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# COMPARISON OF FUZZY LOGIC METHODS OF MAMDANI AND SUGENO IN DETERMINING THE ELIGIBILITY VALUE OF KIP-KULIAH SCHOLARSHIP RECIPIENTS

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***Abstract***

*The government through the KIP-Kuliah program provides educational assistance to students from underprivileged families who continue their education at university. Although this program aims to increase access to higher education, there are several problems in its implementation, such as inaccuracy in determining the eligibility of scholarship recipients. This study aims to determine and compare the eligibility of KIP-Kuliah scholarship recipients in the UNPATTI Mathematics Study Program using the Fuzzy logic method of Mamdani and Sugeno, which considers factors such as parental dependents, parental income, and diploma grades. The calculation results show that the level of accuracy of the Mamdani method is 75.64% and the Sugeno method is 95.15%. Based on these results, it can be concluded that the Sugeno method provides a better level of accuracy than the Mamdani method in determining the eligibility of KIP-Kuliah scholarship recipients in the UNPATTI Mathematics Study Program.*

***Keywords:*** *Fuzzy Logic, Mamdani, Scholarship, Sugeno.*

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## 1. INTRODUCTION

Fuzzy logic is one of the approaches used in decision support systems (SPK), especially in situations involving uncertainty and ambiguity. This method allows the use of uncertain or unfirm values (Fuzzy) to produce more rational decisions in real cases. In scholarship selection, the application of Fuzzy logic can help overcome uncertainties in the assessment of eligibility, such as family income and academic achievement of students **[1]**. Several methods in Fuzzy logic, such as Mamdani and Sugeno, have been widely applied in various fields, including in the selection and decision-making process **[2]**.

Mamdani's method is known as one of the most common approaches in Fuzzy logic that uses linguistic-based rules. The Mamdani Fuzzy Method is a rule-based method (*Rule-based*) which is most commonly used in Fuzzy Logic applications. This method uses Fuzzy implication and de-fuzzification functions to convert Fuzzy inputs into crisp outputs. In various studies, the Mamdani method is often used in selection systems that require results that are easier to interpret linguistically, such as determining scholarship eligibility **[3]**. This method is often used for decision-making problems that require subjective judgment. Sugeno's method, on the other hand, produces linear or constant output, and is suitable for applications that require simple but effective mathematical models **[4]**. The Sugeno Fuzzy method uses a linear or constant output function, which makes it simpler and easier to implement in systems that require fast calculations. The advantage of the Sugeno method is its ability to handle more complex cases with higher efficiency than Mamdani, especially in automation systems and decision-making based on quantitative data **[5]**. In the context of the selection of KIP-Lecture scholarship recipients, an in-depth evaluation of the Mamdani and Sugeno methods can help in determining the method that best suits the needs and characteristics of the selection data **[6]**. This study aims to compare the two methods in an effort to determine a more effective and efficient method in supporting a fair and accurate selection process, so that scholarships can be targeted and accepted by students in need **[7]**.

## 2. RESEARCH METHODS

### 2.1 Fuzzy Logic, Membership Functions, Fuzzy Inference System, Mamdani and Sugeno Method

Fuzzy logic is a precise way to map an input space into an output space **[8]**. Fuzzy logic has been widely applied in various fields both in industry and business. Fuzzy Set is a membership set of each element does not have a clear boundary. In principle, Fuzzy set is an extension of crisp set. The set that divides a group of individuals into two categories, namely members and non-members. In crisp set, the membership value of an item x in a set A is often written as μ A [x] **[9].**

The membership function is a curve that shows the mapping of input data points at a membership degree that has an interval between 0 and 1. One way that can be used to obtain membership values is through a function approach **[10].**

The Fuzzy inference system can also be called a Fuzzy set solution framework. The inference system has 4 units, namely: **[11]**.

1. Fuzzification unit
2. Fuzzy logic reasoning unit

3. Knowledge base unit
4. Defuzzification unit

In this study, system inference will be used with the Mamdani method. The Fuzzy Mamdani method is often known as the min-max method **[12]**. This method was introduced by Ebrahim Mamdani in 1975. While The Sugeno Fuzzy model was proposed by Takagi, Sugeno, and Kang (Takagi, T. & Sugeno, 1985) in an attempt to establish a systematic approach to generating Fuzzy rules from a given input-output dataset **[13]**.

