Minimizing Risk of Accidents by Selecting Reverse Delete Fuzzy-FMEA Route

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Abstract. Roads are often used to travel from one place to another. To shorten the trip, it is usually done via the shortest route. Choosing the shortest route cannot be separated from the risks that can occur, such as accidents. Risk management serves to minimize this from happening. Analysis of the feasibility of the road to be traversed can be a consideration. The method used is Fuzzy Failure Mode and Effect Analysis (Fuzzy-FMEA). This method combines fuzzy logic with the FMEA method which is then processed with the appropriate membership function and fuzzy logic rule evaluation so that a fuzzy number is generated that can indicate the level of risk that the road is safe or not to pass. Based on the trial results, the safest routes for inter-city travel that pass through Jember Regency are Lumajang_1 to Bondowoso_1, Lumajang_2 to Banyuwangi, and Bondowoso_1 to Banyuwangi.

Keywords: risk analysis · safest route · Reverse Delete algorithm · fuzzy-FMEA

1 Introduction

Globalization and connections between different parts of the world have increased the importance of traffic [10]. To shorten traffic time, the shortest path can be used. The shortest path problem is the task of finding the shortest route from the starting point to the destination point. To represent the shortest path problem, graph theory can be used [9]. Graph theory can be used to model real-world problems mathematically [29]. The graph model is proven to be versatile for analyzing various problems related to vertex and edge relationships [30]. This relationship can describe interaction, interpretation, or reciprocal conditions [31]. Analysis in graph theory requires precise definition, terminology, and notation. This is what makes graph theory widely used in various fields [28].

Although the shortest route has been found, in real life there are many situations where we have to face uncertain parameters such as natural disasters or social disasters like accidents [20]. Road traffic accidents are the leading cause of death in children and

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young adults aged 5–29 years [25]. Traffic signs are an important part of road infrastructure. Ignoring traffic signs can contribute to traffic accidents [7]. Several factors influence the occurrence of traffic accidents on the road, such as: human factors, vehicle conditions, traffic characteristics, road infrastructure, environmental conditions, and congestion [3, 27]. When dealing with uncertainty parameters in the search for the shortest route such as accidents, a fuzzy graph model is designed [1].

The term fuzzy was introduced by L. A. Zadeh in 1965 [16, 19]. Fuzzy logic is an extension of multi-value logic whose purpose is approximate reasoning rather than exact solutions [24]. Fuzzy set theory helps decision makers not only to consider existing alternatives under a given limit, but also to develop new alternatives [16]. The fuzzy logic combined with Djikstra can also find the shortest route [23]. Apart from Djikstra, there is another algorithm in graph theory that can be used to find the shortest route, namely the Reverse-Delete algorithm. The way this algorithm works is by selecting the edge weights on the graph starting from the smallest to the largest weight. Then the selection of these weights forms a minimum spanning tree [23].

Fuzzy logic can be applied in risk management, for example is Fuzzy-FMEA (Fuzzy – Failure Mode Effect Analysis) [4, 8, 12, 14, 17, 21, 26]. Fuzzy logic is especially useful when there is uncertainty in the parameters involved in calculating risk [14]. Risk management can be used to minimize the occurrence of failures [6]. Risk is the possibility of failure/accident that can be occur [13]. FMEA is an important technique for identifying failures during the production process [17]. FMEA is also used as a preventive measure on company before sending the product to the customer [21]. FMEA consists of three parameters: occurrence (O), severity (S), dan detection (D) [4, 5, 8, 11, 12, 14, 17, 18, 21, 26].

Based on this, authors are interested using FMEA parameter to describe the level of risk on the road (accident). FMEA parameters are processed using fuzzy logic to produce Fuzzy-FMEA. This Fuzzy-FMEA value describes the level of risk (accidents) on the road. So, by choosing the smallest fuzzy value using Reverse-Delete algorithm, the shortest route can be obtained and minimize the occurrence of accidents on the road. There are two parameters that are considered in this study, the length of the road and number of accidents on the road.

