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Decision Making for Highway Maintenance Using Fuzzy Logic (Case Study: The Aki Balak Street, Tarakan City)

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Abstract—**Highway is one of the facilities that is built to ease the transferring goods from one point to the destination. In the Law of the Republic of Indonesia No. 38 Year 2004 about road infrastructure, it is mentioned that the road has an important role in actualizing the development of nation's life. Road repair by assessing the level of damage so that the researchers conducted this study on the Aki Balak street, Tarakan City with a road length observed along 250 meters. Types of road damage that occurred on the Aki Balak street consists of pothole, alligator cracking, long cracking, edge cracking, bledding, patching and corrugation. The results of the analysis using fuzzy logic applications in road maintenance as decision-making. An optimal decision making system in determining road maintenance from the damage and the causes of that damage occurred has been created. By using MATLAB student version, obtained extensive damage amounted 17.8 m2 with 9.99% condition assessment. Thus the results of routine maintenance at 2.5 with an appropriate alternative maintenance is repairing with flexible pavement, by providing an additional layer (overlay).**

Keywords—*Damage, Fuzzy Logic, Maintenance, Road.*

I. INTRODUCTION

Road is one of infrastructure that has a big role in society life. Roads connect one area to another, this will greatly affect the economic development of a region. Just imagine if a region does not have access to the area, then the basic needs of the community will be difficult to meet. The role of road is also important in education and public health. Roads connect schools, colleges, community health centers and hospitals with user communities. If a pregnant woman approaches childbirth or an emergency patient will find it difficult to reach the hospital from a damaged road then death is the worst risk to be accepted. What an extraordinary benefit the road has to human life. Routine road maintenance is carried out continuously throughout the year and is carried out as soon as possible when the damage has not been widespread. Treatment and repair is done at the stage of damage is still light and had time. This is done because the repairing cost is relatively low and the way to repair them is relatively easy. Regular road maintenance is carried out periodically by rejuvenating the pavement material and other materials. Besides that, the road surface treatment is done. Both routine and periodic maintenance, are not intended to improve capability. The purpose of this research is to know the road maintenance decision obtained from the simulation of road maintenance in the type of damage by using fuzzy logic.

II. LITERATURE STUDY

II.1 Fuzzy operators

a. *AND Operator*

This operator deals with the intersection operation in the α-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].

$$\mu A \cap B = \min(\mu A[x], \mu B[y]) \tag{1}$$

b. *OR Operator*

This operator deals with the intersection operation in the α-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].

$$\mu A \cup B = \max(\mu A[x], \mu B[y]) \tag{2}$$

c. *NOT Operator*

This operator deals with the complement operation on the α-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].

$$\mu A = 1 - \mu A[x] \tag{3}$$

II.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].

II.3 Query Fuzzification

Fuzzification query is assumed to be a conventional (non-fuzzy) DBMS query that will try to create and implement a fuzzy logic based querying system. The concept of a fuzzy relation in a DBMS uses the degree of membership μ defined on the set of domains X = (X1, ... Xn), and has been generated in the outer relation by the mean fuzzy value [3].

II.4 Zadeh Basic Operators For Fuzzy Setup Operations

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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 strengh or α-predicate. It is really possible to use basic operators in the query process of AND and OR operators. α-predicate as the result of operation with the AND operator obtained by taking the smallest membership value among elements in the corresponding set, denoted: μA ∩ B = min (μA [x], μB [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: μA U B = max (μA [x], μB [x]). Alternatives that have fire strengh value or level of conformity with the criteria of choice above the number 0 (zero) to the number 1 (one) [4].

II.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].

$$z = \frac{\int_a^b x\mu_A(x)dx}{\int_a^b \mu_A(x)dx} \qquad (4)$$

Where :
Z = defuzzification value
X = fuzzy set member A μA (X) = degree of
    membership of an element x in a set of a

II.6 Roads

Roads, in Government Regulation No. 34 years 2006 is an infrastructure of a land transportation covering all parts of the road, including complementary building and its equipments that is made for traffic, located on the ground, above ground level, below ground and / or sea level, and on the surface of the sea, except for railroads, lorries, and cable roads.

II.7 Road Construction

Road construction activities are expected to provide ease in access liaison between regions. The road is expected to survive post-construction due to the value in its construction that is high [6].