### 2.2 Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) is a measure of relative error which is formulated as **[14]**.

$$MAPE = \frac{\sum_{t=1}^{n}\left|\frac{y_t - \widehat{y_t}}{y_t}\right| \times 100\%}{n} \quad (1)$$

Based on **Equation (1)** :
$y_t$= Actual Yield Value
$\widehat{y_t}$= Estimated Result Value
$n$= Amount of Data

MAPE is the most commonly used forecasting model accuracy measurement tool. The MAPE value of 10% can be interpreted as the difference between the average forecast value and the actual value is 10%. The smaller the MAPE, the more accurate a model is in forecasting **[15].**

### 2.3 Research Types and Data Sources

The type of research used in this study is included in the quantitative research type, because in this study the calculation elements and research data are in the form of numbers or figures. This research was conducted at the Mathematics Study Program, Pattimura University.

## 3. RESULT AND DISCUSSION

### 3.1 Research Model for Eligibility of KIP-Kuliah Scholarship Recipients

In this section, three important tables are presented related to the research model for eligibility of KIP-Kuliah scholarship recipients, including the universe of conversations for all fuzzy variables, fuzzy sets, and fuzzy rules.

**Table 1. Universe of Conversations for All Fuzzy Variables**

| Function | Variable Name | Universe of Conversations |
|---|---|---|
| *Input* | Number of Dependents of Parents | [1-7] |
| | Parental Income | [0-5,000,000] |
| | Diploma Value | [0-100] |
| *Output* | Eligibility Value | [0-1] |

**Table 2.** Fuzzy Set

| Function | Variables | Fuzzy Set | Universe of Conversations | Domain | Type |
|---|---|---|---|---|---|
| *Input* | Parental Liability | A little | [1-7] | [1-4] | Thanks |
| | | Currently | | [1-7] | Thanks |
| | | Lots | | [4-7] | Thanks |
| | Parental Income | Small | [0-5,000,000] | [0-2,500,000] | Trapmf |
| | | Currently | | [1,500,000-3,500,000] | Thanks |
| | | Big | | [2,500,000-5,000,000] | Trapmf |
| | Diploma Value | Low | [0-100] | [0-80] | Trapmf |
| | | Enough | | [75-85] | Thanks |
| | | Tall | | [80-100] | Trapmf |
| *Output* | Eligibility Value | Not feasible | [0-1] | [0-0.5] | Thanks |
| | | Worthy | | [0.5-1] | Thanks |

**Table 3.** Fuzzy Rules

| *Rules* | Variables | | | |
|---|---|---|---|---|
| | *Input* | | | *Output* |
| | **Parental Liability** | **Parental Income** | **Diploma Value** | **Eligibility Value** |
| R1 | A little | Small | Low | Not feasible |
| R2 | A little | Small | Enough | Worthy |
| R3 | A little | Small | Tall | Worthy |
| R4 | A little | Currently | Low | Not feasible |
| R5 | A little | Currently | Enough | Not feasible |
| R6 | A little | Currently | Tall | Not feasible |
| R7 | A little | Big | Low | Not feasible |
| R8 | A little | Big | Enough | Not feasible |
| R9 | A little | Big | Tall | Not feasible |
| R10 | Currently | Small | Low | Not feasible |
| R11 | Currently | Small | Enough | Worthy |
| R12 | Currently | Small | Tall | Worthy |
| R13 | Currently | Currently | Low | Not feasible |
| R14 | Currently | Currently | Enough | Not feasible |
| R15 | Currently | Currently | Tall | Worthy |
| R16 | Currently | Big | Low | Not feasible |
| R17 | Currently | Big | Enough | Not feasible |
| R18 | Currently | Big | Tall | Not feasible |
| R19 | Lots | Small | Low | Not feasible |
| R20 | Lots | Small | Enough | Worthy |
| R21 | Lots | Small | Tall | Worthy |
| R22 | Lots | Currently | Low | Not feasible |
| R23 | Lots | Currently | Enough | Worthy |
| R24 | Lots | Currently | Tall | Worthy |
| R25 | Lots | Big | Low | Not feasible |
| R26 | Lots | Big | Enough | Not feasible |
| R27 | Lots | Big | Tall | Not feasible |

### 3.2 Fuzzification Process

The next stage is the formation of Fuzzy sets and membership functions. Membership function of Fuzzy sets LITTLE, MEDIUM and MANY of the variable

Parental Dependencies as follows :

$$\mu_{\text{little}}(x) = \begin{cases} 1\,;x \leq 1 \\ \dfrac{4-\text{x}}{4-1}\,;1 \leq x \leq 4 \\ 0\,;x \geq 4 \end{cases}$$

$$\mu_{\text{medium}}(x) = \begin{cases} 0\,;x \leq 1\ atau\ x \geq 7 \\ \dfrac{\text{x}-1}{4-1}\,;1 \leq x \leq 4 \\ \dfrac{7-x}{7-4}\,;4 \leq x \leq 7 \end{cases}$$

$$\mu_{\text{many}}(x) = \begin{cases} 0\,;x \leq 4 \\ \dfrac{\text{x}-4}{7-4}\,;4 \leq x \leq 7 \\ 1\,;x \geq 7 \end{cases}$$