2 Method

A. Fuzzy Logic

The term fuzzy was stated by L.A. Zadeh in 1965 [16, 19]. Fuzzy set theory was developed to improve on oversimplified models. Fuzzy set theory has been applied in many fields, such as operations research, management science, control theory, artificial intelligence/expert systems, human behavior, etc. [16]. Fuzzy logic is an extension of multi-value logic, meaning that a variable in fuzzy logic may have a truth value that ranges from 0 to 1, a value of 0 indicates completely false, while value 1 represents completely true, and any value in the range 0 to 1 shows the fuzzy truth level [21, 24]. The fuzzy rule base consists of a set of “if - then” rules and is the core of the fuzzy system [15]. According to [12] here are the advantages of fuzzy logic:

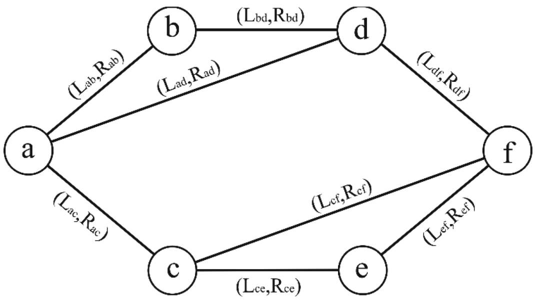

Fig. 1. A Graph Representing a Road with Two Parameters.

1. The concept of fuzzy logic is easy to understand;
2. It is flexible and can tolerate data discrepancies;
3. Be able to model non-linear functions;
4. Able to build on expert experience without the need for additional training;
5. Able to work on simple programming languages.

A variable that can be used to model the quantity of road accidents:

1. μ = parameter variable (road length dan risk priority number);
2. L = roadlength(short, moderate, long);
3. R = riskprioritynumber(small, medium, high);
4. z = Output (very low, low, moderate low, moderate high, hazardous).

In choosing the path to pass, several parameters need to be considered. The road route can be represented in a graph as shown in Fig. 1. The side weight of the graph in Fig. 1 uses two parameters as a consideration, the road length and number of accidents on the road.

The road representation in the form of a graph that has been made is then processed using the membership function. In Fig. 1, the graph has two parameters, so there are two membership functions, namely the membership function of the road length and the membership function of the risk value. The membership value for each function is written with the letters x and y. The letter x is the maximum value of the road length from point a to point f. Meanwhile, Letter y is the maximum risk value from point a to point f.

B. Membership Function of Road Length

The road length membership function has three membership degrees: *short*, *moderate*, and *long*. The road length membership function is shown in Fig. 2.

The membership function in Fig. 2 is a linear function. There are three sets of linear functions on the road length as follows.

Linear function from *short* set.

$$\mu jshort(L)\begin{cases} 1 & ; L \leq 1a/5 \\ \frac{(1a/5-L)}{(3a/5-1a/5)} & ; \frac{1a}{5} \leq L \leq \frac{3a}{5} \\ 0 & ; L \leq 3a/5 \end{cases}$$

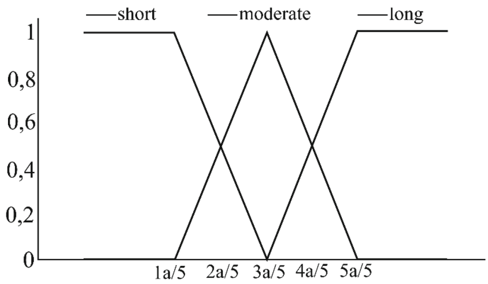

Fig. 2. Membership Function of Road Length.

