The implementation of Mamdani fuzzy inference system (FIS) method for decision making to choose direct and transit airline types in Indonesia

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Abstract. Choosing the type of airline tickets is determined by several factors, including types of direct or transit flights, ticket prices, facility and travel time. The purpose of this research is to determine the decision to purchase the direct and transit type airline tickets. In this research, the data were collected from Yogyakarta-Jakarta (Round Trip) amounted 93 and Yogyakarta-Medan (Round Trip) amounted 21 travel routes. This research used Mamdani fuzzy method with the following steps, determining the membership function of each input variable, determining the fire strength for each type of plane ticket, and determining Mamdani fuzzy inference system max-min. The results show that the highest electability for direct airline ticket types is Batik Air - Garuda (Round Trip) ticket type with the ticket price is IDR 1,501,200, facility score is 60 and travel time is around 140 minutes. While, the highest electability for transit tickets is Garuda - Garuda (Round Trip) with the ticket price is IDR 6,169,400, facility score is 60 and travel time is around 615 minutes.

1. Introduction

Nowadays, transportation in the world has become interesting alternative to all groups in crossing from one place to another. Every year, public vehicles enthusiasts such as airlines are greatly increasing. Recently, airline is the most popular public transportation for travelling. According to data [1], starting from 2015 until 2017, there has been an increase of airline users amounted 75,593,248; 87,208,889 and 95,401,545. In addition, many airlines operate from 2015 until 2017 amounted 791,783; 894,104 and 972,863. The departure and destination places of airline are different. Because of that, the departures from Yogyakarta to Jakarta and Yogyakarta to Medan are chosen for decision making with different routes and information for ticket prices, facility and travel time.

The web information system providing ticket price information makes the customers easier to choose ticket prices suitable with the purpose and type of ticket purchased with ticket price, facility and duration of travel time. However, the customers are still confused in choosing which tickets with different its advantages. Therefore, the decision making system will be used. This system aims to assist in decision making in semi-structured and unstructured situations, where no one knows exactly how decisions should be made [2]. One type of decision making method that is believed to have a certain accuracy is fuzzy logic [3]. Fuzzy was introduced by Lotfi A. Zadeh in 1965 as a mathematical
way to represent uncertainty linguistic. Based on the concept of fuzzy logic, both factors and criteria can be classified without binding restrictions. Fuzzy logic is very useful for solving real world problems in various fields which usually contain uncertainty degree [4]. One of the most important things sparked by Zadeh is Fuzzy Rule-Based System (FRBS) or called Fuzzy Inference System (FIS). Fuzzy inference is a process of mapping formulating from input to output by using fuzzy logic to obtain new knowledge through the decisions or pattern of existing knowledge [5]. Fuzzy logic follows the human reasoning process which explains that a thing is not only seen on its worthiness or inaccuracy as classical logic [6], but also ranges from the completely false to completely true, partially false and partially almost true and certain to very certain, in the form of membership levels ranging values from 0 until 1 [7].

The following research is related to fuzzy logic. The results of the first research [8] has chosen a location for infrastructure investment projects in renewable energy sources by using MATLAB and fuzzy logic. The results obtain four locations in Bosnia and Herzegovina that are appropriate for the renewable energy sources location. The second research, fuzzy logic helps reducing the alpha values to find new gravitational search algorithm with the best results [9]. The third research, fuzzy logic is used as optimization of mathematical function to find imperialist competitive algorithm [10]. The fourth research is that the improvements of the galactic swarm optimization by using fuzzy logic [11]. The fifth research is designing the fuzzy classification [12] with parameter of PSO by using fuzzy logic. The sixth research, applying fuzzy logic in the decision making process in the executive managers selection [13]. The seventh research explained that it uses fuzzy logic of Mamdani method as decision making in choosing a car in Sleman, Yogyakarta [14] and the eighth research, supplier selection by using fuzzy multi-criteria of decision making method and multi-objective programming [15].