Parental Income input is selected to create a more detailed membership function, namely for the SMALL, MEDIUM and LARGE membership functions have a range of [0 – 5,000,000] as follows :

$$\mu_{\text{small}}(x) = \begin{cases} 1\,;x \leq 1.500.000 \\ \dfrac{2.500.000-\text{x}}{2.500.000-1.500.000}\,;1.500.000 \leq x \leq 2.500.000 \\ 0\,;x \geq 2.500.000 \end{cases}$$

$$\mu_{\text{medium}}(x) = \begin{cases} 0\,;x \leq 1.500.000\ atau\ x \geq 3.500.000 \\ \dfrac{x-1.500.000}{3.500.000-1.500.000}\,;1.500.000 \leq x \leq 2.500.000 \\ \dfrac{3.500.000-x}{3.500.000-2.500.000}\,;2.500.000 \leq x \leq 3.500.000 \end{cases}$$

$$\mu_{\text{large}}(x) = \begin{cases} 0\,;x \leq 2.500.000 \\ \dfrac{\text{x}-2.500.000}{3.500.000-2.500.000}\,;2.500.000 \leq x \leq 3.500.000 \\ 1\,;x \geq 3.500.000 \end{cases}$$

Membership function of Fuzzy set LOW, ENOUGH and HIGH of Diploma Grade variable as follows :

$$\mu_{\text{low}}(x) = \begin{cases} 1\,;x \leq 70 \\ \dfrac{80-\text{x}}{80-70}\,;70 \leq x \leq 80 \\ 0\,;x \geq 80 \end{cases}$$

$$\mu_{\text{enough}}(x) = \begin{cases} 0\,;x \leq 75\ atau\ x \geq 85 \\ \dfrac{\text{x}-75}{75-70}\,;75 \leq x \leq 80 \\ \dfrac{85-x}{85-80}\,;80 \leq x \leq 85 \end{cases}$$

$$\mu_{\text{high}}(x) = \begin{cases} 0\,;x \leq 70 \\ \dfrac{\text{x}-80}{85-80}\,;80 \leq x \leq 85 \\ 1\,;x \geq 85 \end{cases}$$

Furthermore, the membership function of the fuzzy sets NOT FAIR and FAIR of the Feasibility Value variable is formulated as follows.

$$\mu_{\text{not fair}}(x) = \begin{cases} 1 \,; x \leq 0 \\ \dfrac{0{,}5 - \mathrm{x}}{0{,}5 - 0} \,; 0 \leq x \leq 0{,}5 \\ 0 \,; x \geq 0{,}5 \end{cases}$$

$$\mu_{\text{fair}}(x) = \begin{cases} 0 \,; x \leq 75 \\ \dfrac{\mathrm{x} - 0{,}5}{0{,}5 - 0} \,; 0{,}5 \leq x \leq 1 \\ 1 \,; x \geq 1 \end{cases}$$

### 3.3 Comparison of Fuzzy Logic Methods of Mamdani and Sugeno in Determining The Eligibility Value of KIP-Kuliah Scholarship Recipients

After processing the data using the Mamdani method and the Sugeno method in Matlab, the results (output) can be obtained as presented in Table 4 below:

