Decision-Making Analysis of Road Maintenance in North Kalimantan Region Using Technology of Fuzzy Logic (Case Study: Liang Bunyu Street Section, West Sebatik Sub-District, Nunukan District)

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Abstract. This study aims to assess the condition of pavement to determine the type and level of damage that occurs on the road, determine the handling or maintenance based on the damage that occurred. Calculating the value of road damage, One way to determine the condition of road damage is to use the Pavement Condition Index (PCI) method and to make road maintenance decisions using Fuzzy Logic, and provide maintenance model simulations. The stage of data collection is done by direct observation to the field and data analysis using PCI and Fuzzy Logic methods to make decisions with the help of Matlab Student Version software. The research location is Liang Bunyu Street, West Sebatik Sub-District, Nunukan district. The results obtained from the data analysis on the damage to the Liang Bunyu Street section have a PCI value of 804.53 of Damaged with Average grade condition based on Pavement Condition Index (PCI) pavement rating. Fuzzy logic Mamdani Method, road maintenance, obtained by road damage of 804.53 m² and Grade Condition 70 %, with the decision of maintenance of 26 is Escalation.

1. Introduction
The importance of roads as infrastructure in facilitating the community to support economic relations activities, both between one city and another, between cities and villages, between one village and another village. Now along the Liang Bunyu street to Bambangan street, the construction of the road has been built until the surface layer is the construction layer. As a result of the flow of traffic flowing through the road, how much damage has been done to the road construction, especially the 6.5 km road section from Liang Bunyu Village to Bambangan Village. Based on the Construction above, this becomes a research area to make a study in the form of: Evaluation of Types and Levels of Road Damage that will produce a type of maintenance. The purpose of this study was to conduct an assessment to determine and classify types, the level of road pavement damage, and determine the value of pavement conditions by finding the Pavement Condition Index (PCI) value and the type of maintenance using the technology of applying fuzzy logic.
2. Literature study

2.1. Fuzzy operators

a. AND Operator
This operator deals with the intersection operation in the $\alpha$-predicate set as the result of the AND operator operation that is obtained by taking the smallest membership value among the elements in the corresponding set [1].

$$\mu_{A \cap B} = \min(\mu_A[x], \mu_B[y])$$  \hspace{1cm} (1)

b. OR Operator
This operator deals with the intersection operation in the $\alpha$-predicate set as the result of the AND operator operation that is obtained by taking the smallest membership value among the elements in the corresponding set [1].

$$\mu_{A \cup B} = \max(\mu_A[x], \mu_B[y])$$  \hspace{1cm} (2)

c. NOT Operator
This operator deals with the complement operation on the $\alpha$-predicate set as the result of operation with the NOT operator obtained by subtracting the membership value of the element in the corresponding set from 1 [1].

$$\mu_A = 1 - \mu_A[x]$$  \hspace{1cm} (3)

2.2. Fuzzification
Fuzzification is a process of taking the value of crisp input and determining the degree of membership from each appropriate fuzzy set. After the value of the degree of membership is obtained, then do the process of calculating the truth value of each existing premise by using min operation or max operation [2].

2.3. Query Fuzzification
The concept of a fuzzy relation in a DBMS uses the degree of membership $\mu$ defined on the set of domains $X = (X_1, ... X_n)$, and has been generated in the outer relation by the mean fuzzy value [3].

2.4. Zadeh Basic Operators For Fuzzy Setup Operations
In such a conventional set, there are several operations that are specifically defined to combine and modify the fuzzy set. Membership value as of 2 fuzzy sets known as fire strength or $\alpha$-predicate. It is really possible to use basic operators in the query process of AND and OR operators. $\alpha$-predicate as the result of operation with the AND operator obtained by taking the smallest membership value among elements in the corresponding set, denoted: $\mu_{A \cap B} = \min(\mu_A[x], \mu_B[x])$. As for the results of operations with the OR operator, obtained by taking the largest membership value among elements in the corresponding set, denoted: $\mu_{A \cup B} = \max(\mu_A[x], \mu_B[x])$. Alternatives that have fire strength value or level of conformity with the criteria of choice above the number 0 (zero) to the number 1 (one) [4].

2.5 Defuzzification
Defuzzification is the process of getting the crisp value of a fuzzy set. In Mamdani Method, to obtain that value, Centroid Method or find the weight of the middle value of the curve of the fuzzy region (center of gravity) is used, with a mathematical formulation on Equation: [5].
Where \( Z \) = defuzzification value; \( X \) = fuzzy set member \( A \); \( \mu A (X) \) = degree of membership of an element \( x \) in a set of \( a \).

2.6 Assessment of pavement conditions
Assessment of the conditions of road pavement is the most important aspect in terms of determining road maintenance and repair activities. To assess the condition of the pavement, it is first necessary to determine the type of damage, the cause, and the extent of damage.

