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Determining National Road Performance and Sustainability Indicators

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Abstract*— This study aims to determine factors influencing performance assessment of road infrastructure and design proposals for non-toll road performance and sustainability assessment models. As of now, the existing assessment is limited to the construction of new roads and road improvements. It also still needs some exploration by using other sub-criteria that have not been used, especially for roads that have been operated and maintained. The design of the road infrastructure performance assessment model is done by selecting sub criteria based on literature reviews and expert interviews. Then filtering out variables using relative important index (RII) and weighting variables using pairwise comparisons method. Based on the results of the analysis, economic criteria have the highest weight of 30%, followed by engineering criteria of 26%, then social criteria of 20.1%, environmental criteria of 12.1% and finally management criteria with weights of 11.8%. A paradigm change needs to be done so that in a development not only does it prioritize the increase of economic activities, but it also needs to be considered for management aspects and environmental aspects, with the word weight gain on economic criteria and engineering criteria, which can be reduced to minimize the gap with interests in the 2 criteria that have low weight.

Keywords*— Relative Important Index, Pairwise Comparison, Triple Bottom Line, Sustainable Development

I. INTRODUCTION

Roads are the basic infrastructure in the development of a region. With the existence of roads, a region can exchange goods and services and enable the movement of people in one area with other surrounding areas; roads have an important role in various fields, namely economy, socio-cultural, environment, politic, defense and security [1]. Nowadays, the application of sustainable construction must be carried out at each asset life cycle, with an infrastructure asset management approach [2].

The first thing to do is to assess the main function of the road in connecting activity centers and flowing traffic flows, then an assessment of the sustainability of the economic, social and environmental aspects is followed in operation and maintenance phase. Infrastructure asset management is knowledge, science or program to manage infrastructure so that it can carry out its functions, effectively, efficiently based on the principle of sustainability in every life cycle of infrastructure asset [3]. Road infrastructure asset management is a process used to ensure that existing road infrastructure assets provide adequate levels of service for a certain period of time [4].

At present, there are "pemeringkatan jalan hijau" guidelines for road sustainability rating tools in Indonesia, but the scope is still limited to the design and construction stage for new construction works and road upgrading. Therefore, it is necessary to develop a road infrastructure performance assessment model with the scope of maintenance work so that it can know the preservation benefits of a road that has been operating. Studies of post-construction assessments of road infrastructure have received little attention; this can lead to a lack of information on the effectiveness of investments in the road sector [5]. In addition to investment effectiveness, social and environmental aspects need to be considered so that a balance between the main functions of the road can be achieved, the benefits of improving the economy, the benefits of fulfilling the social needs of the community, and achieving a negative impact on the environment. Performance and sustainability assessments are intended to optimize the function of road infrastructure assets so that they not only fulfill the technical strength and aesthetics of design, but also improve the economy and at the same time provide social equality and reduce the negative impacts caused by the environment [6]. In conducting these assessments, it is necessary to determine the criteria and sub-criteria and the weights which are the objectives of this study.

II. LITERATURE OF REVIEW

In providing an overview to get to the core of the problem in this research, a literature review is needed in the form of concepts that are relevant to the measurement of road infrastructure performance and previous related research.

A. Road Performance

The main function of a road network is to connect well the nodes in the service area, flowing well in the service area and covering service areas with good density. While the quality of the supporting performance of the main function is having a good network structure and having good general physical conditions. Component Quality consists of 3 network performance components and two basic quality network components as supporting network performance. The quality

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components of network performance are the quality of relationships, which consist of the quality of connectivity and quality of accessibility; quality of traffic flow and quality coverage. While the quality components supporting the quality of network performance are: the quality of the network structure and the general quality of the physical network. Quality measures are formulated for each Quality Component, network aggregate, and quantitative in nature. The network base model used is a simple 'Network-node' model, which consists of three levels: region model, travel demand model, and road network model [7].

B. Road Operation and Maintenance

Public roads are operated after being determined to meet the eligible requirements of road functions technically and administratively in accordance with the guidelines set by the Minister of Public Works and Public Housing and the relevant minister [8]. A public road section is declared technically feasible if it meets the following requirements:

a. technical structure of road pavement;
b. technical structure of road supplementary/support building;
c. technical of road geometry;
d. technical use of road parts;
e. technical implementation of management and traffic engineering; and
f. technical of road equipment.

