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# Route Choice Optimization Based on Travel Cost using Hybrid Fuzzy – Dijkstra Algorithm

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***Abstract*—Drivers usually see the only length of each road used as a parameter in case of finding a route to save travel costs. Many factors should be used as a parameter in determining routes, such as road density, traffic volume, vehicle speed, and IRI (International Roughness Index). The purpose of this research is to determine the most inexpensive route in Depok City. The method used is the hybrid fuzzy-Dijkstra algorithm, it is a combination of two methods, fuzzy algorithm, and Dijkstra algorithm. The method is proposing a continuous tool which inherits the advantages. The Fuzzy logic is used for the modeling several parameters of road, there are traffic density, vehicle speed, traffic volume, and road length. The output of the fuzzy logic model as the weighted of travel cost and the output of fuzzy logic would be used as the input of the Dijkstra algorithm for searching the shortest path. So the results obtained from the optimization of these two algorithms are optimal results of finding a route with the lowest of travel costs.**

***Keywords—Fuzzy Logic, Dijkstra, Mamdani, Algorithm, Travel Cost***

## I. INTRODUCTION

Road is an infrastructure of land transportation that covers all parts of the road, including its complementary buildings and equipment intended for traffic, which are on the surface of the land, above the surface of the land, below the surface of the land and/or water, and above the water surface, except railroad, lorry and cable roads [1]. Public roads are roads intended for public traffic. The location of this study is in Depok City, West Java Province, with a population density of 2.254.513 people in 2019, and the increase of 1,838,671 people from 2018 [2]. The number of vehicles in Depok is known in 2019 is 1,180,391 vehicles, up 970,000 vehicles from 2017 [3]. The increase in the number of vehicles is not accompanied by the number of lane roads so that vehicles accumulate on the road sections which results in congestion and buildup of vehicles on a road section [4]. Motorists usually only pay attention to the length of the road in determining the route and only based on personal perception in determining which route is considered the lowest cost, however, it is very ineffective. Hybrid fuzzy - Dijkstra algorithm can be used to assist the driver in determining the route, taking into account the parameters contained on the road. The results of the finding route, in general, can be utilized to reach the intended location quickly. In special conditions, this finding route can be used to such as a search for tourist locations and minimize fuel use or minimize travel costs [5]. Fuzzy logic is used to model the number of inputs [6]. Fuzzy logic can be used to modeling situations where decision making is in a complex setting and it is difficult to develop mathematical models manually [7]. The output value of fuzzy logic can be used as an input value for another algorithm, in this case, the Dijkstra algorithm [8]. Fuzzy logic is widely accepted and applied to a variety of real problems, and to model the knowledge possessed by humans [9]. Therefore, in this study, the author uses fuzzy logic to model the characteristics of the road. The Dijkstra algorithm is an algorithm for solving the shortest path problem, with the value of each non-negative path [8]. This algorithm resolves the problem by generating one route, from one initial location to the many destination locations, to find the lowest cost, closest, or fastest route [10]. Therefore, in the process of determining the route to be chosen a very detailed mathematical calculation is needed, by considering the characteristics of the road and the parameters of the road, the authors use fuzzy logic to give specific considerations in providing weight values for each road section and Dijkstra algorithm to find the route taken, so that the route with the lowest cost travel costs is obtained [11]. The next part of this paper presents the related work. Part 3 explains the optimization of models and data used in research. In section 4, explaining the results of the calculations and analyses that have been done are the output values of the Fuzzy logic and Dijkstra's algorithm which is the operating cost value of the lowest cost vehicle from the point of origin to the destination point. Part 5 concludes with conclusions and some comments and feedback for subsequent research.

## II. RELATED WORK

Optimization of transportation problems stands for optimizing travel costs that will travel from several sources to various destinations [12]. Optimizing the transport route will improve the planning process and the selection of the transport route, which will reduce transport congestions [13]. The route selection method has experienced the transition from a single objective to multi-objectives and has gradually been developed

