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Application of Fuzzy Mamdani Method to Predict the Number of Blood Bags Based on Demand and Supply Data Using Matlab

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Abstract

Fuzzy logic is a control system technique in solving problems and is applied to systems, from basic systems to difficult or complex systems. Fuzzy logic is the proper method to plan an input space into an output space using MATLAB's mathematical theory of fuzzy sets. The reason for using fuzzy logic is because it is related to uncertainty. The unstable demand for blood bags in hospitals makes the supply of blood bags excessive or lacking from demand. The lack of blood supply results in the unfulfilled demand for blood needed by the hospital, while the excess blood supply worsens the quality of blood. In this study, we will predict the number of bags produced using the Mamdani Fuzzy Inference System (FIS) method based on the minimum demand and maximum demand values and the minimum supply and maximum supply that produce output from the defuzzification process. Applying the Mamdani Fuzzy Inference System (FIS) method based on demand and supply data obtains optimal output with MATLAB in predicting the number of blood bags produced. The results of the study showed that the Mean Absolute Percentage Error (MAPE) fuzzy logic Mamdani error value was 24%, the accuracy value of the Fuzzy Inference System (FIS) Mamdani in determining the number of blood bag production was 76%, and the production output generated through the Fuzzy Inference System (FIS) Mamdani was 4,774 blood bags. The number of blood requests at the hospital is 4,443 blood bags, so the amount of blood that must be produced to meet the hospital's demand is 4,774 bags.

Keywords: *PMI Lhokseumawe City, Fuzzy Logic, Mamdani Method, Demand, Supply.*

1. Introduction

Fuzzy Logic "Fuzzy Set" was proposed by Prof. Lotfi Zadeh in 1965.[1]. Fuzzy logic is a control system technique for solving problems and is applied to systems ranging from basic systems to difficult or complex systems [2][3]. This analysis can be applied to hardware, software, or both. Fuzzy logic is a precise way to plan an input space into an output space using the mathematical theory of fuzzy sets with the help of MATLAB Software [4]. MATLAB Toolbox has 5 Graphical User Interface (GUI) tools used for training in matrix theory, linear algebra, and numerical analysis in the fields of signal processing, control systems, fuzzy logic, numerical networks, optimization, image processing, and other simulations [5][6]. One of the advantages of fuzzy logic theory is its ability to process reasoning in language [7]. The reason for using fuzzy logic is because it deals with uncertainty and helps humans in decision-making [8][9]. A fuzzy inference system is a data processing process in the form of crisp input [10][11]. In data processing, there are several steps in the fuzzy system to obtain data in the form of crisp output [12]. The Fuzzy Inference System has three methods: Mamdani, Sugeno, and Tsukamoto [10]. The Mamdani method of fuzzy inference system is also called the Max-Min method [13][14]. This method uses fuzzy rules based on membership functions and the limitations of each fuzzy set in determining the output, where the output produced from the defuzzification process uses the centroid method [15][16]. This method was discovered by Ebrahim H. Mamdani in 1975 [17][18][19].

The availability and distribution of blood supply in hospitals is essential as a health service to the community for hospital patients who need it. Unstable demand causes the supply of blood bags to be excessive or lacking from demand. If it continues to occur repeatedly, the lack of blood bag supply can result in the hospital's blood bag needs not being met. Excessive blood bag supply can result in blood quality getting worse and unhealthy, which then must be destroyed because it has expired. The significant demand for blood is influenced by infections or diseases experienced by patients, such as anemia, dengue fever, and other diseases, and high demand occurs during Islamic Eid, Christmas, and New Year celebrations [20][21][22].

This study will discuss the prediction of the number of blood bag production using the Fuzzy Mamdani method based on the minimum and maximum demand and supply values that produce output from the defuzzification process using the centroid method. By applying the Mamdani fuzzy method, it is expected that the output produced with the help of MATLAB Toolbox software can help predict the number of blood bag production.