Linear function from *moderate* set.

$$\mu jshort(L)\begin{cases} 0 & ; L \le 1a/5 atau L \ge 5a/5 \\ \frac{(P-1a/5)}{(3a/5-1a/5)} & ; \frac{1a}{5} \le L \le \frac{3a}{5} \\ \frac{(5a/5-L)}{(5a/5-3a/5)} & ; 3a/5 \le L \le 5a/5 \end{cases}$$

Linear function from *long* set.

$$\mu jlong(L)\begin{cases} 0 & ; L \le 3a/5 \\ \frac{(L-1a/5)}{(5a/5-3a/5)} & ; \frac{3a}{5} \le L \le \frac{5a}{5} \\ 1 & ; L \le 5a/5 \end{cases}$$

C. Membership Function of Road Risk

The road risk membership function has three membership degrees: *small*, *medium*, and *high*. The road risk membership function is shown in Fig. 3. The membership function in Fig. 3 is a linear function. There are three sets of linear functions on road risk as follows.

Linear function from *small* set.

$$\mu jsmall(R)\begin{cases} 1 & ; R \le 1b/5 \\ \frac{(1b/5-R)}{(3b/5-1b/5)} & ; \frac{1b}{5} \le R \le \frac{3b}{5} \\ 0 & ; R \le 3b/5 \end{cases}$$

Linear function from *medium* set.

$$\mu jmedium(R)\begin{cases} 0 & ; R \le 1b/5 atau R \ge 5b/5 \\ \frac{(R-1b/5)}{(3b/5-1b/5)} & ; \frac{1b}{5} \le R \le \frac{3b}{5} \\ \frac{(5b/5-R)}{(5b/5-3b/5)} & ; 3b/5 \le R \le 5b/5 \end{cases}$$

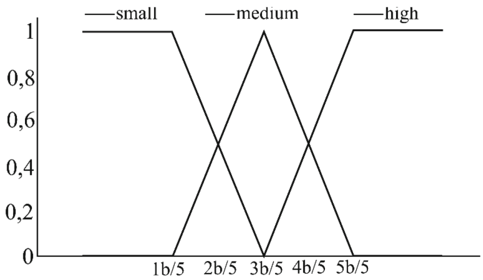

Fig. 3. Membership Function of Road Risk.

Linear function from *high* set.

$$\mu jhigh(R)\begin{cases} 0 & ; R \leq 3b/5 \\ \frac{(R-1b/5)}{(5b/5-3b/5)} & ; \frac{3b}{5} \leq R \leq \frac{5b}{5} \\ 1 & ; R \leq 5b/5 \end{cases}$$

D. Fuzzy – Failure Mode Effect Analysis (Fuzzy-FMEA)

In the 1960s, FMEA was formally applied to the aerospace industry in the United States for safety and reliability analysis. Since its inception, FMEA has been in common use and has shown great success in various industries, such as the automotive, health care, marine, nuclear and electronics industries [5, 18].

FMEA is an important method for the development of risk analysis in maintenance management strategies [11]. FMEA is used to identify, analyze and prevent product failures while in production [5, 8, 12, 17, 21].

In general, the determination of critical failure priority can be determined by calculating the Risk Priority Number (RPN) value. This can be achieved by multiplying the O, S, and D indices of each failure [4, 8, 11, 12, 14, 17].

1. Severity (S)

Severity assesses the criticality of the impact from the potential harm that may occur. The S score is assessed based on the impact of the effect of the failure mode.

2. Occurence (O)

Occurrence predicts the recurrence of potential risks that will occur for a particular situation or framework. The probability score is evaluated against the probability that the effect occurs as a result of the failure mode.

3. Detection (D)

Detection is that the possibility of damage can be identified before the effect of the damage on a procedure or framework is evaluated for differentiation. The D score is assessed based on the ability to recognize the results of the breakdown mode.

