different assessment form compared to the priority determination based on ranking or weight. The logistic regression showed how possible it is for a road section to be included in the maintenance program. The benchmark is the amount of opportunity from an alternative, and it is more appropriate when applied to planning at the first level.

ACKNOWLEDGMENTS

The authors express their gratitude to the State Polytechnic of Kupang, for funding this research.

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