2. Research Methods

The fuzzy logic calculation of the Mamdani method has several stages. First, a fuzzy set (fuzzyfication) is formed, determining the universe of discourse and domain derived from input and output variables' minimum and maximum value data to determine the membership function and curve image. Second, forming fuzzy rules based on input variables (demand and supply) and output variables (production). Formation of fuzzy rules by analyzing all data based on the limitations of each fuzzy set obtained from each variable.
The calculation of Mamdani fuzzy logic in the MATLAB program uses 5 Graphical User Interface (GUI) tools to build, edit, and observe fuzzy reasoning systems. First is the Fuzzy Inference System (FIS) Editor, which is the initial step to form input and output variables. Second, the Membership Function Editor forms each variable membership function: demand, supply, and production. Third, the Rule Editor will form the arrangement or grouping of all fuzzy rules based on the fuzzy regulations created as a solution or opportunity for the possibility to occur. Fourth, Rule Viewer is a form of application of the amount of input demand and supply data to produce output. Fifth, Surface Viewer depicts a graph of the reasoning results between input and output variables.
Calculation of Mamdani's fuzzy Percentage Error (PEt), namely the calculation of the percentage of error value based on the actual production value and the predicted output value of MATLAB results. The calculation of the Percentage Error (PEt) uses the following equation:

PEt = ………………………………………………… (1)

$$\left(\frac{At-Ft}{At}\right) x\ 100\%$$

Comparison of the results of Mamdani fuzzy calculations and Percentage Error Calculations can be made by calculating the Mean Absolute Percentage Error (MAPE) to obtain the error value results. Second, accuracy in receiving the truth value of the Mamdani Fuzzy Inference System (FIS). The calculation of the Mean Absolute Percentage Error (MAPE) uses the following equation:

MAPE = ………………………………………………… (2)

$$\frac{1}{n}\sum_{t=1}^{n}\left(\frac{At-Ft}{At}\right) x\ 100\%$$

Meanwhile, the accuracy calculation uses the following equation:

Akurasi = 100% - ………………………………………………… (3)

$$\frac{1}{n}\sum_{t=1}^{n}\left(\frac{At-Ft}{At}\right) x\ 100\%$$

3. Results and Discussion

3.1. Blood Bag Demand, Supply and Production Data

The data on demand, supply, and production of blood bags for April 2023 to April 2024 are shown in Table 1.

Table 1. Data on Demand, Supply, and Production of Blood Bags

Year	Month	Demand (Bag)	Inventory (Bag)	Production (Bag)
2023	April	372	313	313
	May	333	321	284
	June	333	315	283
	July	384	484	304
	August	172	173	172
	September	329	317	317
	October	331	381	331
	November	361	254	355
	December	380	403	379
2024	January	409	382	389
	February	373	231	330
	March	353	244	303
	April	313	139	209
Total		**4443**	**3957**	**3969**

3.2. Fuzzy Logic Calculation Mamdani Method

3.2.1. Forming Fuzzy Sets (Fuzzyfication)

The input variables are divided into two fuzzy sets, namely the demand and supply of blood bags, and the fuzzy set of output variables is the production of blood bags. The values of the universe of discussion on the input and output variables are in Table 2. The maximum and minimum values of the input variables and output variables can be seen in Table 3, and the limits of the fuzzy set values of the input variables and output variables are in Table 4.

Table 2. Fuzzy Variable Universal Set

Function	Variable	Universal Set
Input	Demand	[172-409]
	Inventory	[139-484]
Output	Production	[172-389]

Table 3. Maximum and Minimum Values of Output and Input Variables

Function	Variable	Domain
Input	Demand	[172-409]
	Inventory	[139-484]
Output	Production	[172-389]

Table 4. Boundary Values for the Set of Fuzzy Input Variables and Output Variables

Function	Variable	Fuzzy Set	Range
Input	Demand (x)	Low	[172-251]
		Medium	[252-331]
		High	[332-409]
	Inventory (y)	Low	[139-254]
		Medium	[255-370]
		High	[371-484]
Output	Production (z)	Low	[172-244]
		Medium	[245-317]
		High	[318-389]