III. METHOD

This study was conducted with the steps as in Figure 1. The data collected consisted of primary data (obtained directly from research objects in the field) and secondary data (obtained from documents and books related to research). The use of fuzzy logic is easy to apply through the experiences of experts directly without having to go through the training process.
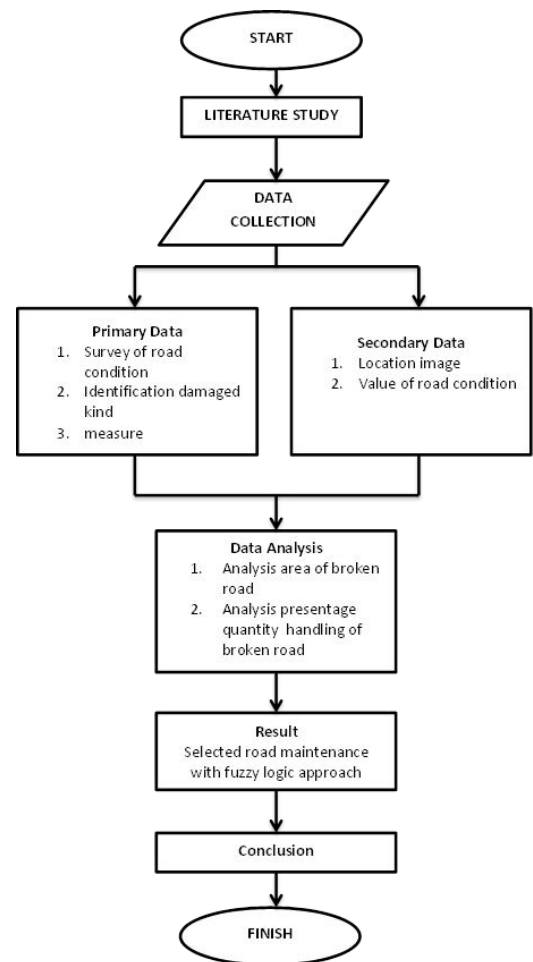

Figure.1 Flowchart of Research

IV.1 Location and time

Data collecting is as follows:
- On the Aki Balak Street, Tarakan city
- Road Area observed along 250 meters with road width of 6 meters. Start from the front of the bicycle workshop to ± near the entrance of Persemaian area
- Data collection takes approximately 2 weeks.

IV.2 Materials and tools

Materials and tools needed for this research include:
III.2.1 Hardware
Spesification of PC : Processor Intel (R) Core (TM) 2 Duo CPU P7570@2.26GHz 2.27GHz RAM 2 GB.

III.2.2 Software dan Aplication
MATLAB R2010a Version Student, used to design the Fuzzy Simulation

IV. RESULTS AND DISCUSSION

The simulation was performed to get optimal result on road maintenance from the survey's result of road damage that happened on Aki Balak street of Tarakan city with road length of 250 meters and road width ± 6 meters. Using the MATLAB R2010a Version Student program requires appropriate data so that the result of the

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simulation produces according to what happened in the field.

IV.1 Analysis of Mamdani Method

Table. 1
A Fuzzy set of Mamdani Method

Function	Variable	Set Name	Universe of conversation	Domain
Input	Damaged (m²)	Easy	[0-70]	[1-30]
		Medium		[15-50]
		Hard		[30-70]
	Grade (%)	Bad	[0-10]	[1-4]
		Average		[3-7]
		Good		[5-10]
output	Maintenance (hour)	Routine	[0-10]	[0-3]
		Periodic		[2-6]
		Escalation		[4-10]

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.
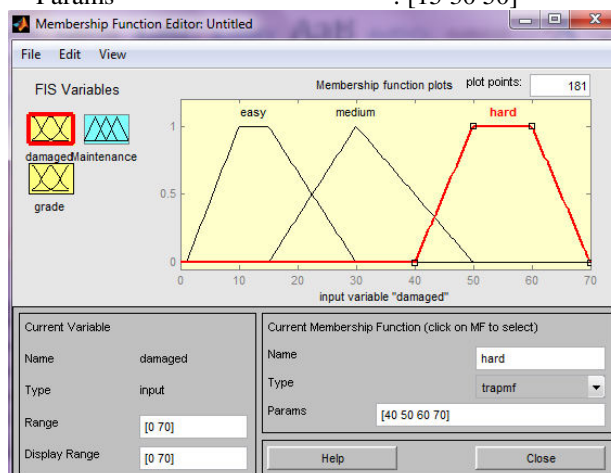
IV.2 Completion