The purpose of this research is to design and implement a decision making system to determine the airline types that will be purchased regarding the tickets prices, facility and travel time by using data on the airline type tickets from Yogyakarta to Jakarta direct lines (Round Trip) and Yogyakarta to Medan transit lines (Round Trip) from May 15, 2019 until May 15, 2019.

2. Method

2.1 The Concept of Fuzzy Logic
The fuzzy system was first invented by Lotfi A Zadeh in 1965 as described in a paper entitled "Fuzzy Set" [16]. Logic reasoning is the methods and basic principles of decision making in intelligent systems [17-18]. In classical logic, the proportion value is not only true and false, but also having interval value of [0,1]. The principle of fuzzy logic is widely used in various fields such as diagnosing of diseases, forecasting of economics, automatic washing machines, etc. The fuzzy logic is a new logic consisting of modern science and discovered a few years ago [19].

2.2 The Degree of Membership
The degree of membership in fuzzy logic can be determined by using calculation involving graph function. The degree of membership of $x$ is denoted by $\mu(x)$. There are several functions that can be used, including linear representation, triangular curve representation, trapezoid curve representation, shoulder shape curve representation, s-curve representation, and bell shape curve representation [20]. There are several function curves used in determining the degree of membership, including [19]:

\begin{align*}
\text{Linear Representation} & : \mu(x) = \frac{x}{\alpha}, \\
\text{Triangular Curve} & : \mu(x) = \begin{cases} 
0 & \text{for } x < a \\
\frac{x-a}{b-a} & \text{for } a \leq x \leq b \\
1 & \text{for } x > b
\end{cases}, \\
\text{Trapezoid Curve} & : \mu(x) = \begin{cases} 
0 & \text{for } x < a \\
\frac{x-a}{b-a} & \text{for } a \leq x \leq b \\
\frac{x-c}{d-c} & \text{for } b < x \leq c \\
1 & \text{for } x > c
\end{cases}, \\
\text{Shoulder Shape Curve} & : \mu(x) = \begin{cases} 
0 & \text{for } x < a \\
\frac{x-a}{b-a} & \text{for } a \leq x \leq a+b \\
1 & \text{for } x > b
\end{cases}, \\
\text{s-Curve} & : \mu(x) = \frac{x-a}{b-a}, \\
\text{Bell Shape Curve} & : \mu(x) = \frac{1}{1+\left(\frac{x-a}{b-a}\right)^2}
\end{align*}
2.2.1 Increasing Linear Membership Function

The graph in Figure 1 can be formulated as follows.

\[ \mu(x, a, b) = \begin{cases} 
0, & \text{if } x \leq a \\
\frac{x-a}{b-a}, & \text{if } a \leq x \leq b \\
1, & \text{if } x \geq b 
\end{cases} \]

![Figure 1. Graph of Membership Function of Increasing Linear](image)

2.2.2 Decreasing Linear Membership Function

The graph in Figure 2 can be defined as follows.

\[ \mu(x, a, b) = \begin{cases} 
0, & \text{if } x \leq a \\
\frac{b-x}{b-a}, & \text{if } a \leq x \leq b \\
1, & \text{if } x \geq b 
\end{cases} \]

![Figure 2. Graph of Membership Function of Decreasing Linear](image)

2.3 Fuzzy Implications

In this research, we use Mamdani minimum implication. This Mamdani minimum implication is formulated as follows.

\[ \alpha = \mu_{A \rightarrow B}(x, y) = \min \{\mu_A(x), \mu_B(y)\} \]

2.4 Singleton Fuzzifier

The mapping of real number \( x^* \in U \) to fuzzy singleton \( A' \subseteq U \) whose its degree of membership is 1 and 0 for others in \( U \) called singleton fuzzifier. The function is described as follows [16].

\[ \mu_{A'}(x) = \begin{cases} 
1, & \text{if } x = x^* \\
0, & \text{otherwise} 
\end{cases} \]

2.5 Fuzzy Inference Engine

Fuzzy inference engine used in this research is the minimum inference. The minimum implication inference is defined in the following pattern [16].

\[ \mu_{B'}(y) = \max_{i=1}^{M} \left[ \sup_{x \in U} \min \left( \mu_{A_1'}(x), \ldots, \mu_{A_n'}(x), \mu_{B_1'}(x) \right) \right] \]
### 2.6 Fuzzy System Design

The flowchart of steps carried out in the research is described in the following chart.