Based on Table 4, the form of the membership function for the demand variable, supply variable, and production variable is as follows:

1. Demand Variables

$$\mu_{Low} = \begin{cases} 1 & ; \quad x \leq 251 \\ \frac{331-x}{331-251} & ; \quad 251 < x < 331 \\ 0 & ; \quad x \geq 331 \end{cases}$$

$$\mu_{Medium} = \begin{cases} 0 & ; \quad x \leq 251 \text{ or } x \geq 409 \\ \frac{x-251}{331-251} & ; \quad 251 < x \leq 331 \\ \frac{409-x}{409-331} & ; \quad 331 < x < 409 \end{cases}$$

$$\mu_{High} = \begin{cases} 0 & ; \quad x \leq 331 \\ \frac{x-331}{409-331} & ; \quad 331 < x < 409 \\ 1 & ; \quad x \geq 409 \end{cases}$$

The representation of the curve shape based on the membership function on the fuzzy set demand variable is shown in Figure 1.

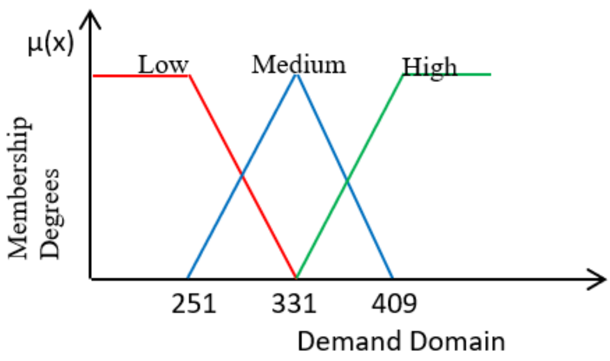

Fig 1. Fuzzy Set Demand Variable

Based on Figure 1, the domain value of the fuzzy set demand variable in the category is slightly between the red line with a domain value of [172-251], and the highest degree of membership (μ(x) = 1) is between x≤251. The medium category is between the blue line with a domain value of [252-331], and the highest degree of membership (μ(x) = 1) is 331. The many categories are between the green line with a domain value of [332-409], and the highest degree of membership (μ(x) = 1) is between x≥409

2. Inventory Variables

μ_{Low} =

$$\begin{cases} 1 & ; \quad y \le 254 \\ \frac{370-y}{370-254} & ; \quad 254 < y < 370 \\ 0 & ; \quad y > 370 \end{cases}$$

μ_{Medium} =

$$\begin{cases} 0 & ; \quad y \le 254 \ or \ y \ge 484 \\ \frac{y-254}{370-254} & ; \quad 254 < y \le 370 \\ \frac{484-y}{484-370} & ; \quad 370 < y < 484 \end{cases}$$

μ_{High} = s

$$\begin{cases} 0 & ; \quad y \le 370 \\ \frac{y-370}{484-370} & ; \quad 370 < y < 484 \\ 1 & ; \quad y > 484 \end{cases}$$

The representation of the curve shape based on the membership function of the fuzzy set inventory variable is shown in Figure 2.

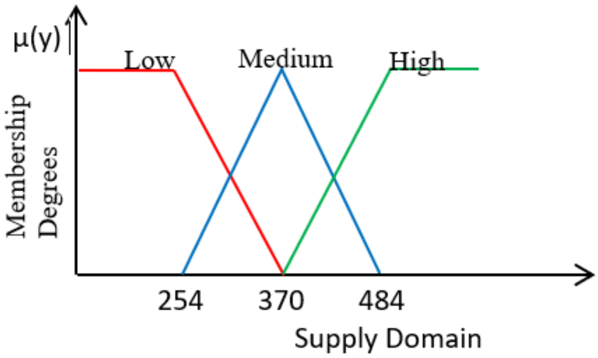

Fig 2. Fuzzy Set Inventory Variable

Based on Figure 2, the domain value of the fuzzy set inventory variable in the category is slightly between the red line with a domain value of [139-254], and the highest degree of membership (μ(x) = 1) is between x≤254. The medium category is between the blue line with a domain value of [255-370], and the highest degree of membership (μ(x) = 1) is 370. The large category is between the green line with a domain value of [371-484], and the highest degree of membership (μ(x) = 1) is between x≥484