a. The extent of damaged [x], consists of 3 fuzzy sets, namely EASY, MEDIUM, and HARD. Based on the width of the largest and smallest damage, then the function of compassion is formulated as follows
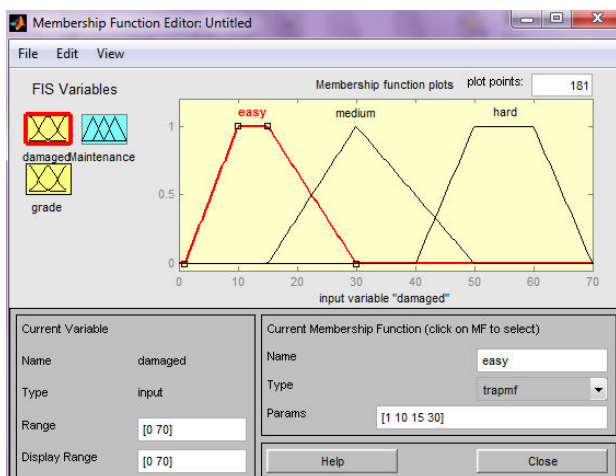
Nama	: Easy
Range	: [0 70]
Display Range	: [0 70]
Type	: trapmf
Params	: [1 10 15 30]
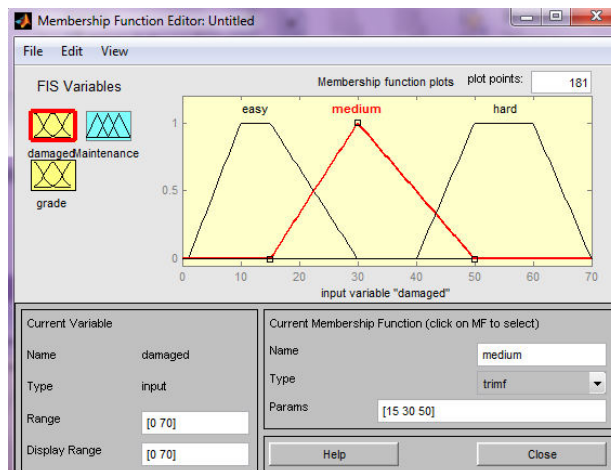
Nama	: Medium
Range	: [0 70]
Display Range	: [0 70]
Type	: trimf
Params	: [15 30 50]

Nama	: Hard
Range	: [0 70]
Display Range	: [0 70]
Type	: trapmf
Params	: [40 50 60 70]

b. Grade of condition [y], consisting of 3 fuzzy sets. Namely: GOOD, MIDDLE, and BAD. Based on the highest valuation in good condition then membership function is formulated as follows

Nama	: Bad
Range	: [0 10]

Display Range   : [0 10]
Type   : trapmf
Params   : [1 2 3 4]
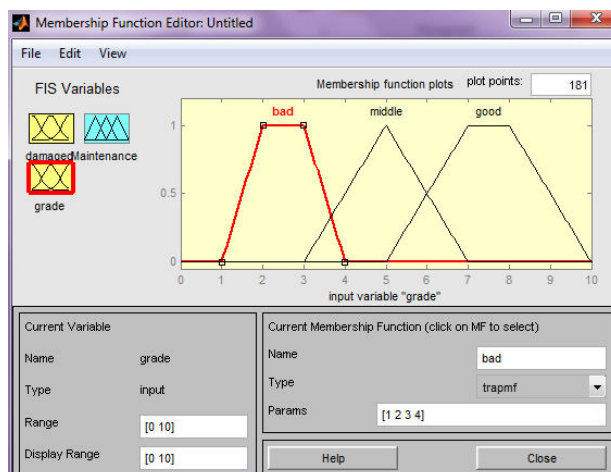