Table 1. Risk Parameter Index (S, O, and D)

Effect	**Severity Level**	**Probabiliy of Occurence**	**Detection Criteria**	**Rating**
Very Low	The system can operate with relatively few failures	Low: There have been relatively few processing-related failures	The probability is high enough to detect a failure	1
Low	The system cannot operate with minor failure	Moderate: Infrequent failures with little impact	Possibilities are currently detecting a failure	2
Moderately Low	The system cannot operate with minor failures/incapacity	Moderate: Infrequent failures with little impact	Moderate probability of detecting a failure	3
Moderately High	The system is inoperable due to a severe failure	High: Repeated failure, a process that often fails	A fairly low probability of detecting a failure	4
Hazardous	When the failure method is high	High: Repetitive failure, a process that often fails	There is little chance of detecting a failure	5

4. Risk Priority Number (RPN)

RPN is the result of ranking from three data sources (Severity, Occurrence and Detection). It can be used during a failure risk assessment. The following is the formula for calculating the risk value.

$$\text{RPNFMEA} = \text{occurence} \times \text{severity} \times \text{detection}.$$

The RPN provides directions for ranking potential damage and identifies recommended actions to outline/process changes that will reduce Severity or Occurrence. The risk parameter index ratings (S, O, and D) are as shown in Table 1.

According to [5, 8, 12, 14, 17, 26], Fuzzy-FMEA methodology is an important theory that deals with solving information. In Fuzzy-FMEA risk index parameters such as Severity (S), Occurence (O), and Detection (D) are fuzzified with the corresponding membership function. The road length is also fuzzified with the corresponding membership function. The output results (z) of the fuzzification are very low, low, moderate low, moderate high, and hazardous. The process of changing parameters through the fuzzy logic process is illustrated in Fig. 4. The two parameters of road length and road risk have three variables, the road length (*short*, *moderate*, *long*) and the road risk (*small*, *medium*, *high*) so there are 9 rule evaluations, as in Fig. 5. The fuzzy output set has five variables with each limit value, 0.045 (*verylow*); 0.25 (*low*); 0.5 (*moderatelow*); 0.75 (*moderatehigh*); 1 (*hazardous*). The limit value of the five output variables is shown in Table 2. After going through the rule evaluation, a graph is obtained as shown in Fig. 6.

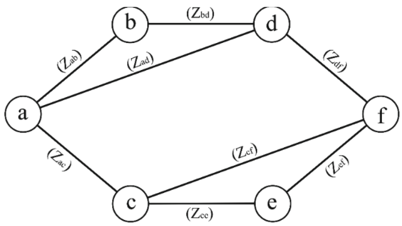

Fig. 4. The Graph Results from the Fuzzy Logic Process.

Fig. 5. Fuzzy-FMEA Road Length and Road Risk Process

E. Reverse-Delete Algorithm

The Reverse-Delete Algorithm is a heuristic algorithm that is specifically designed to solve the minimum spanning tree problem. This algorithm is included in the greedy algorithm type, which takes the largest choice of graph side weights. The working principle of this algorithm is the opposite of Kruskal's algorithm. The selection of side weights in this algorithm starts from the smallest to the largest weight. Then the edges that make up the cycle are removed, and the resulting minimal spanning tree is obtained [22]. The following in Fig. 7 shows the flowchart of the Reverse-Delete algorithm.

Following are the steps of Reverse-Delete algorithm in forming the minimum spanning tree:

(1) Data is converted from a weighted graph;
(2) Data that has been converted are then ordered from the edge with the largest weight;
(3) Initialize the index $i = 0$;
(4) If index $i < n$ then edge with weigth i will be save as temp;
(5) Edge with weight i has been saved is then deleted;
(6) If V_1 connected to V_2 then back to step (4), with $i = i + 1$;