3. Production Variables

μ_{Low} =

$$\begin{cases} 1 & ; \quad z \le 244 \\ \frac{317-z}{317-244} & ; \quad 244 < z < 317 \\ 0 & ; \quad z > 317 \end{cases}$$

μ_{Medium} =

$$\begin{cases} 0 & ; \quad z \le 244 \ or \ z \ge 389 \\ \frac{z-244}{317-244} & ; \quad 244 < z \le 317 \\ \frac{389-z}{389-317} & ; \quad 317 < z < 389 \end{cases}$$

$$\mu_{High} = \begin{cases} 0 & ; \quad z \leq 317 \\ \frac{z-317}{389-317} & ; \quad 317 < z < 389 \\ 1 & ; \quad z \geq 389 \end{cases}$$

The representation of the curve shape based on the fuzzy set membership function on the production variable is shown in Figure 3.

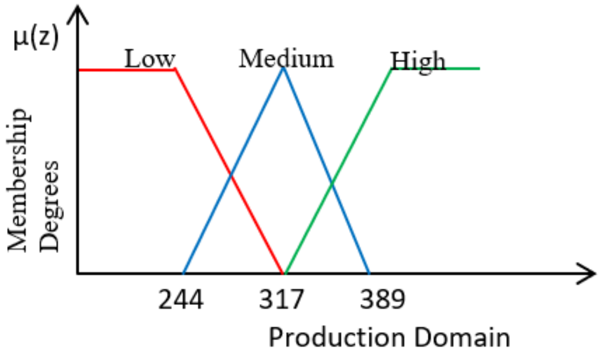

Fig 3. Fuzzy Set Production Variables

Based on Figure 3, the value of the fuzzy set production variable domain in the category is a little between the red line with a domain value of [172-244], and the highest degree of membership (μ(x) = 1) is between x≤244. The medium category is between the blue line with a domain value of [245-317], and the highest degree of membership (μ(x) = 1) is 317. The many categories are between the green line with a domain value of [318-389], and the highest degree of membership (μ(x) = 1) is between x≥389.

3.2.2. Forming Fuzzy Rules (Application of Implication Function)

The fuzzy rules are 〖IF〗 ^(x_1) 〖 is〗 ^(A_1) AND ….. AND x_n 〖 is〗 ^(A_n) THEN y is B or IF Demand is … AND Supply is … THEN Production is ….. The fuzzy rules can be formed from 2 variables, namely input and output, with three fuzzy sets, namely the categories of little, medium, and many, which is 32 = 9 rules.

3.3. MATLAB R2019a Programming On Mamdani Fuzzy Logic Calculation

The software programming in this study uses MATLAB to calculate the number of blood bag production each month based on the data on the number of requests and the data on the number of supplies, especially at the defuzzification stage. The 5 GUI tools that can be used to build, edit, and observe the fuzzy reasoning system are as follows:

1. Fuzzy Inference System (FIS) Editor
   The formation of input and output variables can be seen in Figure 4.

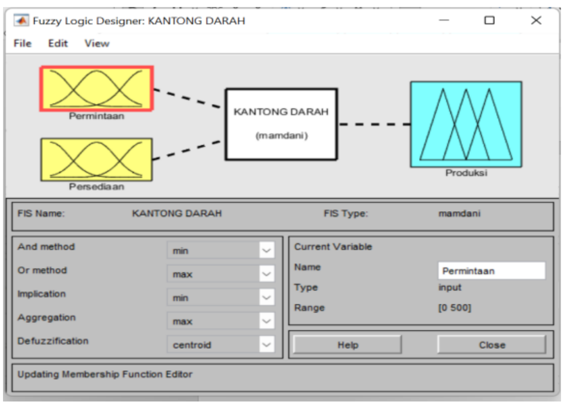

Fig 4. Forming Input Variables and Output Variables

Based on Figure 4, two input variables are on the left in yellow, and the output variables are on the right in blue. The Mamdani Fuzzy Inference System (FIS) process is in the middle of the white.