Shortly after the road is built, then conducted operations and utilization. In constructing or improving a road there is the design life that can be achieved. This design life is influenced by the factor of design quality , quality of materials, natural conditions, as well as the factor of use or operation of the road. Immediately after the road was built and used, damage will begin, as a result of the traffic and weather. Road that has been operating could be confirmed experience a decline in conditions, so that road maintenance is needed to extend the design life and can provide optimal levels of service for road users [9].

C. Road Preservation

Pavement preservation states a proactive action to maintain the road to its function. This handling is believed to be able to reduce the cost burden, maintenance time that requires handling time, and at the macro level can reduce the increase in pavement construction activities. Thus, it will also influence the disruption of traffic flow, which can greatly minimize the impact. If the program is implemented in a timely manner, road users can get a better sense of security and mobility, reducing congestion caused by road damage and maintenance programs, and the most important is being able to provide guarantees for the extension of road life [10].

D. Sustainability Development

Sustainable development is development that aims to meet the needs of the current generation without reducing the ability of future generations to meet their own needs [11]. This concept is often revealed to be the triple bottom line (TBL) which requires the creation of a balance in economic aspects, social aspects and environmental aspects which is an adaptation of the the concept applied in the corporation [12]. There are bias in the three instruments for assessing the sustainability of infrastructure development implemented in several developed countries, management aspects can complement the three existing pillars of sustainability and indeed adjustments are needed if the rating tools will be applied to different Countries [13]. While the core of road performance is closely related to technical aspects, which are absolute criteria that must be fulfilled because they are related to the main function of the road. Thus this aspect must be maintained before assessing other aspects, including the level of sustainability.

The concept of sustainable development today is gaining world attention. This concept states a necessity to stop non-renewable damage to the ecosystem and the awareness that environmental problems must be able to accommodate human needs, both now and in the future [14]. The concept of sustainability combines economic, environmental, social, and energy goals, all of which affect and are influenced by transportation. In addition to fulfilling the criteria for sustainable development, the measurement of road infrastructure performance is also carried out to meet public demands where a project does not only produce output in the form of road construction but it also needs to be explored further both positive and negative impacts.

The main focus of the actual engineering approach is to provide projects with technical excellence, something that currently does not only refer to technical and aesthetic strength, but also includes ways in which sustainability is taken into account in design, construction and operation. In response to these demands, the emergence of a sustainability rating tool for infrastructure become important [6]

III. METHODOLOGY

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A. Relative Important Index (RII)

The methodology in this study is as follows. In the initial stage, a literature study questionnaire and semi structured interview were conducted with experts from Balai Besar Pelaksanaan Jalan Nasional (BBPJN) VIII to obtain criteria and sub-criteria that influence the performance measurement of a road. After the data has been collected, done by reducing variables using relative important index (RII) method with the following formula.

$$RII = \frac{\sum W}{(A \times N)} \qquad (1)$$

Where W is the weighting given to each factor by the respondents (ranging from 1 to 5), A is the highest weight (i.e. 5 in this case), and N is the total number of respondents.

B. Pairwise Comparison

After the variable indicator reduction is done, it is continued by weighting the variables using the pairwise comparison method based on expert opinion from Direktorat Jenderal Bina Marga. Pairwise comparison is another method

for weighting several criteria. It stems from the Analytic Hierarchy Process (AHP), a famous decision-making framework developed by Saaty [15], with the following matrix.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \quad (2)$$

To pairwis ating the data from the AHP (I t was processed using el Version 7.06.2015.

IV. RESULT AND ANALYSIS

A. Profile of Respondents

This research is limited to the perspective of project owners, namely the Ministry of Public Works and Public Housing. Respondents in this study were divided into two groups. The first respondent was an official in the BBPJN VIII Surabaya who was consulted for a variable reduction questionnaire, while the second respondent was an official at the Central Directorate General of Highways who was consulted for the weighting questionnaire. Respondents with work experience of 11 years to 20 years became the majority of all respondents with a total of 11 people, while respondents with work experience 0-10 years 21-30 years were respondents with the same number, each of which was as many as seven people. Then for the classification of respondents based on education, respondents were only divided into two groups, namely Bachelor Degree and Master Degree. Percentage of respondents with Bachelor Degree are as many as 11 people with a percentage of 44% and respondents with Master Degree are as many as 14 people with a percentage of 56% as. Finally, based on the position group which also determines the perceptions of the answers given, the respondents are divided into five groups as shown in Fig. 1 below.