**Figure 3.** The Flowchart of Mamdani Max-Min Method

### 3. Result and Discussion

This research used secondary data of direct and transit lines. There are 93 data of direct line from Yogyakarta to Jakarta. There are 21 data of transit line from Yogyakarta to Medan. The selection criteria are ticket prices, facility and travel time. Table 1 shows the airline types of direct line and its criteria [21].

From Table 1, the criteria can be made where the price of the universal set of ticket price is [0 3,000,000], that of facility is [0 60], and that of travel time is [0 300].

#### Table 1. Data of Direct Flight from Yogyakarta to Jakarta

| Type of Airline | Ticket Price (P) (Rupiah) | Travel Time (T) (Minute) | Facility (F) (Score) |
|-----------------|---------------------------|--------------------------|---------------------|
| 1               | Lion - Lion               | 1,431,800                | 135                 | 0                   |
| 2               | Lion - Citilink           | 1,688,500                | 135                 | 15                  |
| 3               | Lion – Batik Air          | 1,688,600                | 130                 | 30                  |
| ...             | ...                       | ...                      | ...                 | ...                 |
| 93              | Garuda - Garuda           | 2,385,600                | 165                 | 60                  |

#### 3.1. Direct Line from Yogyakarta to Jakarta (Round Trip)

The membership functions for input variables are formulated as follows.

#### 3.1.1. Input

1. Ticket Prices

   The membership function of acceptability of ticket price, $\mu_P$, is stated as follows.
\[ \mu_P(x) = \begin{cases} 
1 & ; 0 \leq x \leq 1,200,000 \\
\frac{2,500,000 - x}{1,300,000} & ; 1,200,000 \leq x \leq 2,500,000 \\
0 & ; x \geq 2,500,000 
\end{cases} \]

2. Facility

The membership function of acceptability of facility, \( \mu_F \), is stated as follows.

\[ \mu_F(x) = \begin{cases} 
0 & ; 0 \leq x \leq 30 \\
\frac{x - 30}{25} & ; 30 \leq x \leq 55 \\
1 & ; x \geq 55 
\end{cases} \]

3. Travel Time

The membership function of acceptability of travel time, \( \mu_T \), is stated as follows.

\[ \mu_T(x) = \begin{cases} 
1 & ; 0 \leq x \leq 130 \\
\frac{200 - x}{70} & ; 130 \leq x \leq 200 \\
0 & ; x \leq 200 
\end{cases} \]

Based on the formula of membership function degree, the decision making to choose the direct type line uses the following steps.

1. Calculate the degree of each membership by using formula that has been made and the implications.

| Type of Airline       | Ticket Price | Time | Facility | \( \alpha \) |
|-----------------------|--------------|------|----------|-------------|
| 1  Lion – Lion         | 0.821        | 0.9  | 0        | 0           |
| 2  Lion – Citilink    | 0.624        | 0.9  | 0        | 0           |
| 3  Lion – Batik Air   | 0.624        | 1    | 0        | 0           |
| \cdots                | \cdots       | \cdots | \cdots   | \cdots     |
| 93 Garuda – Garuda    | 0.088        | 0.5  | 1        | 0.088       |
2. Determine the minimum implications of the membership degree with each criterion. If there are consumers who want to buy an airline ticket, it is recommended to follow rule.

\[ Q_{MM}(x,y) = \min [\mu(x), \mu(y)] \]

The results of selecting other types of airlines are presented in Table 3.

| Type of Airline    | Min |
|-------------------|-----|
| 1 Lion – Lion     | 0   |
| 2 Lion – Citilink | 0   |
| 3 Lion – Batik Air| 0   |
| ⋮                 | ⋮   |
| 93 Batik Air – Garuda | 0.088 |