2. Membership Function Editor
   The membership function of the request variable is shown in Figure 5.

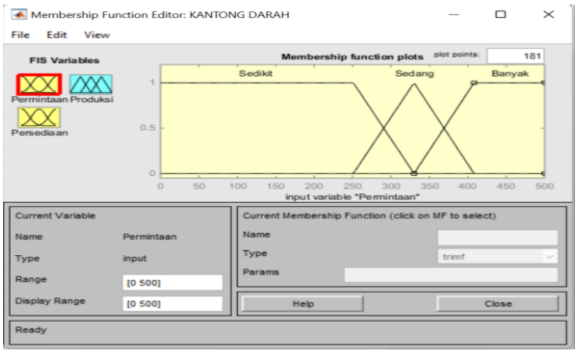

Fig 5. Membership Function of Demand Variable

Based on Figure 5, the demand input variable forms a membership function in the small, medium, and large categories with a range value of [172-409] marked in the red box on the left. The membership function of the inventory variable is shown in Figure 6.

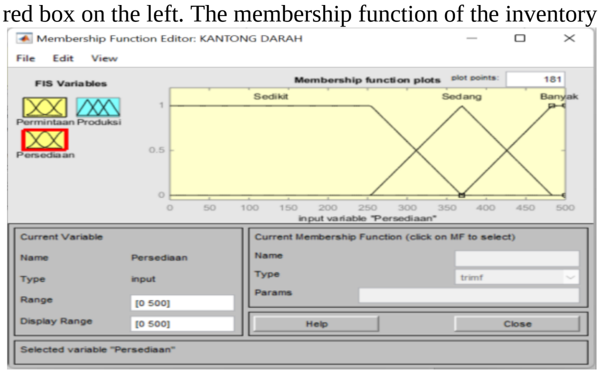

Fig 6. Membership Function of Inventory Variable

Based on Figure 6, the inventory input variable forms a membership function in the small, medium, and large categories with a range value of [139-484] marked in the red box on the left. The membership function of the production variable is shown in Figure 7.

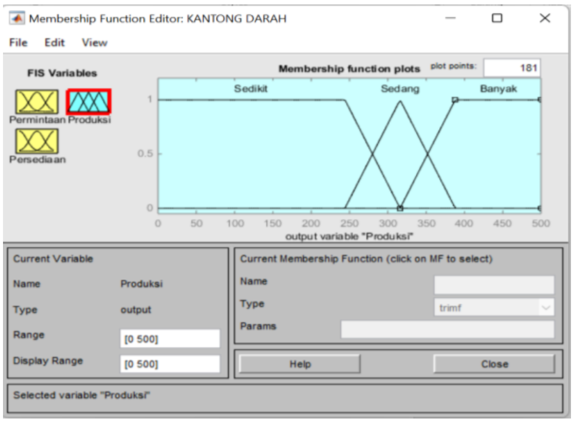

Fig 7. Membership Function of Production Variables

Based on Figure 7, the production input variables form membership functions in the small category, medium category, and many categories with range values [172-389] marked in the red box on the left.

3. Rule Editor

   The Rule Base that can be formed is shown in Figure 8.