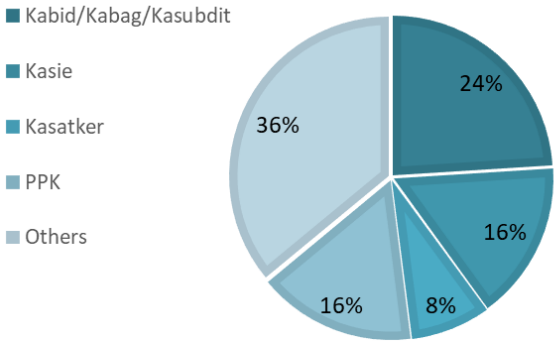

Fig. 1. Respondents Based on Position Type

From 25 respondents, the largest respondents in this study were positions with other categories of 36%, then followed by Echelon 3 level positions consisting of Head of Division and Head of Sub-Directorate as much as 24%. Respondents with the position of Head of Work Unit occupy the least portion of 8% because there are only 2 Heads of Work Units who fill out the questionnaire.

B. Variable Reduction

Then to reduce the indicator variable, relative important index (RII) is used. A reduction is done by pre-filtering the remaining indicators, the results of which are four sub-criteria omitted because they are below the determined RII cut-off point which is ⩾ 0,75. Until this stage, there are five criteria and 25 sub-criteria to be used in the next stage that can be seen in Table I as follows.

TABLE I. SELECTED CRITERIA AND SUB CRITERIA

Code	Criteria and Sub Criteria	RII Value
Economy Criteria (X1)		
x1.1	Vehicle operating costs	0.77
x1.2	The time value of the trip	0.83
x1.3	Regional economic growth	0.77
x1.4	Accident costs	0.73
x1.5	Regional accessibility level	0.84
x1.6	Level of regional mobility	0.80
Social Criteria (X2)		
x2.1	Safety	0.91
x2.2	Equality of road users	0.69
x2.3	Traffic violations	0.69
x2.4	Security	0.86
x2.5	Project negative impact	0.77
x2.6	Employment opportunities	0.80
Environment Criteria (X3)		
x3.1	Vehicle Emissions	0.74
x3.2	Energy saving	0.82
x3.3	Availability of drainage	0.92
x3.4	Availability of green open space	0.85
x3.5	Noise level	0.76
x3.6	Use of space	0.79
x3.7	Ambient air quality	0.76
Engineering Criteria (X4)		
x4.1	Road conditions	0.92
x4.2	Level of service	0.87
x4.3	Degree of saturation	0.83
x4.4	Road capacity	0.86
x4.5	The speed at free flow	0.84
Management Criteria (X5)		
x5.1	Compliance with NSPM	0.83
x5.2	Project sustainability management	0.82
x5.3	Sustainability risk management	0.84
x5.4	Sustainable procurement	0.84
x5.5	Inspection & auditing	0.86

C. Weighting Criteria

Weighting criteria and sub-criteria are done using a questionnaire containing five criteria and 25 selected sub-criteria described above, the weight of each criterion and sub-criterion can be seen in Fig. 2 as follows.

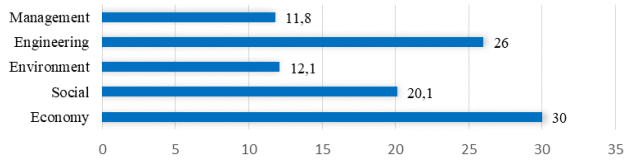

Fig. 2. Weighted Criteria

In accordance with Fig. 2, economic criteria get the highest weight of 30% because the main purpose of maintaining a road is to improve the regional economy. The engineering criteria relate to the ability of a road to carry out its functions; this criterion gets the second highest weight of 26%. Furthermore, the social criteria are in third place with a weight of 20.1%. In

a road maintenance project, it is certain that it will have an impact on the social conditions around the road being maintained even though the impact is not too large. Then in the fourth order are environmental criteria with a weight of 12.1%. Whereas those who get the smallest weight are the management criteria needed to ensure maintenance on a road that meets the applicable rules and prioritizes the principle of sustainability, the weight of this criterion is 11.8%.