2.6.1 Types of damage.
1. Deformation
   Deformation is a change in the road surface of the original profile (after construction).
2. Cracks
   Cracks can occur in various forms. This can be caused by several factors and involves complex mechanisms. Theoretically, cracks can occur if the tensile stress that occurs in the asphalt layer exceeds the maximum tensile stress that can be held by the pavement.
3. Surface texture damage
   Damage to surface texture is a gradual loss of pavement material from the surface layer to the bottom. Pavement seems to break into small parts, such as peeling due to sunburn, or has parallel streak lines. Loose grains can occur above all surfaces, with the worst locations in the traffic lane. Broadly speaking, the damage can be divided into two parts, namely structural damage, including pavement failure or damage from one or more pavement components which results in the pavement unable to bear the traffic load; and functional damage resulting in disruption to road users' safety and comfort so that vehicle operating costs increase [7].

   According [8], there are 19 types of damage to the pavement for the highway: Alligator cracking, bleeding, block cracking, bums and sags, corrugation, depression, edge cracking, joint reflection, lane / shoulder drop off, longitudinal and transverse cracking, patching and utility cut patching, polished aggregate, potholes, weathering and ravelling [9]. In this logic data owner attach Policies with data, which contain a description of which actions are allowed with which data, but there is the problem of Continuous auditing of agent, but they provide solution that incorrect behavior. Should monitor and agent should give justification for their action, after that authority will check the justification. Examples of absorption include adopting new products and manufacturing processes developed elsewhere, upgrading old products and process, improving organisational efficiency, achieving quality certification, etc [10].

3. Method
This research was carried out with steps according to the stage of the flowchart. Data collected consists of primary data obtained directly from the object of research in the field and secondary data obtained from documents and books relating to research. The application of fuzzy logic technology is easily implemented through the experience of experts directly without having to go through the training process in making decisions.

3.1 Location and time
Data collecting is as follows:
- The research site was carried out on the Liang Bunyu street to the Border of Liang Bunyu village - Bambangan Village as far as 6.5 km (Sta 0 + 000 - Sta 6 + 500)
- Data collection takes approximately 4 weeks.

3.2 Materials and tools
Materials and tools needed for this research include:
3.2.1 Hardware
Specifiation of PC : Processor Intel (R) Core (TM) i7-7700HQ CPU@2.8GHz 2.8GHz RAM 8 GB.

3.2.2 Software dan Apllication MATLAB R2017a Version Student, used to design the Fuzzy Simulation

![Flowchart of Research](image)

Figure.1 Flowchart of Research

4. Results and discussion
The results of the research on the 6.5 Km Liang Bunyu road obtained a PCI value where the value will be analyzed by fuzzy logic to get a decision on the type of road maintenance to be used in accordance with the required
Table. 1 A Fuzzy set of Mamdani Method

| Function | Variable          | Set Name | Universe of conversation | Domain |
|----------|-------------------|----------|--------------------------|--------|
| Input    | Damaged (m²)      | Easy     | [0-805]                  | [0-403]|
|          |                   | Medium   |                          | [200-500]|
|          |                   | Hard     |                          | [403-805]|
|          | Grade (%)         | Good     | [0-100]                  | [0-40] |
|          |                   | Average  |                          | [30-70]|
|          |                   | Bad      |                          | [50-100]|
| output   | Maintenance (Day) | Routine  | [0-30]                   | [0-15] |
|          |                   | Periodic |                          | [7-25] |
|          |                   | Escalation|                         | [15-30]|

Table. 2 Rules of Mamdani Method

| Rules | Damaged | Grade | Function of implications | Maintenance |
|-------|---------|-------|--------------------------|-------------|
| R1    | Easy    | Good  |                          | Routine     |
| R2    | Medium  | Average|                          | Periodic    |
| R3    | Hard    | Bad   |                          | Escalation  |
| R4    | Medium  | Bad   |                          | Escalation  |

[R1] IF Damaged is EASY, AND Grade is GOOD, THEN Maintenance is ROUTINE
[R2] IF Damaged is MEDIUM, AND Grade is AVERAGE, THEN Maintenance is PERIODIC
[R3] IF Damaged is HARD, AND Grade is BAD, THEN Maintenance is ESCALATION.
[R4] IF Damaged is MEDIUM, AND Grade is BAD, THEN Maintenance is ESCALATION.

Table.3 Percentage of Road Damage Level

| No | Type of damage       | Damaged ( m²) |
|----|----------------------|---------------|
| 1  | Alligator Cracking   | 561.54        |
| 2  | Depression           | 152.82        |
| 3  | Edge Cracking        | 11.65         |
| 4  | Longitudinal Cracks  | 43.84         |
| 5  | Pothles              | 0.94          |
| 6  | Shoving              | 13.19         |
| 7  | Raveling             | 20.55         |
|    | **Total**            | **804.53**    |

Based on survey result, for the example using type of damage Alligator Cracking with value damaged 561.54 M² and for the grade is 69.8 % have result for value of maintenance is 22.5. 22.5 in the range is periodic.
5. Conclusion

The result of analysis based on data on Liang Bunyu Street section. Using Technology of Fuzzy logic Mamdani Method, road maintenance, obtained by road damage of 804.53 m² and Grade Condition 70%, with the decision of maintenance of 26 is Escalation.

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