**Table 4. Feasibility Value Based on Input and Output of Mamdani and Sugeno Methods**

| No | Parental Liability | Parental Income | Diploma Value | Eligibility Value (Actual) | Mamdani Method | Sugeno Method |
|---|---|---|---|---|---|---|
| **Class of 2021** | | | | | | |
| 1 | 3 | 500,000 | 86.82 | 1 | 0.822 | 1 |
| 2 | 5 | 2,000,000 | 89.48 | 1 | 0.808 | 1 |
| 3 | 2 | 900,000 | 89.9 | 1 | 0.822 | 1 |
| 4 | 2 | 500,000 | 90.13 | 1 | 0.822 | 1 |
| 5 | 4 | 3,000,000 | 88.5 | 1 | 0.5 | 0.75 |
| 6 | 3 | 2,800,000 | 82 | 0.5 | 0.575 | 0.558 |
| 7 | 4 | 1,000,000 | 91.14 | 1 | 0.837 | 1 |
| 8 | 2 | 2,750,000 | 86.46 | 1 | 0.417 | 0.625 |
| 9 | 2 | 2,800,000 | 90.69 | 0.5 | 0.413 | 0.617 |
| 10 | 6 | 2,750,000 | 88 | 1 | 0.623 | 0.875 |
| 11 | 6 | 500,000 | 80.6 | 1 | 0.822 | 1 |
| **Class of 2022** | | | | | | |
| 12 | 4 | 500,000 | 90.31 | 1 | 0.837 | 1 |
| 13 | 1 | 1,750,000 | 86.57 | 0.5 | 0.622 | 0.875 |
| 14 | 2 | 500,000 | 85.6 | 0.5 | 0.814 | 1 |
| 15 | 2 | 2,500,000 | 87.46 | 0.5 | 0.413 | 0.667 |
| 16 | 2 | 500,000 | 83.8 | 0.5 | 0.796 | 1 |
| 17 | 3 | 700,000 | 88.58 | 1 | 0.822 | 1 |
| 18 | 3 | 5,000,000 | 80.66 | 0.5 | 0.178 | 0.5 |
| 19 | 5 | 500,000 | 83.29 | 1 | 0.792 | 1 |
| 20 | 3 | 2,500,000 | 92.41 | 1 | 0.587 | 0.833 |
| 21 | 5 | 1,000,000 | 91.77 | 1 | 0.822 | 1 |
| **Class of 2023** | | | | | | |
| 22 | 3 | 750,000 | 83.43 | 1 | 0.792 | 1 |
| 23 | 2 | 500,000 | 86.79 | 0.5 | 0.822 | 1 |
| 24 | 4 | 400,000 | 85 | 1 | 0.808 | 1 |
| 25 | 6 | 500,000 | 87.27 | 1 | 0.822 | 0.85 |
| 26 | 6 | 2,800,000 | 90 | 1 | 0.6 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 27 | 4 | 750,000 | 90 | 1 | 0.837 | 1 |
| 28 | 4 | 500,000 | 85.05 | 1 | 0.809 | 1 |
| 29 | 3 | 500,000 | 86 | 1 | 0.817 | 1 |
| 30 | 3 | 550,000 | 87.8 | 1 | 0.822 | 1 |
| 31 | 7 | 2,500,000 | 92.55 | 0.5 | 0.837 | 1 |

From the results of the application of the Fuzzy logic method of Mamdani and Sugeno, the results of the comparison of the eligibility value of the KIP-Kuliah scholarship recipients with the Fuzzy logic assessment of the Mamdani and Sugeno method in the UNPATTI Mathematics Study Program using the average percentage or Mean Absolute Percentage Error (MAPE) so that the calculation results are obtained as follows:

- MAPE in Mamdani method

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y_t}}{y_t} \times 100\% \right|}{n}$$
$$= \frac{5{,}36}{22} \times 100\% = 24{,}36\%$$

The level of truth = 100% − 24.36% = 75.64%

- MAPE in Sugeno method

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{y_t - \hat{y_t}}{y_t} \times 100\% \right|}{n}$$
$$= \frac{1{,}067}{22} \times 100\% = 4{,}85\%$$

The level of truth = 100% − 4.85% = 95.15%

So it can be concluded that the Fuzzy inference system, the Sugeno method is more accurate, because the percentage error value is smaller than the Mamdani method, so it can be used to determine the eligibility value of KIP-Kuliah scholarship recipients in the UNPATTI Mathematics Study Program.

The results of this study indicate that the Sugeno fuzzy inference method has a higher level of accuracy compared to the Mamdani method in determining the eligibility of KIP-Kuliah scholarship recipients in the Mathematics Department at UNPATTI, with a MAPE value of 4.85% and an accuracy rate of 95.15%. These findings are in line with the study by **[13]**, which applied the Sugeno method in the selection of Bidikmisi scholarship recipients and found that this method excels in terms of decision-making efficiency and speed. Meanwhile, the study by **[14]**, which compared both methods, concluded that Sugeno outperforms in computational efficiency, although Mamdani is better at handling subjective variables. This research also complements the findings of **[15]**, who demonstrated that the Mamdani method is effective in handling ambiguous scholarship criteria and provides accurate decisions. Therefore, the results of this study reinforce the understanding that the choice of fuzzy method should be aligned with the characteristics of the data and the goals of the system. In the context of assessing scholarship eligibility based on numerical data and requiring high efficiency, as in this study, the Sugeno method proves to be more appropriate.

## 4. CONCLUSION

Based on the results of determining the eligibility value of KIP-Kuliah scholarship recipients using the Mamdani and Sugeno Fuzzy logic methods based on data from Students of the 2021, 2022, and 2023 classes of the UNPATTI Mathematics Study Program, it can be concluded that the Sugeno method Fuzzy inference system is more accurate, because the percentage error value is smaller than the Mamdani method, so it can be used to determine the eligibility value of KIP-Kuliah scholarship recipients in the UNPATTI Mathematics Study Program.

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