toward intelligent route selection [14]. To optimize the delivery of goods one of them can be done by reducing transportation costs, transportation time, environmental pollution and energy consumption, in this journal more focused on reducing transportation costs through the most efficient route [13]. Lowest travel cost, primary parameters while choosing between an origin and destination are travel time, traffic safety, intervals, cost (fuel), traffic sign, jam and habitual effects [15]. Fuel consumption and environmental pollution can be reduced. The methods in this study are compared in terms of fuel-saving, environmental effects, and faster road flow. Accordingly, neutral fuel consumption with a fuzzy logic method is averagely %15.9 less than the classical method [16]. The distribution of uncertainty from which route is the most inexpensive, and effective method to find routes in the network is uncertain. The optimal solution to the shortest path problem in which the research is the route with the lowest cost in a non-deterministic network was usually obtained by a heuristic algorithm method [17]. The fuzzy set theory allows the use of ambiguity and plurality of linguistic expressions. It can be mapped into fuzzy sets and interpreted in computer languages. Fuzzy setups describing imprecise terms and fuzzy logic make the basis of fuzzy systems or fuzzy management or flaw in expert systems [13]. Non-deterministic factors often appear in programming problems. In the past, probability or fuzzy theory has been employed to deal with these non-deterministic factors. Uncertainty theory provides a new approach to deal with non-deterministic factors [18]. Dijkstra, the shortest route that queries iteratively and adjusts the cost of the result routes. The procedure is continued until the required number is found unless the adjustments of the result set generate no better result. The penalization process should be bound or it will bring an unnecessary high average of distance values. Also, the penalization factor should be dynamic enough to suit the actual demand [19].

## III. Optimization Model

### A. *Study Area and Data*

The location of this research is in Depok City, West Java Province, Indonesia, a city located in the south of the capital city of the Republic of Indonesia. Depok city is one of the most populous cities in West Java because it is an area that supports the national capital, so that it has hight movement of vehicle every day, especially during rush hour, ie in the morning where most people go to work and in the afternoon where people leave work, so at that time there was a buildup of vehicles on several roads. The following is an overview of the road sections to be reviewed.

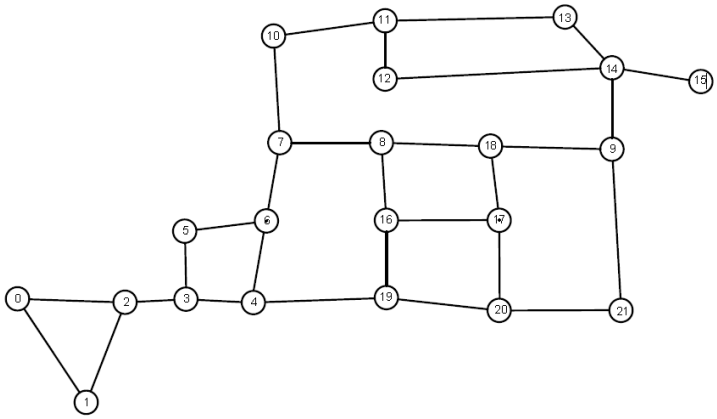


*Fig 1. Road sections of studi location*

The figure shows, that the nodes created as many as 22 nodes, with the initial nodes are given a symbol 0 and the last node is given a symbol 21. In this research, wanted to find out the lowest cost of travel expenses from node 0 to node 15.

In the X to the Y direction, it is a road in one direction, i.e. the movement from Y to X, so the road cannot be traversed by the driver from the direction of node X to node Y, the rider must go through alternative line if he wants to go in direction 15.

The data used in this study are secondary data, obtained from the Depok City Transportation Department.

The data used are attributes that are on the highway, with parameters and criteria used as follows:

μ = Parameter (road length, vehicle speed, traffic density, traffic volume)
a = Traffic density (hight density, dense, moderate, loose, very loose)
b = Traffic volume (very hight, hight, moderate, low, very low)
c = Vehicle speed (very fast, fast, moderate, slow, very slow)
d = Length of road (very long, long, moderate, short, very short.)
e = Output (very exensive, expensive, moderate, chep, very cheap)