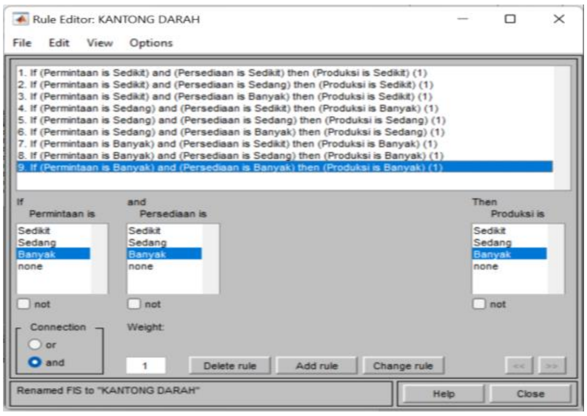

Fig 8. Fuzzy Rules

Based on Figure 8, fuzzy rules (rule base) are rules based on fuzzy logic that is collected to unify the situation of the state, which is then combined with all input and output variables for each fuzzy set in the few categories, medium categories and many categories that produce fuzzy set domain values. In addition, with the display of fuzzy inference diagrams, Rule bases can be combined using a rule viewer with each rule in the rule base processing input variables to obtain output variable results.

4. Rule Viewer
   The defuzzification results in April 2023 are in Figure 9

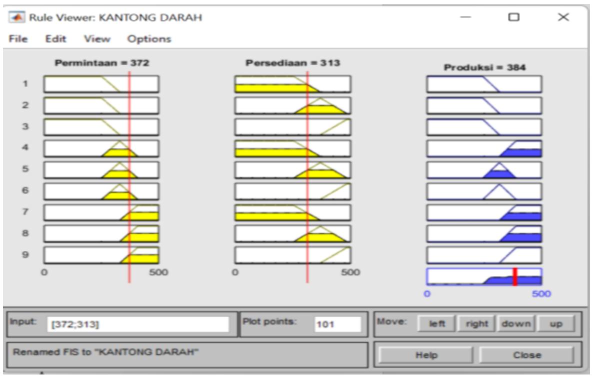

Fig 9. Rule Viewer for April

Based on Figure 9, the number of requests is 372, and the number of supplies is 313, so the number of blood bags that must be produced is 384. The thin vertical line in red in the input variable section shows the value of the fuzzy set for each fuzzy rule. However, the thick, straight line in red in the production section shows the defuzzification value of the value entered as the value of each input variable for demand and supply.

5. Surface Viewer
   The three-dimensional variable distribution display is shown in Figure 10.

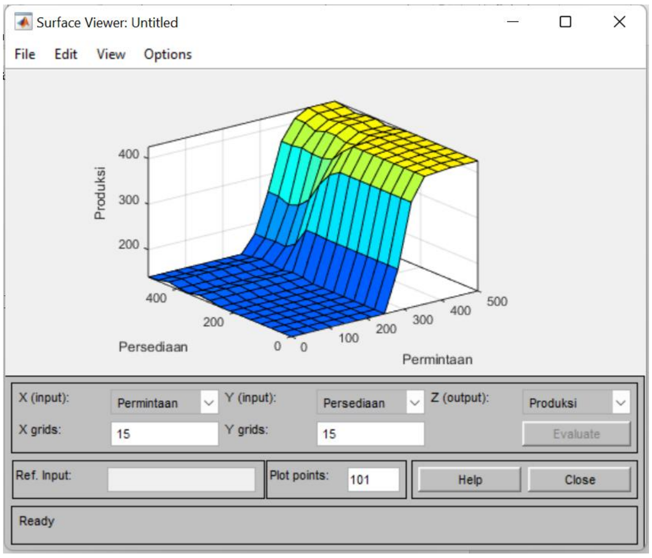

Fig 10. Surface Viewer

3.4. Calculation of Percentage Error (PEt) Fuzzy Mamdani

The calculation of Percentage Error (PEt) is a calculation of the percentage of error value based on the actual value of blood bag production (At) and the predicted value or forecast of blood bags (Ft). The calculation of Percentage Error (PEt) uses the following equation.

PEt =

$$\left(\frac{At - Ft}{At}\right) x\ 100\%$$

=

$$\left(\frac{313 - 384}{313}\right) x\ 100\%$$

= 22.68371%

The recapitulation of the results of the Percentage Error (PEt) calculations is in Table 5.