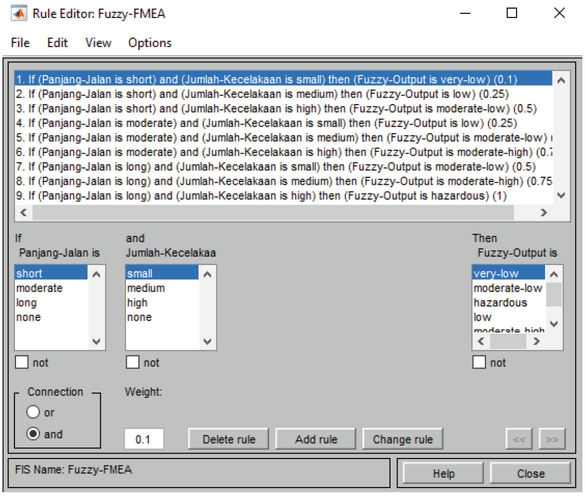

Fig. 6. Rule Evaluation

Table 2. Fuzzy Output Value Limit

	Road Risk			
Road Length		*Small*	*Medium*	*High*
	Short	0, 045	0, 25	0, 5
	Moderate	0, 25	0, 5	0, 75
	Long	0, 5	0, 75	1

(7) If V_1 not connected to V_2 then weight $i =$ temp, back to step (6);
(8) If index $i = n$ then produce minimum spanning tree and program is completed.

3 Design and Experiment

Data collection was carried out in Jember's Regency in several ways, including road surveys, asking questions to related offices, and interviews with local residents. Data in this research are the length of the road and the number of accidents that occur on the road. This research produces the shortest route search program which can be used as a reference in selecting the inter-city travel route that passes through Jember Regency. The program creates a path that can minimize the risk of accidents. This program was created using MATLAB R2018b.

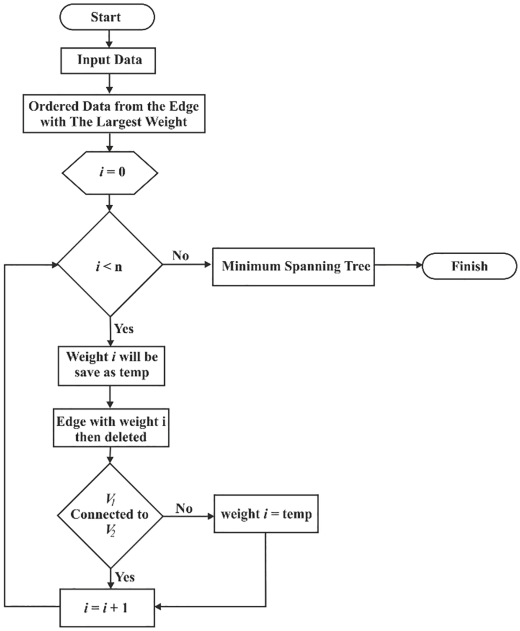

Fig. 7. Flowchart of Reverse-Delete Algorithm to find The Minimum Spanning Tree

4 Results and Discussion

The program display is as in Fig. 8. The experimental process in finding the shortest route uses data with 119 points. The point represents the intersection of each road. Some of these points are connected by a line that represents a highway. These points and lines are analogous to the vertices and sides of a graph. So that the research data can be converted into a graph to further find a route that minimizes the risk of accidents. The sides (length of the road) in the data range from 0–12 km. The accident data obtained is data on road accidents that occurred between 2017–2021. The number of accidents in the data ranges from 0–6. The distance parameters (road length) and the number of accidents is fuzzified with the corresponding membership function and a fuzzy output in the form of a matrix is generated. 119. The output fuzzy matrix is saved in Microsoft Excel file. To describe the real points used the latitude and longitude at each point obtained from the location of the GPS (Global Positioning System). The FMEA method is used to classify this fuzzy output into 5 ranges based on severity, occurrence, and detection as in Table 1. The 5 ranges are obtained by 9 fuzzy logic rule evaluations as in Fig. 5.