TABLE 1. PARAMETER OF ROAD

| Route Name | Nodes | Parameter | | | |
|---|---|---|---|---|---|
| | | Traffic Density | Traffic | Vehicle Speed | Length of Road |
| | | Passenger Car unit | | | |
| | | | | Km/h | Km |
| Margonda I | 7-10 | 65.80 | 2907.90 | 33.00 | 2.80 |
| Margonda II | 6-7 | 126.80 | 4039.40 | 31.90 | 1.50 |
| Margonda III | 4-6 | 72.90 | 3778.30 | 29.07 | 3.60 |
| Arif Rahman Hakim | 5-6 | 80.40 | 2520.50 | 31.34 | 2.60 |
| Nusantara | 3-5 | 36.20 | 1596.70 | 41.30 | 2.50 |
| Dewi Sartika | 3-4 | 36.20 | 1496.70 | 41.30 | 1.70 |
| Pitara Raya I | 0-1. | 54.10 | 559.00 | 22.00 | 2.00 |
| Pitara Raya II | 1-2 | 54.10 | 559.00 | 22.00 | 2.20 |
| Sawangan I | 2-3 | 70.20 | 1163.80 | 31.60 | 2.20 |
| Sawangan III | 0-2 | 102.60 | 1361.40 | 25.20 | 2.20 |
| Juanda I | 7-8 | 65.90 | 2459.60 | 37.30 | 1.50 |
| Juanda II | 8-18 | 65.90 | 2459.60 | 37.30 | 1.50 |
| Juanda III | 18-9 | 65.90 | 2459.60 | 37.30 | 2.00 |
| M Yusuf | 8-16 | 40.80 | 2275.00 | 26.10 | 1.80 |
| Siliwangi | 4-19 | 71.70 | 1062.00 | 26.20 | 1.50 |
| Tole Iskandar I | 16-19 | 60.6 | 946.00 | 34.40 | 1.10 |
| Tole Iskandar II | 19-20 | 71.1 | 1247.00 | 33.50 | 1.90 |
| Kemakmuran Raya | 17-20 | 60.4 | 902.20 | 31.70 | 1.70 |
| Keadilan Raya | 18-17 | 60.4 | 902.20 | 31.70 | 1.60 |
| Proklamasi | 16-17 | 60,4 | 902.20 | 31.70 | 1.70 |
| Radar Auri | 14-15 | 63.6 | 1001.5 | 27.10 | 2.20 |
| Raya Bogor Segmen I | 21-9 | 68.2 | 2262.7 | 33.20 | 4.50 |
| Raya Bogor Segmen II | 9-14 | 39.2 | 2184.1 | 20.90 | 2.00 |
| Raya Bogor Segmen III | 13-14 | 39.2 | 2184.1 | 20.90 | 3.50 |
| M. Jasin | 10-11 | 89 | 2210.5 | 28.80 | 1.00 |
| M. Jasin | 11-13 | 89 | 2210.5 | 28.80 | 2.00 |
| Raya RTM | 11-12 | 89 | 2210.5 | 28.80 | 1.00 |
| Raya Pondok Duta | 12-14 | 89 | 2210.5 | 28.80 | 3.60 |
| Tole Iskandar 3 | 20-21 | 72.8 | 1299 | 32.20 | 1.70 |

The data used in this study are data about the traffic condition of the city of Depok in the morning. Depok City has the shortest segment length on the 6-7 section of only 1.5 km. so that the dense traffic density in section 6-7 with a density value of 126.80. this is caused by the volume of traffic in the field belongs to the high category with the number of vehicles passing in the morning as much as 4039.40 vehicles per hour, so it affects the speed of the moving vehicle is at 31.90 km. Each of these parameters has criteria, namely very low, low, moderate, hight, and very hight. Based on the data obtained and the literature used, the details of each of the parameters used are as follows:

TABLE 2. PARAMETERS CRITERIA OF ROAD

| Parameter | | Criteria | | | | |
|---|---|---|---|---|---|---|
| | | Very Low | Low | Moderate | Hight | Very Hight |
| Traffic Density | Lower Limit | 0 | 45 | 75 | 105 | 135 |
| | Peak Value | 30 | 60 | 90 | 120 | 150 |
| | Upper Limit | 45 | 75 | 105 | 135 | 165 |
| Traffic | Lower Limit | 0 | 1200 | 2000 | 2800 | 3600 |
| | Peak Value | 800 | 1600 | 2400 | 3200 | 4000 |
| | Upper Limit | 1200 | 2000 | 2800 | 3600 | 4400 |
| Vehicle Speed | Lower Limit | 0 | 18 | 30 | 42 | 54 |
| | Peak Value | 12 | 24 | 36 | 48 | 60 |
| | Upper Limit | 18 | 30 | 42 | 54 | 66 |
| Length of Road | Lower Limit | 0 | 7.5 | 12.5 | 17.5 | 22.5 |
| | Peak Value | 5 | 10 | 15 | 20 | 25 |
| | Upper Limit | 7.5 | 12.5 | 17.5 | 22.5 | 27.5 |