The high weighting of economic criteria has implications for the objectives of road management to prioritize increasing economic growth as the main reason for carrying out maintenance and operation of roads. While engineering criteria imply that this aspect can still be reduced in importance, which will slightly reduce the quality of the function of a road to pursue targets on economic aspects. Then for social criteria has an ideal weight of, so that it has implications for the fulfillment of social aspects by prioritizing road users as the subject of development. Then for environmental sub-criteria which have a small weight which has implications for the lack of fulfillment in efforts to reduce environmental impacts both during operations and during road maintenance or preservation. Regarding the management criteria, it also gets a small amount of weight which has implications for the lack of efforts to fulfill the sustainability aspect when the road maintenance project is implemented. The next discussion will describe the weighting results of each sub-criteria used in determining the assessment criteria. In the graph, weighting data series for each sub-criterion is displayed.

Economy Criteria

Economic criteria use five sub-criteria as parameters; 5 of these sub-criteria are based on proposed criteria that have been reduced through RII and special considerations from competent experts as can be seen in Fig. 3 as follows.

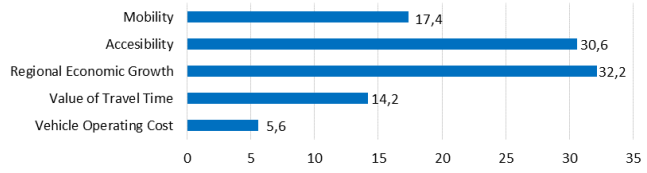

Fig. 3 Economic Sub-Criteria Weight

Based on Fig. 3 above, from the five sub-economic criteria, it can be seen that the highest weight is 32.2%, namely in the sub-criteria of regional economic growth. The sub-criteria that get the second highest weight is the accessibility level of the region of 30.6%.The third sub-criterion is the time value of the trip with the criteria of 14.2%. The value of travel time is the amount of money someone is willing to spend on a trip. The fourth sub-criterion is the sub-criteria for mobility levels with weights of 17.4%. Mobility is the concept of ease of travel which takes into account the smooth running of a trip in connection with the use of road infrastructure by all communities. The last sub-criteria are vehicle operating costs with a weight of 5.6%. Vehicle operating costs are several costs calculated in the use of a vehicle. Vehicle operational costs consist of fixed costs and variable costs.

The high weighting of the regional economic growth sub-criteria implies that the maintenance and operation of a road is expected to contribute to economic growth which can be seen from gross regional domestic products. Then for the sub-criteria weight value the level of accessibility also has implications for increasing the ease of the community in traveling through road transportation infrastructure in accordance with the area served. While the weight of the mobility sub-criteria has implications for efforts to provide fulfillment of the needs of all road users by providing adequate road transportation infrastructure in accordance with population growth. For the sub-criteria weight value of the travel time value and sub-criteria for vehicle operational costs, it implies that at the stage of road maintenance the two sub-criteria are not the main priority.

Social Criteria

Social criteria try to measure the impact related to human subjects in the maintenance of a road by using four sub-measurement criteria. Based on the opinions of experts for the weight of social sub-criteria, it can be seen in Fig. 4 as follows.

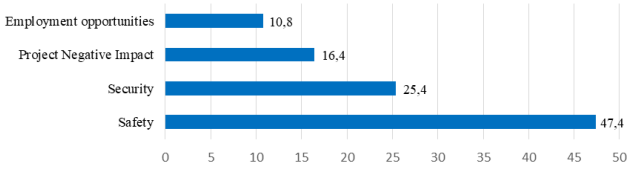

Fig. 4. Social Sub-Criteria Weight

Based on Fig. 4 the highest weight, which is equal to 47.4% which means that the safety aspect has the highest importance compared to other sub-criteria proposed to measure social criteria in the maintenance of a road. Then for the sub-criteria with the second highest weight of 25.4% are the road security sub-criteria. Security is a condition where a person is protected from threats or dangers that threaten the safety of his soul. Then for the sub-criteria with the third highest weight of 16.4%, that is the impact of the project on the surrounding community which is used to see the negative impacts caused during the implementation of road maintenance. Job opportunities are the sub-criteria with the smallest weight of 10.8% which are used to assess the extent to which the project can involve the surrounding community in the implementation of the maintenance project. The cash-intensive program is an old program that is currently being re-initiated to increase employment, one of which is on road maintenance projects.