Nama   : Average
Range   : [0 10]
Display Range   : [0 10]
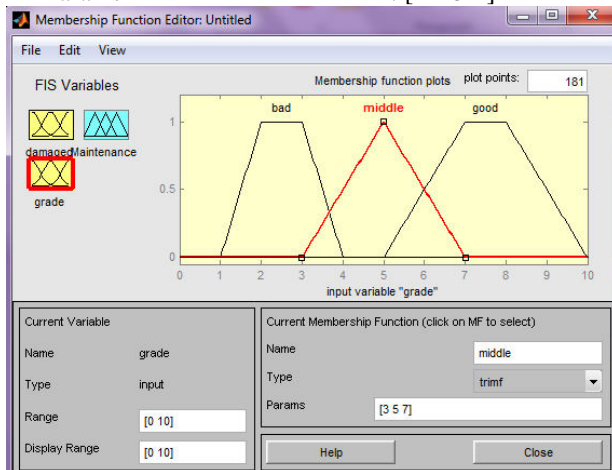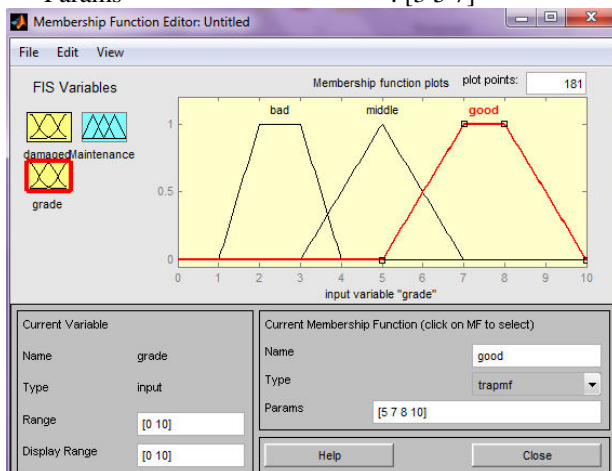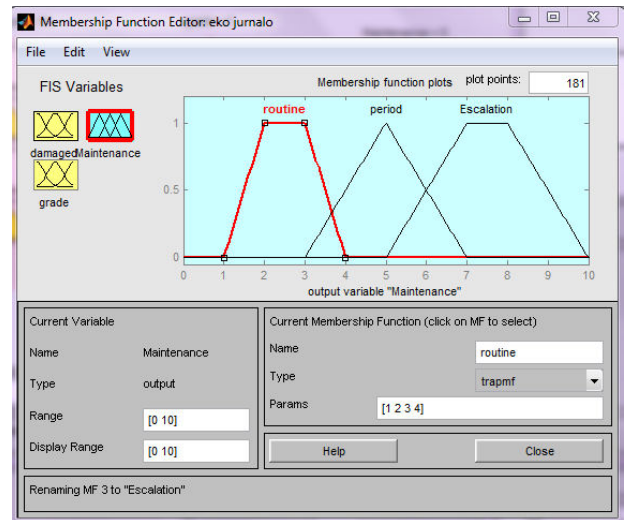Type   : trimf
Params   : [3 5 7]

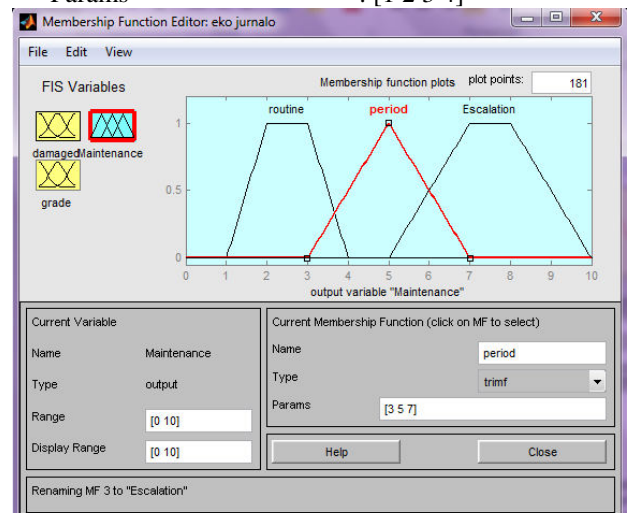Nama   : Good
Range   : [0 10]
Display Range   : [0 10]
Type   : trapmf
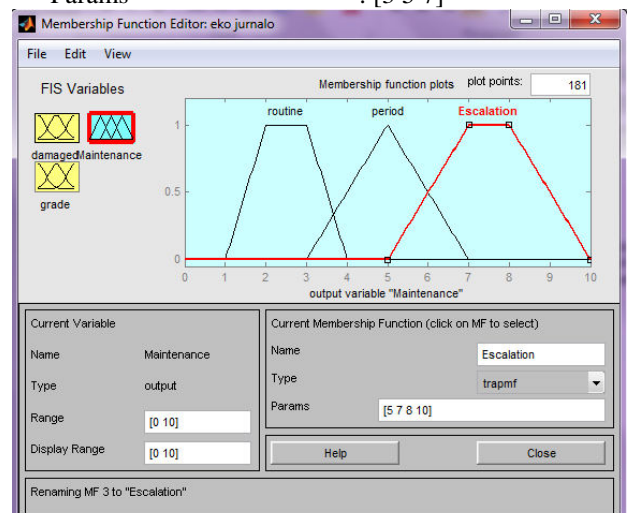Params   : [5 7 8 10]

c. Maintenance of the road [z], consists of 3 fuzzy sets, namely: Routine, Periodic, Escalation. Based on the damaged and Grade, the function of membership function is formulated as follows.