Table 5. Calculation of Percentage Error (PEt) Fuzzy Mamdani

Month	**Actual Production (At)**	**Mamdani Fuzzy Production (Ft)**	***Error***	***Error Absolut Value***	***Error Percentages (PEt) (%)***
April	313	384	-71	71	22.68371
May	284	374	-90	90	31.69014
June	283	379	-96	96	33.92226
July	304	400	-96	96	31.57895
August	172	140	32	32	18.60465
September	317	371	-54	54	17.0347
October	331	319	12	12	3.625378
November	355	420	-65	65	18.30986
December	379	395	-16	16	4.221636
January	389	424	-35	35	8.997429
February	330	419	-89	89	26.9697
March	303	421	-118	118	38.94389
April	209	328	-119	119	56.9378
Total	**3969**	**4774**	**-805**	**893**	**313.5201**

3.5. Comparing Mamdani Fuzzy Results and Calculating Percentage Error

The recapitulation of the results of the prediction of the number of blood bag production and the calculation of the Percentage Error (PEt) are in Table 6.

Table 6. Recapitulation of the Results of Defuzzification of Blood Bag Production and Calculating the Percentage Error (PEt)

Month	**(t)**	**Demand**	**Inventory**	**Production**	**Mamdani**	***Error***	***Percentages Error***

				(At)	**Method Production (Ft)**	***Absolut Value***	***(PEt)* (%)**
April	1	372	313	313	384	71	22.68371
Mei	2	333	321	284	374	90	31.69014
June	3	333	315	283	379	96	33.92226
July	4	384	484	304	400	96	31.57895
August	5	172	173	172	140	32	18.60465
September	6	329	317	317	371	54	17.0347
October	7	331	381	331	319	12	3.625378
November	8	361	254	355	420	65	18.30986
December	9	380	403	379	395	16	4.221636
January	10	409	382	389	424	35	8.997429
February	11	373	231	330	419	89	26.9697
March	12	353	244	303	421	118	38.94389
April	13	313	139	209	328	119	56.9378
Total		**4443**	**3957**	**3969**	**4774**	**893**	**313.5201**

The following equation is used to calculate the Mean Absolute Percentage Error (MAPE) to obtain the error value results.
MAPE =

$$\frac{1}{n}\sum_{t=1}^{n}\left(\frac{At-Ft}{At}\right) x\ 100\%$$

=

$$\frac{1}{13}\ x\ 313{,}5201\%$$

= 24.1169%
≈ 24%

Based on the calculation results, the average percentage error of Mamdani fuzzy logic's Mean Absolute Percentage Error (MAPE) is 24%. Mamdani uses the following equation to calculate the truth value or accuracy of the fuzzy inference system (FIS).

Akurasi = 100% -

$$\frac{1}{n}\sum_{t=1}^{n}\left(\frac{At-Ft}{At}\right) x\ 100\%$$

= 100% - 24.1169%
= 75.8831%
≈ 76%

Based on the calculation results, the accuracy value of the application of the Mamdani Fuzzy Inference System (FIS) is 76%. So, the Mamdani Fuzzy Inference System (FIS) method can be used to determine the amount of blood bag production based on demand and supply data.

4. Conclusion

Based on the results of the research conducted by the author, it can be concluded that the application of the Fuzzy Inference System (FIS) Mamdani method obtained calculation results with a Mean Absolute Percentage Error (MAPE) fuzzy logic Mamdani method error value of 24% and the accuracy value of the Fuzzy Inference System (FIS) Mamdani to obtain blood bag production results is 76% and the production output produced through the Fuzzy Inference System (FIS) Mamdani using MATLAB R2019a software obtained predicted results for the number of blood bags produced as many as 4,774 blood bags. Therefore, as a blood production unit, the Blood Donor Unit can use the Fuzzy Inference System (FIS) Mamdani method with the help of MATLAB software to calculate blood bag production.

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