The high weight of the safety sub-criteria has implications for the efforts of road providers to ensure that safety aspects are the highest priority in the operation of roads. Then it is supported by security aspects which have implications for the priority of providing secure security facilities on a road. The negative impact of road maintenance and employment opportunities is not given priority because these two sub-criteria do not have significant influence during road maintenance.

Environment Criteria

Based on the weighting questionnaire that has been given to experts, the environmental sub-criteria get the weight that can be seen in Fig. 5 as follows.

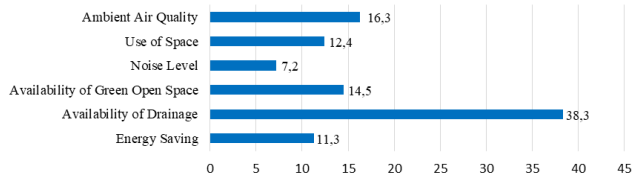

Fig. 5. Environmental Sub-Criteria Weight

From the figure above, it can be seen that the sub-criteria for drainage availability have the highest weight of 38.3% compared to the other five sub-criteria proposed. While the second sub-criteria, namely ambient air quality, is used to measure the level of pollutant content around the road caused by vehicle traffic during the operation of the road section, this sub-criterion gets a weighting of 16.3%. The third sub-criterion is the availability of green open space which is a sub-criterion for measuring the adequacy of green open space around roads to reduce the level of pollution caused during the operation of the road. These sub criteria get a weight of 14.5%. Sub-criterion with the fourth highest weight namely space utilization, this sub-criterion gets a weight of 12.4%. The next sub-criteria with the fifth highest weight, namely energy saving is a criterion for measuring the reduction in energy used during the operation of the road. These sub criteria get a weight of 11.3%. Sub-criteria that get the smallest weight is the noise level which is the impact of the operation of a road caused by traffic flow. There is a noise level quality standard that is adjusted to the use of land where the road is located. The weight obtained from the noise level is 7.2%. The high weight on the sub-criteria for the availability of drainage has implications for the priority of the provision and function of drainage on environmental criteria. Drainage functions to drain water so it does not damage the road body, does not damage the vehicle and does not disturb surrounding settlements. Then for the weight of the air quality sub-criteria it has implications for increasing owner awareness to reduce pollution as a result of operating the road in various ways.

Engineering Criteria

The engineering criteria in this study used five sub-criteria in performance measurement. Based on the weighting questionnaire given to experts, the engineering sub-criteria get the weight as can be seen in Fig. 6 as follows.

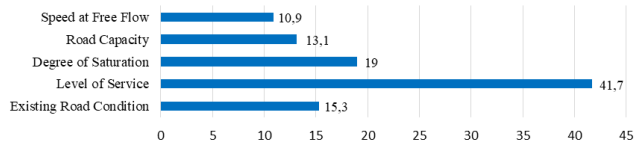

Fig. 6. Engineering Sub-Criteria Weight

Based on the weighting questionnaire that has been given to the respondents, the highest weight is obtained by sub-service level criteria with weights of 41.7%. Service level is the amount of traffic flow that can be passed by certain segments by maintaining a certain level of speed or degree of saturation. Next, the second highest weight, namely the sub-criteria of the degree of saturation, is a sub-criterion for determining road capacity compared to the flow of traffic passing on the road with the weight obtained at 19%. The degree of saturation is positively correlated with the value of the service level. Furthermore, for the third highest weight, the existing road conditions are used to see the current road conditions based on the level of damage and grade level, the weight gained by this sub-criteria is 15.3%. The fourth sub-criterion is road capacity with a weight of 13.1%. The last for the smallest weight is obtained by sub speed criteria on free flow with a weight value of 10.9%.