Traffic density criteria are based on the maximum value and minimum value of traffic density contained in the segment that is reviewed, so in this journal set the peak value for traffic density that is 150 with a lower limit of 135 and an upper limit of 165, which then the peak value is divided into 5, for distribution to

other criteria, so that the peak value for very low is 30, low is 60, moderate is 90, and hight is 120. For the criteria on the traffic volume and length of road parameters, the way to determine the peak value, the upper and lower limits of each criterion is the same as how to determine the criteria for traffic density, which is to determine the maximum value owned by these parameters which is then divided and distributed to each criterion. Meanwhile, to determine the criteria for this vehicle speed is based on government regulations governing traffic, namely Regulation of The Minister of Transportation of The Republic Indonesia Number PM 111 of 2015, Concerning Procedures For Determining Vehicle Speed [20], for urban roads vehicle speed is limited to 50 km/hour in very smooth traffic conditions. Table 1 is the data used for input, while for output the data is used for non-permanent vehicle operating costs, the following details:

TABLE 3. CRITERIA DETAIL

| Parameter | | Criteria | | | | |
|---|---|---|---|---|---|---|
| | | Very Cheap | Cheap | Moderate | Expensive | Very Expensive |
| Traffic Density | Lower Limit | 0 | 1000 | 2000 | 3000 | 4000 |
| | Peak Value | 500 | 1500 | 2500 | 3500 | 4600 |
| | Upper Limit | 1000 | 2000 | 3000 | 4000 | 5000 |

The value of the value obtained from the operating cost of the vehicle is not fixed (Running Cost) for private vehicles, assuming the value of IRI (international roughest index) is the carousel value of the most severe or heavily damaged road criteria in Depok City, because the road that is reviewed on the Depok City enters the urban road so that the value of IRI for the category of heavy damage is 12. The following is a calculation for vehicle operating costs based on the construction and building guidelines of the ministry of public works and public housing concerning the calculation of vehicle operating costs number Pd T-15-2005 [21].

BTT = BiBBMj + BOi + Bpi + Bui + BBi (1)

Where:
BTT = Fixed cost (IDR/km)
BiBBMj = Fuel consumption fee (IDR /km)
BOi = Oil consumption fee (IDR /km)
BPI = Maintenance fee (IDR /km)
Bui = Wage cost of maintenance personnel (IDR/km)
BBi = The cost of consumption of tires (IDR/km).

(i) Track costs – of providing and maintaining a surface over which transports services can operate

### *B. Algorithm Model*

The algorithm model used in this study uses 2 models namely the fuzzy algorithm and the Dijkstra algorithms. Fuzzy logic is used to model the number of inputs and is used for model situations where decision making is in a complex setting and it is difficult to develop mathematical models. The Dijkstra algorithm is an algorithm for solving the shortest path problem, with the value of each non-negative path. This algorithm resolves the problem by producing one route, from one initial location to one destination location. Therefore, it takes an analysis and mathematical calculations that are very detailed in the process of determining the route to be selected, with consideration of road characteristics and phenomena that occur, is used fuzzy logic to give specific consideration in providing the weighted value of each road section and the algorithm of Dijkstra's to find the route taken, so that get the fastest road route. For more details can see the following explanation.

#### *1) Fuzzy Logic*

Fuzzy Logic was introduced by Lotfi Zadeh and presented as a means of data processing by allowing the use of partial set memberships over crisp set memberships or Non-membership, fuzzy logic is generally applied to problem issues that contain elements of uncertainty, imprecise, noisy, and so on, fuzzy logic is developed based on how humans think, so the fuzzy logic bridges precise machine language with human language that emphasizes the significance [22]. The following is the fuzzy logic flowchart.

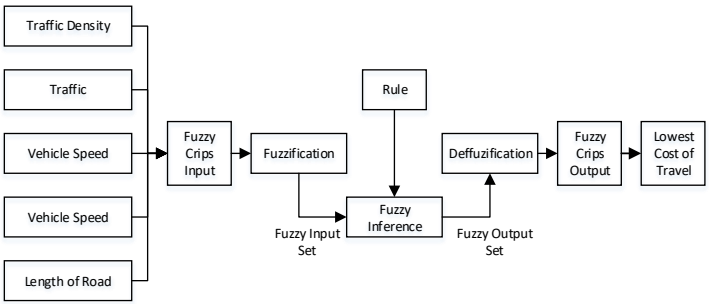


*Fig. 2. Flowchart of fuzzy logic*

The flowchart explains, there are three main processes in fuzzy logic to implement in a case, namely fuzzification, fuzzy inference, and defuzzification. The following is the full explanation.