The use of *if - then* logic because the type of fuzzy logic used is Sugeno logic order zero. The smallest fuzzy number obtained is 0,045 while the largest fuzzy number obtained is 0,874. There are 2 factors that influence the size of the fuzzy numbers, the length of the road and the number of accidents. Although the length of the road is large, but the number of accidents is high, the resulting fuzzy number will also be large. Vice versa, if the length of the road is small but the number of accidents is low, it will still result in a large fuzzy number. To produce a low fuzzy number, it is necessary have a match

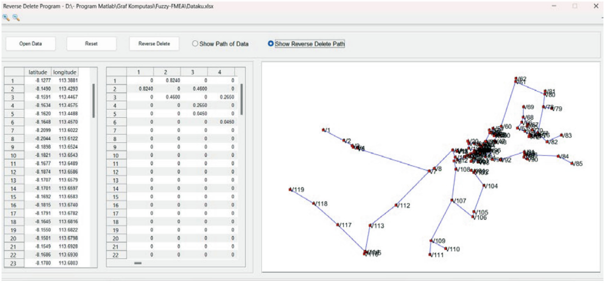

Fig. 8. Reverse-Delete Program Display

between the number of accidents that are small, and the length of the road is small. The fuzzy number for each road can be used as a reference for whether the road is feasible to travel. If it approaches 0 then the road is fit to go on, but if it approaches 1 the road is not feasible to take. Likewise with the route that will be generated later. Even though accidents are sometimes unavoidable, accidents can still be minimized by choosing a road that is feasible to pass. After going through the fuzzification process and obtaining the fuzzy output, then with the Reverse-Delete algorithm a route that minimizes the risk of accidents is obtained as in Fig. 8.

In this program the average fuzzy number is 0,17737. The program also has a long computation time of 14,7881 s. The fuzzy number is obtained from the sum of all fuzzy numbers on each road (side). The resulting average fuzzy number can be categorized as a very low risk level, which means that the path is safe to pass. The resulting route is used for travel or traveling from neighboring cities (Lumajang, Bondowoso, Banyuwangi) through Jember Regency. Suppose V_1 is the Lumajang_1 point, V_{119} is the Lumajang_2 point, V_{62} is the Bondowoso_1 point, V_{83} is the Bondowoso 2 point, V_{85} is the Banyuwangi point. Based on the program in Fig. 8, the Lumajang - Bondowoso route is generated as in Table 3. In Tables 3 and 4 routes are obtained for the Lumajang - Bondowoso trip. These routes can minimize the risk (accidents) that occurs on the road. The fuzzy mean of the four routes ranges from 0,111 to 0,207. If based on the fuzzy rule evaluation this value is included in the very low risk criteria, or it can be said that the route is safe to pass.

Based on the program in Fig. 8, the Lumajang - Banyuwangi route is generated as in Table 4. In Table 4, there are 2 routes for Lumajang - Banyuwangi trip. These routes can minimize the risk (accidents) that occurs on the road. The fuzzy mean of the two routes is 0,198 and 0,186. If based on the fuzzy rule evaluation this value is included in the very low risk criteria, or it can be said that the route is safe to pass.

Based on the program in Fig. 8, Bondowoso - Banyuwangi route is generated as in Table 5. In Table 5, there are 2 routes for the Bondowoso - Banyuwangi trip. These routes can minimize the risk (accidents) that occurs on the road. The fuzzy mean of the two routes is 0,138 and 0,163. If based on the fuzzy rule evaluation this value is included in the very low risk criteria, or it can be said that the route is safe to pass.