The highest weight obtained by the sub-criteria of service level and degree of saturation has implications for efforts to continue to make improvements so that the level of service is between level A and level C, which means that road infrastructure can still flow traffic properly. Whereas the implications for the sub criteria of degree of saturation must be maintained so that the maximum value does not exceed 0.75. While the sub-criteria for free flow velocity and road capacity sub-criteria are stages to determine the degree of saturation and service level. For sub criteria, road conditions are parameters of maintenance performance, which has implications for the priority of road maintenance, where the parameter values are still considered to be lacking.

Management Criteria

The management criteria in this study used five sub-criteria. Based on the questionnaire that has been given to the experts, the weight of the sub-criteria of management is obtained as can be seen in Fig. 7 below.

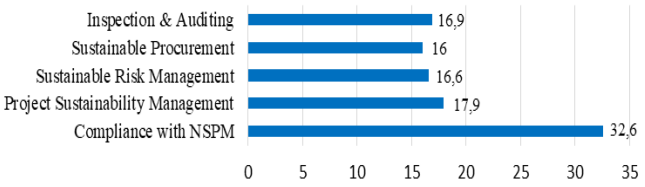

Fig. 7. Management Sub-Criteria Weight

The compliance criteria for NSPM (norms, standards, guidelines/pedoman, manual) get the highest weight of 32.6% because in the procurement of a project, NSPM is a set of instructions that must be adhered to ensure the quality of the project both in administrative order and in the physical quality of construction which finally can be used for the benefit of the community. The sub-criteria in the second place is the project sustainability management plan which is a sub-criteria for assessing the extent to which the overall concept of sustainability is applied in road maintenance. The sub-criteria get a weight of 17.9%. The third sub-criterion is inspection & auditing which is a sub-criterion to assess how often inspections and audits are carried out on roads, both during the planning, construction, and operation of the road weighing 16.9%. Furthermore, the fourth sub-criterion, namely the sustainability risk management, is a sub-criterion for assessing the extent to which risk management in a project is implemented. These sub criteria get weights of 16.6%. The criteria with the smallest weight, namely sustainable procurement is environmentally friendly public procurement, which is a procedure where environmental considerations are taken into account in the public procurement process with a weight of 16%.

The high weighting of sub-criteria compliance with NSPM has implications for the commitment to improve compliance with applicable regulations, applicable standards, and existing

guidelines and manuals. Thus it can improve the orderly administration and orderly regulations in procurement and management and guarantee the uniformity of the physical quality produced. Then for the other 4 sub-criteria which have almost the same weight that ranges from 16% - 17%, this has implications for the priorities in the 4 sub-criteria which are still low because it is indeed less significant for road preservation or maintenance.

V. CONCLUSION & RECOMMENDATION

A. Conclusion

Based on this study, it can be seen that out of the five criteria proposed, economic criteria get the highest weight of 30%. This shows that according to experts in the road sector, regional economic growth is the main reason for maintaining national roads. Then the technical criteria also get the second highest weight of 26%. Whereas in the third place there are social criteria which also have an ideal weight of 20.1%, the weight of this criterion needs to be maintained. On the other hand, management criteria and environmental criteria still weigh below 20%, respectively at 11,8% and 12,1%. Thus a paradigm change needs to be carried out so that in road maintenance it prioritizes not only to increase economic activity, but it also needs to consider management aspects and environmental aspects, in other words, the level of importance on economic criteria and technical criteria can be reduced to minimize gaps with two criteria low weight.

B. Recommendation

Recommendations based on the results of the research and conclusions above are that stakeholders can change the paradigm of a development that prioritizes the achievement of economic improvement, so that it can shift to the concept of sustainable development by considering social aspect, environmental aspects and management aspects. This will create a balanced development in all fields and provide optimal benefits for the benefit of society. The application of the concept of sustainable development can be arranged through the term of reference (TOR) and contract documents, followed by supervision, implementation and monitoring and evaluation in the field for the next work package while maintaining aspects. For further research, this is still limited to determining the sub-criteria that influence its weight. So, it is necessary to validate the model using the criteria and sub-criteria in this study by including some existing road maintenance project data, so that the performance and sustainability of a road section can be seen. Before entering project data, it is necessary to make a uniform measurement unit for all sub-criteria used because each sub-criteria has a different unit.

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