*2) Fuzzification*

Fuzzification is a process to change an input from a strict form (crisp) to fuzzy (linguistic variable) which is usually presented in the form of fuzzy sets with a membership function [23]. The membership function described the degree of membership owned by traffic density, traffic volume, vehicle speed, and length of the road, which has five degrees of membership, among other things eg: very low, low, moderate, hight and very hight from road criteria.

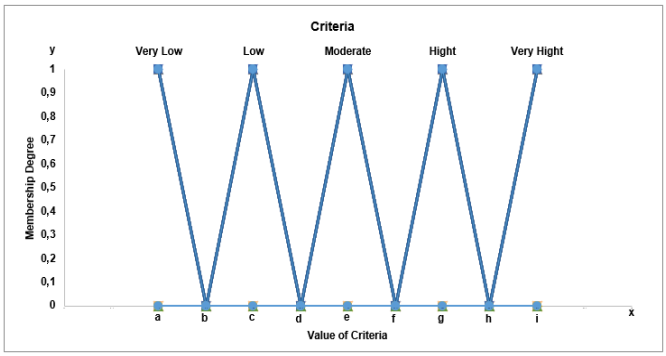


*Fig. 3. Membership degree criteria of fuzzy*

Each membership function has a linear function, which is used to provide information about the value of each degree of membership. The linear function which is owned by the traffic density is as follows:

Linear functions for very low sets ($\mu_{Very\ Low}$): (2)

$$1\ ;x < a$$

$$\frac{b-x}{a-0}\ ;a \le x \le b$$

$$0\ ;x \ge b$$

Linear functions for low sets ($\mu_{Low}$): (3)

$$0\ ;x < b$$

$$\frac{x-b}{c-b}\ ;\ b \le x \le c$$

$$\frac{d-x}{d-c}\ ;\ c \le x \le d$$

Linear functions for moderate sets ($\mu_{moderate}$): (4)

$$0\ ;x < d$$

and MAX-MIN operations

*4) Deffuzification*

Defuzzification is the process of obtaining a single number from the output of the aggregated fuzzy set [27]. It is used to transfer fuzzy inference results in a crisp output. In other words, defuzzification is realized by a decision-making algorithm that selects the best crisp value based on a fuzzy set [28]. Several methods exist in the literature to perform defuzzification, the most popular of which is the center of gravity (CoG) method [29]. For discrete triangular linear functions, the CoG method is obtained by moments of the area as defined by:

$$\frac{x-d}{e-d}\ ;\ d \le x \le e$$

$$\frac{f-x}{f-e}\ ;\ e \le x \le f$$

Linear functions for hight sets ($\mu_{Hight}$): (5)

$$0\ ;x < f$$

$$\frac{x-f}{g-f}\ ;\ f \le x \le g$$

$$\frac{h-x}{h-g}\ ;\ g \le x \le h$$

Linear functions
for hight very hight sets ($\mu_{Very\ Low}$): (6)

$$0\ ;x < h$$

$$\frac{x-h}{i-h}\ ;h \le x \le i$$

$$1\ ;x \ge i$$

Where “a, b, c, d ,f ,g, h, i” are value of criteria

*3) Fuzzy Inference*

Fuzzy inference is a method that interprets the values in the input vector and, based on some sets of rules, assigns values to the output vector [24]. In Fuzzy Logic, the truth of any statement becomes a matter of a degree [25]. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic [26]. The mapping then provides a base from which decisions can be made or patterns discerned. The process of fuzzy inference involves all of the pieces described so far, i.e., membership functions, Fuzzy logic operators, and if-then rules as defined by:

If (A is x) And (B is y) And (C is z) Then
(D = Min x,y,z) (7)

Author uses the fuzzy mamdani model using AND

$$Z = \frac{\int \mu_X(z)\, z dz}{\int \mu_X(z)\, dz} \quad (8)$$

*5) Dijkstra Algoritm*

Dijkstra's algorithm is a form of the greedy algorithm to solves the problem of finding the shortest path from a point in a graph to a destination [5]. It turns out that one can find the shortest paths from a given source to all points in a graph at the same time, the sequence of work of the algorithm is shown in the following flowchart:

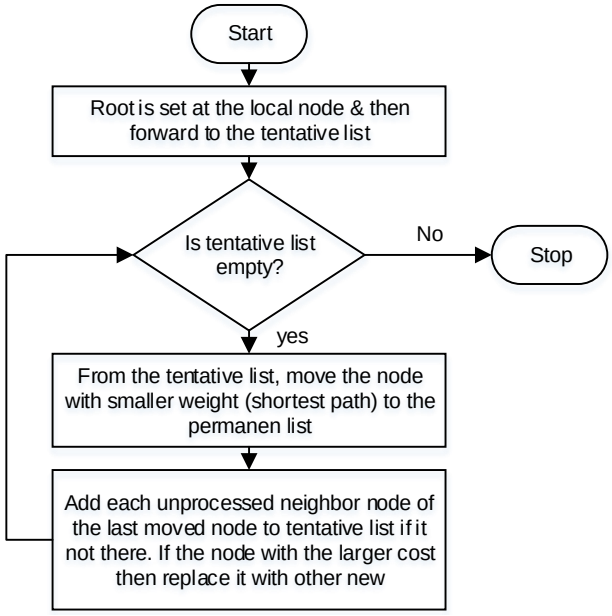


*Fig. 4. Dijsktra's Flowchart*

This algorithm includes a graph search algorithm that is used to solve the shortest path problem with one source on a graph that has no negative side cost and produces the shortest path tree. Dijkstra's algorithm uses an adjacent list to represent a network. Broadly speaking the Dijkstra algorithm divides all nodes into two, then is put into different tables, namely permanent tables and temporal tables. The permanent table contains the initial nodes and the nodes that have gone through the inspection process and their labels have been changed from temporal to permanent. The temporal table contains the nodes that are associated with nodes in the permanent table. Route selection in the Dijkstra algorithm is done with Best First Search (BFS) [10], a best-first search is a combination of depth-first search and breadth-first search methods where the search is allowed to visit nodes at lower levels if nodes at higher levels have worse heuristic values. After getting the results from fuzzy logic, it is processed by the Dijkstra algorithm with C ++ programming language.

## IV. RESULT AND DISCUSSION

Based on the data that has been obtained and the calculation that has been done, it is obtained the value for each road segment in Depok in the morning condition, the following is an explanation to get the value:

### *A. Fuzzification*

Fuzzy set formation of the road consists of several parameters, in this case, the author uses 4 (four) membership functions from each parameter (traffic density, vehicle speed, traffic volume, and road length), and then from each membership function
The author makes 5 criteria for each membership function, then created the membership degree for mapping the data input into the membership value, which is valued from 0 to 1. to get the membership degree value the formula was written in the section optimization model by using the limits on each parameter that has been determined also in section 2

### *B. Fuzzy Inference*

After created the membership degree, then inserted the data into the fuzzy Mamdani rule model [30], Using the max-min rule from the Mamdani model, the output value in this section (fuzzy inference) is the minimum value of each rule. There are 4 (four) membership functions with 5 membership variables so that the rules obtained are 5 ^ 4 = 625 rules.

TABLE 4. Fuzzy Rules

| No | If | Density | And | Velocity | And | Traffic Volume | And | Length Of Road | Then | Travel Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | If | Hight Density | And | Very Slow | And | Very Hight | And | Very Short | Then | Expensive. |
| 17 | If | Hight Density | And | Very Slow | And | Low | And | Short. | Then | Moderate |
| 127 | If | Dense | And | Very Slow | And | Very Hight | And | Short. | Then | Expensive. |
| 157 | If | Dense | And | Slow. | And | Hight. | And | Short. | Then | Moderate |
| 336 | If | Moderate | And | Fast. | And | Moderate | And | Very Short | Then | Cheap. |
| 371 | If | Moderate | And | Very Fast | And | Very Low | And | Very Short | Then | Very Cheap |
| 502 | If | Very Loose | And | Very Slow | And | Very Hight | And | Short. | Then | Moderate |
| 625 | If | Very Loose | And | Very Fast | And | Very Low | And | Very Long | Then | Cheap. |

### *C. Defuzzification*

After obtaining the minimum value of each existing rule, then the value is filtered and searched the largest value of 5 criteria travel cost (very expensive, expensive, Moderate, cheap, very cheap) By using the MAX formula in Microsoft Excel,

Then the value will be input as a membership degree of travel cost, to determine the value of the upper limit and lower limit of cost. Plot the limit value to the graph to make it easier to do readings, as shown in the following figure:

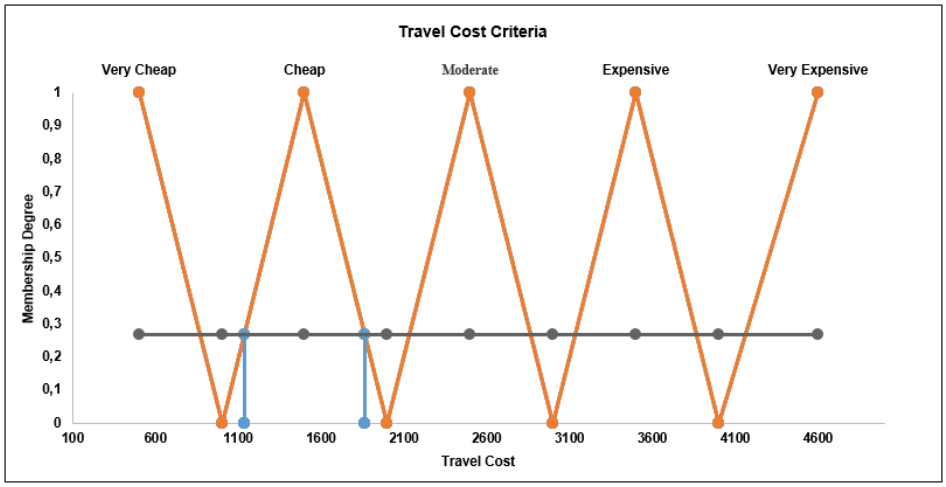


*Fig. 5. Criteria of Travel Cost*

After plotting the data into the chart, then calculating the value of the moment and the area of the restricted areas, then the value of the moment is divided by the value of the operating cost of the vehicle is not fixed on the section reviewed the following is the fuzzy output value on each road section:

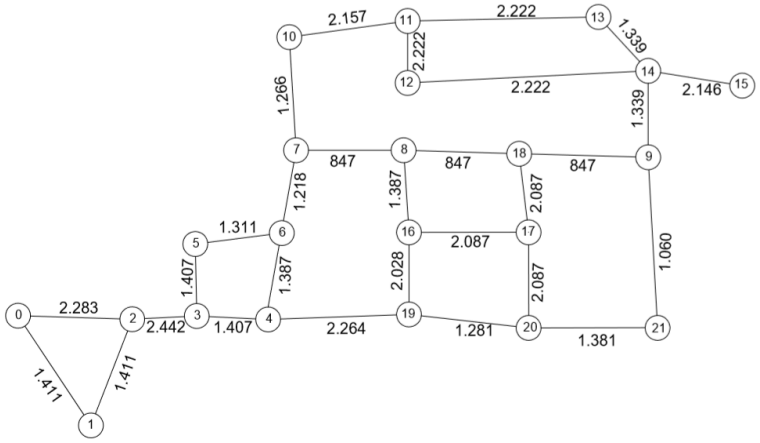


*Fig. 6. Fuzzy Output*

The fuzzy output is the value of the operating cost of the vehicle that has been acquired for each section, which is then the value of the output will be input by the Dijkstra's algorithm.

### *D. Dijkstra Algorithm*

To get a route with the lowest travel cost with the Dijkstra algorithm, this research uses two tools, there are the C ++ programming language and manual calculation using Microsoft Excel, to validate the results of the C ++ program. The following results can be from the two tools used

Results of analysis with the C ++ programming language:

| Vertex | Distance | Path |
|---|---|---|
| 0 -> 1 | 1411 | 0 1 |
| 0 -> 2 | 2283 | 0 2 |
| 0 -> 3 | 4725 | 0 2 3 |
| 0 -> 4 | 6132 | 0 2 3 4 |
| 0 -> 5 | 6175 | 0 2 3 5 |
| 0 -> 6 | 7486 | 0 2 3 5 6 |
| 0 -> 7 | 8704 | 0 2 3 5 6 7 |
| 0 -> 8 | 9551 | 0 2 3 5 6 7 8 |
| 0 -> 9 | 11245 | 0 2 3 5 6 7 8 18 9 |
| 0 -> 10 | 9970 | 0 2 3 5 6 7 10 |
| 0 -> 11 | 12127 | 0 2 3 5 6 7 10 11 |
| 0 -> 12 | 14349 | 0 2 3 5 6 7 10 11 12 |
| 0 -> 13 | 13923 | 0 2 3 5 6 7 8 18 9 14 13 |
| 0 -> 14 | 12584 | 0 2 3 5 6 7 8 18 9 14 |
| **0 -> 15** | **14730** | **0 2 3 5 6 7 8 18 9 14 15** |
| 0 -> 16 | 10424 | 0 2 3 4 19 16 |
| 0 -> 17 | 11764 | 0 2 3 4 19 20 17 |
| 0 -> 18 | 10398 | 0 2 3 5 6 7 8 18 |
| 0 -> 19 | 8396 | 0 2 3 4 19 |
| 0 -> 20 | 9677 | 0 2 3 4 19 20 |
| 0 -> 21 | 11058 | 0 2 3 4 19 20 21 |