Table 3. Comparison of Routes and Fuzzy Average for Lumajang – Bondowoso Trips

Destination	**Route**	**Fuzzy Average**	**Risk Criteria**
Lumajang_1 – Bondowoso_1	(V_1, V_2); (V_2, V_3); (V_3, V_4); (V_4, V_6); (V_6, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{39}); (V_{39}, V_{37}); (V_{37}, V_{45}); (V_{45}, V_{46}); (V_{46}, V_{59}); (V_{59}, V_{58}); (V_{58}, V_{55}); (V_{55}, V_{53}); (V_{53}, V_{51}); (V_{51}, V_{52}); (V_{52}, V_{60}); (V_{60}, V_{61}); (V_{61}, V_{62})	**0,111**	*Very Low*
Lumajang_1 - Bondowoso_2	(V_1, V_2); (V_2, V_3); (V_3, V_4); (V_4, V_6); (V_6, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{39}); (V_{39}, V_{37}); (V_{37}, V_{45}); (V_{45}, V_{46}); (V_{46}, V_{59}); (V_{59}, V_{58}); (V_{58}, V_{55}); (V_{55}, V_{53}); (V_{53}, V_{51}); (V_{51}, V_{52}); (V_{52}, V_{60}); (V_{60}, V_{61}); (V_{61}, V_{80}); (V_{80}, V_{78}); (V_{78}, V_{77}); (V_{77}, V_{76}); (V_{76}, V_{82}); (V_{82}, V_{83})	0,156	*Very Low*
Lumajang_2 – Bondowoso_1	(V_{119}, V_{118}); (V_{118}, V_{117}); (V_{117}, V_{114}); (V_{114}, V_{113}); (V_{113}, V_{112}); (V_{112}, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{39}); (V_{39}, V_{37}); (V_{37}, V_{45}); (V_{45}, V_{46}); (V_{46}, V_{59}); (V_{59}, V_{58}); (V_{58}, V_{55}); (V_{55}, V_{53}); (V_{53}, V_{51}); (V_{51}, V_{52}); (V_{52}, V_{60}); (V_{60}, V_{61}); (V_{61}, V_{62})	0,192	*Very Low*
Lumajang_2 Bondowoso_2	(V_{119}, V_{118}); (V_{118}, V_{117}); (V_{117}, V_{114}); (V_{114}, V_{113}); (V_{113}, V_{112}); (V_{112}, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{39}); (V_{39}, V_{37}); (V_{37}, V_{45}); (V_{45}, V_{46}); (V_{46}, V_{59}); (V_{59}, V_{58}); (V_{58}, V_{55}); (V_{55}, V_{53}); (V_{53}, V_{51}); (V_{51}, V_{52}); (V_{52}, V_{60}); (V_{60}, V_{61}); (V_{61}, V_{80}); (V_{80}, V_{78}); (V_{78}, V_{77}); (V_{77}, V_{76}); (V_{76}, V_{82}); (V_{82}, V_{83})	0,207	*Very Low*

Table 4. Comparison of Routes and Fuzzy Average for Lumajang – Banyuwangi Trips

Destination	**Route**	**Fuzzy Average**	**Risk Criteria**
Lumajang_1 – Banyuwangi	(V_1, V_2); (V_2, V_3); (V_3, V_4); (V_4, V_6); (V_6, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{40}); (V_{40}, V_{31}); (V_{31}, V_{42}); (V_{42}, V_{43}); (V_{43}, V_{94}); (V_{94}, V_{95}); (V_{95}, V_{96}); (V_{96}, V_{93}); (V_{93}, V_{92}); (V_{92}, V_{91}); (V_{91}, V_{88}); (V_{88}, V_{87}); (V_{87}, V_{86}); (V_{86}, V_{84}); (V_{84}, V_{85})	0,198	*Very Low*
Lumajang_2 - Banyuwangi	(V_{119}, V_{118}); (V_{118}, V_{117}); (V_{117}, V_{114}); (V_{114}, V_{113}); (V_{113}, V_{112}); (V_{112}, V_7); (V_7, V_8); (V_8, V_{11}); (V_{11}, V_{10}); (V_{10}, V_{12}); (V_{12}, V_{16}); (V_{16}, V_{17}); (V_{17}, V_{23}); (V_{23}, V_{25}); (V_{25}, V_{27}); (V_{27}, V_{29}); (V_{29}, V_{30}); (V_{30}, V_{32}); (V_{32}, V_{38}); (V_{38}, V_{40}); (V_{40}, V_{31}); (V_{31}, V_{42}); (V_{42}, V_{43}); (V_{43}, V_{94}); (V_{94}, V_{95}); (V_{95}, V_{96}); (V_{96}, V_{93}); (V_{93}, V_{92}); (V_{92}, V_{91}); (V_{91}, V_{88}); (V_{88}, V_{87}); (V_{87}, V_{86}); (V_{86}, V_{84}); (V_{84}, V_{85})	**0,186**	*Very Low*