Nama   : Routine
Range   : [0 10]
Display Range   : [0 10]
Type   : trapmf
Params   : [1 2 3 4]

Nama   : Periodic
Range   : [0 10]
Display Range   : [0 10]
Type   : trimf
Params   : [3 5 7]

Nama   : Escalation
Range   : [0 10]

Display Range	: [0 10]
Type	: trapmf
Params	: [5 7 8 10]

Table.3
Percentage of Road Damage Level

No.	Type of damage	Segment on The Road (%)
1	Pothole	3.36
2	Alligator Cracking	3.00
3	Long Cracking	1.04
4	Bledding	0.94
5	Corrugation	0.77
6	Patching	0.55
7	Edge Cracking	0.33
	Total	9.99

Based on survey result, the amount of road damage on Aki Balak street in Tarakan city with the observed length of road along 250 m. With a total surface damage level of 9.99%.
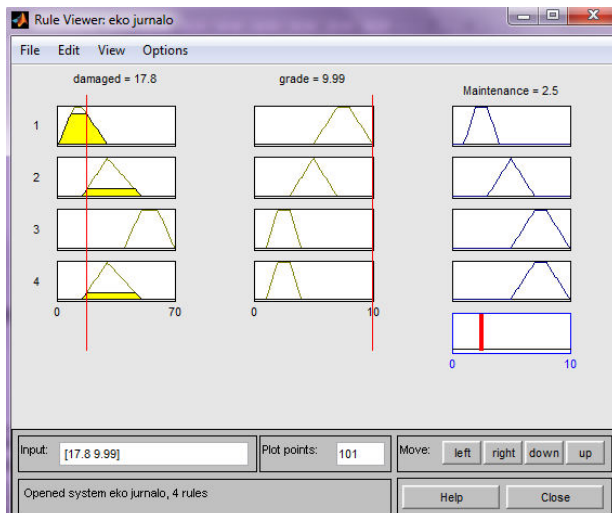
Information: :

The interval [0.70]	shows the Universe of conversation for variable of road damage length
The interval [0.10]	shows the Universe of conversation for the road conditions assessment variable
The Interval [0.10]	shows the Universe of Conversation for road maintenance variables

The first column in the picture above shows the membership level of damaged 17.7 m2 on the variable of road damage, the second column shows the 9.95% rate of membership in the road grade condition variable. The third column shows the consequences of the function of the rule implications according to the condition. The function of the implication used in this process is the MIN function, that is, by taking the minimum area of the input variable as its output. The last line or last column shows the combined fuzzy area of each rule, which is a consequence of the fuzzy rule composition. In the figure, the thick red vertical line on the maintenance variable indicates that the maintenance of the road is ROUTINE

maintenance that is 2.5. The value of maintenance is included in the membership of the fuzzy set of routine. So it can be concluded that road maintenance is ROUTINE with the length of the road studied 250 m and the road width ± 6 m.

From the result of simulation decision of road maintenance in table got result of wide damage:

$$Z = \frac{0.5*20+0.4285*50+0.5*3+0.5*3}{0,5+0.4285+0.5+0.5} = \frac{34.425}{1.9285}$$
$$= 17.8 \text{ m}^2$$

Where the value is derived from the rules that have been modeled from the analysis of the implication function. While assessment of road condition is obtained from assessment of Aki Balak street from STA 0 + 000 - 0 + 250 of 9.99% in good condition. From table percentage of road damage level. So, the calculation analysis of the results of the center point are:

$$Z = \frac{3.125+3.003+2.649}{1.25+1.638+0.67} = 2.466 = 2.5$$

ROUTINE

V. CONCLUSION

From the result of analysis based on data on Aki Balak Street along 250 m. Using Fuzzy logic Mamdani Method, road maintenance, obtained by road damage of 17.8 m2 and Grade Condition 9.99%, with the decision of maintenance of 2.5 is ROUTINE.

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