In this research, the C++ programming language has found the lowest cost route from node 0 to node 15 by passing several roads, based on the calculations that have been done, the road segments that will be traversed by riders are from 0 – 2 – 3 – 5 – 6 – 7 – 8 – 18 – 9 – 14 – 15, with the costs incurred in the amount of Rp. 14687

### *E. Manual validation*

The following are the results of manual calculations using Microsoft Excel:

TABLE 4. MANUAL RESULT

| Road | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1411 | 2283 | | | | | | | | | | | | | | | | | | | |
| 0,1 | | | 2823 | | | | | | | | | | | | | | | | | | | |
| 0,2 | | | | 4725 | | | | | | | | | | | | | | | | | | |
| 0,2,3 | | | | | 6132 | 6132 | | | | | | | | | | | | | | | | |
| 0,2,3,4 | | | | | | | 7519 | | | | | | | | | | | | | 8396 | | |
| 0,2,3,5 | | | | | | | 7443 | | | | | | | | | | | | | | | |
| 0,2,3,5,6 | | | | | 8830 | | | 8661 | | | | | | | | | | | | | | |
| 0,2,3,5,6,7 | | | | | | | | | 9508 | | 9927 | | | | | | | | | | | |
| 0,2,3,5,6,7,8 | | | | | | | | | | | | | | | | | 10895 | | 10355 | | | |
| 0,2,3,5,6,7,8,18 | | | | | | | | | | 11202 | | | | | | | | 12442 | | | | |
| 0,2,3,5,6,7,8,18,9 | | | | | | | | | | | | | | | 12541 | | | | | | | |
| 0,2,3,5,6,7,8,18,9,14 | | | | | | | | | | | | | | | | 14687 | | | | | | |
| 0,2,3,4,6 | | | | | | | | 8737 | | | | | | | | | | | | | | |
| 0,2,3,4,6,7 | | | | | | | | | 9584 | | 10003 | | | | | | | | | | | |
| 0,2,3,4,6,7,8 | | | | | | | | | | | | | | | | | 10971 | | 10431 | | | |
| 0,2,3,4,6,7,8,18 | | | | | | | | | | 11277 | | | | | | | | 12518 | | | | |
| 0,2,3,4,6,7,8,18,9 | | | | | | | | | | | | | | | 12617 | | | | | | | |
| 0,2,3,4,6,7,8,18,9,14 | | | | | | | | | | | | | | | | 14763 | | | | | | |
| 0,2,3,4,19 | | | | | | | | | | | | | | | | | 10424 | | | | 9677 | |
| 0,2,3,4,19,20 | | | | | | | | | | | | | | | | | | 11764 | | | | 11058 |
| 0,2,3,4,19,20,21 | | | | | | | | | | 12119 | | | | | | | | | | | | |
| 0,2,3,4,19,20,21,9 | | | | | | | | | | | | | | | 13458 | | | | | | | |
| 0,2,3,4,19,20,21,9,14 | | | | | | | | | | | | | | | | 15604 | | | | | | |

Based on manual calculations that have been carried out, the route with the lowest cost that can be passed is 0 - 2 - 3 - 5 - 6 - 7 - 8 - 18 - 9 - 14 - 15, with a travel cost of Rp. 14687, these results are the same as the results of the discussion of C ++ programming, so it can be concluded that the program has been made can be justified.

In addition to looking for route 15, we also find the lowest cost route to other destinations. In this research, only counts from node 0 to node 15 which is the furthest point and does not count for vice versa ie node 15 to node 0.

## V. CONCLUSION

The result of this research can be implemented to the driver's decision making to find the best route in unpredictable traffic. The value of the resulting travel costs can be more than one route, from one point of origin with many destinations. This research can also be utilized by private vehicle riders, whether in the form of motorcycles or cars, either to transport goods or people, to distribute goods from one place to many destinations and to minimize transportation costs. Suggestions from this research, it can be developed and made into a program or application to be able to assist motorists in determining routes to save on travel costs. And data used as input material, in the future it can be presented in real-time, according to the needs of road users, so that the route that can be chosen will change at any time.

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