Table 5. Comparison of Routes and Fuzzy Average for Bondowoso – Banyuwangi Trips

Destination	**Route**	**Fuzzy Average**	**Risk Criteria**
Bondowoso_1 – Banyuwangi	(V_{62}, V_{61}); (V_{61}, V_{60}); (V_{60}, V_{52}); (V_{52}, V_{51}); (V_{51}, V_{53}); (V_{53}, V_{55}); (V_{55}, V_{58}); (V_{58}, V_{59}); (V_{59}, V_{46}); (V_{46}, V_{45}); (V_{45}, V_{37}); (V_{37}, V_{39}); (V_{39}, V_{38}); (V_{38}, V_{40}); (V_{40}, V_{31}); (V_{31}, V_{42}); (V_{42}, V_{43}); (V_{43}, V_{94}); (V_{94}, V_{95}); (V_{95}, V_{96}); (V_{96}, V_{93}); (V_{93}, V_{92}); (V_{92}, V_{91}); (V_{91}, V_{88}); (V_{88}, V_{87}); (V_{87}, V_{86}); (V_{86}, V_{84}); (V_{84}, V_{85})	**0,138**	*Very Low*
Bondowoso_2 - Banyuwangi	(V_{83}, V_{82}); (V_{82}, V_{76}); (V_{76}, V_{77}); (V_{77}, V_{78}); (V_{78}, V_{80}); (V_{80}, V_{61}); (V_{61}, V_{60}); (V_{60}, V_{52}); (V_{52}, V_{51}); (V_{51}, V_{53}); (V_{53}, V_{55}); (V_{55}, V_{58}); (V_{58}, V_{59}); (V_{59}, V_{46}); (V_{46}, V_{45}); (V_{45}, V_{37}); (V_{37}, V_{39}); (V_{39}, V_{38}); (V_{38}, V_{40}); (V_{40}, V_{31}); (V_{31}, V_{42}); (V_{42}, V_{43}); (V_{43}, V_{94}); (V_{94}, V_{95}); (V_{95}, V_{96}); (V_{96}, V_{93}); (V_{93}, V_{92}); (V_{92}, V_{91}); (V_{91}, V_{88}); (V_{88}, V_{87}); (V_{87}, V_{86}); (V_{86}, V_{84}); (V_{84}, V_{85})	0,163	*Very Low*

5 Conclusions

Accidents are one of the risks in driving on the highway. Although sometimes accidents cannot be avoided, it can be minimized. One way to minimize the occurrence of accidents on the road is to use risk management, one of which is the FMEA method. To shorten the journey, it is often traveled with the route that has the shortest route. In this paper, two things are the focus of the research, finding the route with the lowest accident rate and finding the shortest route. To solve these problems, fuzzy logic can be used. Combining fuzzy logic and FMEA method will produce fuzzy-FMEA. The reason for using fuzzy logic is because accidents are uncertain parameters and can change at any time. The length of the road and the number of accidents are verified by the corresponding membership function. The output process generated by this fuzzy logic is adjusted to the risk parameter index in Table 1. Meanwhile, to produce the shortest route, we use the Reverse-Delete algorithm. The display of the Reverse-Delete program is in Fig. 8.

In our research, we have shown that this route can effectively produce very small fuzzy averages. The advantage of this paper is that the route produced when compared to GPS is effective in minimizing the distance and risk of accidents. There are several possibilities for expanding this research in the future, first, although in this study the resulting route can minimize the distance and accidents, there are many other uncertainty factors that can be taken into consideration such as traffic jams, natural disasters, etc. Second, in this study also have not been able to find a route for travel between places in Jember Regency. This is because the number of points used has not reached all the places in Jember Regency.

Based on the research conducted, several inter-city travel routes through Jember Regency were obtained. These routes are as in Table 3, Table 4, and Table 5. Each route in the table has a different fuzzy average, the closer to zero the value is, it can be said to be safe to pass.

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