3. Determine the fuzzy inference system to determine the recommended types of airlines by using the following formula:

\[ \mu_{B'}(y) = \max_{i=1}^{M} \left[ \sup_{x \in U} \min \left( \mu_{A'_1}(x), …, \mu_{A'_n}(x) \right), \mu_{B'_i}(x) \right] \]

Based on this formula, the recommendations for the airline types have met the criteria: ticket prices, facility and travel time obtained sequentially as presented in Table 4.

| Type of Airline                          | Fire Strength |
|-----------------------------------------|---------------|
| 1 Batik Air – Garuda (Round Trip)       | 0.76          |
| 2 Garuda – Batik Air (Round Trip)       | 0.7           |
| 3 Garuda – Sriwijaya (Round Trip)       | 0.68          |

4. Choose the airline types based on fire strength shown in Table 4.
   1) The first alternative is Batik Air - Garuda (Round Trip) airline type with a fire strength value is 0.76. The ticket price is IDR 1,501,200, facility score is 60 and travel time is around 140 minutes.
   2) The third alternative is the type of Garuda - Sriwijaya (Round Trip) airline with a fire strength value is 0.68. The ticket price is IDR 1,611,700, facility score is 60 and travel time is around 150 minutes.

3.2. Transit Line from Yogyakarta to Medan (Round Trip)

The membership functions for input variables are defined as follows.

3.2.1. Input
   1. Ticket Price
      The membership function of acceptability of ticket price, \( \mu_{PP} \), is stated as follows.
      \[ \mu_{PP}(x) = \begin{cases} 
      1, & 0 \leq x \leq 6,000.000 \\
      1,000.000 - x, & 6,000.000 \leq x \leq 7,000.000 \\
      0, & x \geq 7,000.000 
      \end{cases} \]

   2. Facility
      The membership function of acceptability of facility, \( \mu_{FF} \), is stated as follows.
$\mu_{FF}(x) = \begin{cases} 
0, & 0 \leq x \leq 40 \\
\frac{x - 40}{20}, & 40 \leq x \leq 60 \\
1, & x \geq 60 
\end{cases}$

Figure 8. Membership Function of Acceptability of Facility for Transit Line

3. Travel Time

The membership function of acceptability of travel time, $\mu_{TT}$, is stated as follows.

$\mu_{TT}(x) = \begin{cases} 
1; & 0 \leq x \leq 550 \\
\frac{950 - x}{400}; & 550 \leq x \leq 950 \\
0; & x \leq 950 
\end{cases}$

Figure 9. Membership Function of Acceptability of Travel Time for Transit Line

By using same method, the transit line research is obtained from Table 5.

Table 5. Recommendation for Three Types of Transit Airlines

| Type of Airline                      | Fire Strength |
|-------------------------------------|---------------|
| 1 Garuda – Garuda (Round Trip)      | 0.83          |
| 2 Garuda – Garuda (Round Trip)      | 0.8           |
| 3 Garuda – Garuda (Round Trip)      | 0.77          |

Choose the type of airline based on fire strength shown in Table 5.

1) The first alternative is Garuda - Garuda (Round Trip) airline type with a fire strength value is 0.83. The ticket price is IDR 6,169,400, facility score is 60 and the travel time is around 615 minutes.

2) The final alternative is the type of Garuda - Garuda (Round Trip) airline with a fire strength value is 0.77. The ticket price is IDR 6,169,400, facility score is 60 and travel time is around 640 minutes.

4. Conclusions and Suggestions

Based on the results and discussions, it can be concluded in the following points.

1. Direct type ticket from Yogyakarta to Jakarta (Round Trip) which the fire strength value is 0.76 is the best option with ticket price at IDR 1,501,200, facility score is 60, and travel time is 140 minutes.

2. Transit type ticket of Yogyakarta to Medan (Round Trip) with fire strength of 0.83 is the option with ticket price at IDR 6,169,400, facility score is 60, and the travel time is around 615 minutes.

For further research, the selection criteria of direct and transit airplane tickets needs to be added with other influencing factors and the Sugeno or Tsukamoto methods can be used to improve the results.
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