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FUZZY MAMDANI FORECASTING OF BLOOD BAG SUPPLY AT INDONESIAN RED CROSS BLOOD IN DELI SERDANG REGENCY UNIT

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An increase in population will cause an increase in the amount of processed blood reserves. Therefore, it is necessary to forecast the amount of production within a certain period of time to see the number of blood bags that may be needed in order to meet demand correctly and in the appropriate amount. The method used is Mamdani fuzzy with data sourced from the Indonesian Red Cross Blood Unit Deli Serdang Regency from January 2019 to January 2020. This study shows that the Mamdani District fuzzy method can be implemented for forecasting the production of blood bags in January and February 2020.

1. INTRODUCTION

Blood transfusion service is a health service effort that includes planning, mobilizing and preserving blood donors, providing blood, distributing blood, and giving blood to patients for the purpose of healing disease and restoring health [1]. As much as 2.5% of the population in an area is the ideal percentage of processed blood reserves [2]. So that the increase in population will cause an increase in the need for processed blood reserves. Quoting from the Central Bureau of Statistics of Deli Serdang, Deli Serdang Regency has a population of around 1,931,441 people in the 2020 population census [3].

Inventory management is an activity related to planning, implementing and supervising the determination of material requirements so that operational requirements can be met on time and inventory can be suppressed optimally [4]. Inventory control aims to keep the existing inventory or stock at an optimal level so that inventory costs are minimal [5]. Demand forecasting is the level of product demand that is expected to be realized in the future through testing past conditions [6].

Fuzzy logic is a scientific theory known as Max-Min. This theory was first introduced by Ebrahim Mamdani in 1975. *Fuzzy* Mandani started from making *fuzzy* sets, designing rules which are often known as rules or other terms. The application of the implication function that becomes the benchmark for decision making, management composition, and defuzzification [7]. *Fuzzy* rules are built through the Mamdani type "IF/THEN" conditional statement [8]. Fuzzy is a type of reasoning that is intended to mathematically represent uncertainty and obscurity in which a logical statement is neither true nor false [9]. The difference between boolean logic and *fuzzy* logic is that the boolean logic result is 0 or 1 (true or false) [10], the *fuzzy* logic result is between 0 and 1 [11].

Several previous related studies that examined a similar case, namely DL Rahakbauw, "*Application of the Fuzzy Mamdani Method to Predict the Amount of Rubber Production (Case Study: Data on Supply and Demand for Rubber Production at PTP Nusantara XIV (Persero) Awaya Plantation, Elpaputih Bay, Maluku-Indonesia)* examined the amount of rubber inventory using the fuzzy mamdani method and the percentage of truth value obtained is 87.82706%, which means that it is close to very good in determining the amount of rubber production at PTP Nusantara XIV (Persero) Kebun Awaya/Teluk Elpaputih [12].

2. METHOD

Sample Data

The data collected in this study includes data on demand, supply, and production in the period from January to December 2019. The results of the categorization are converted into values that are

proportional to the domain values, then converted into membership values [13]. The data can be seen in tables 1 and 2.

Table 1. Data On Demand, Production And Supply Of O And A Blood Bags

Month	Amount Pocket Blood					
	O			A		
	Request	Production	Supply	Request	Production	Supply
January	292	271	21	139	194	55
February	93	242	149	100	112	12
March	409	398	12	222	158	64
April	446	450	4	248	208	40
May	158	211	53	94	115	21
June	225	195	30	148	93	55
July	345	329	16	173	230	57
August	572	491	81	340	367	27
September	500	439	61	247	261	14
October	412	437	25	178	265	87
November	437	441	4	233	163	70
December	339	392	53	209	374	165
Amount	4228	4296	509	2331	2540	667

Table 2. Data On Demand, Production And Supply Of B And AB Blood Bags

Month	Amount Pocket Blood					
	B			AB		
	Request	Production	Supply	Request	Production	Supply
January	198	204	6	58	75	17
February	144	190	46	34	59	25
March	243	271	28	78	83	5
April	262	266	4	90	69	21
May	104	193	89	29	47	18
June	181	143	38	50	61	11
July	235	210	25	48	97	49
August	336	340	151	98	112	14
September	278	183	95	89	75	14
October	258	381	123	70	63	7
November	300	248	52	70	81	11
December	259	365	106	88	82	6
Amount	2798	2994	763	802	904	198

Procedure steps

To get the output required 4 stages, namely [14]:

1. Formation of *fuzzy sets*

   In the *Fuzzy* Mamdani method, both input and output variables are divided into one or more *fuzzy sets* . Data processing is done by determining the data variables of the universe of conversation, followed by forming a fuzzy set. Fuzzification is defined as input that changes the actual truth value (crips input) into fuzzy input, in the form of linguistic values based on membership functions [15].

   There are 3 fuzzy variables being modeled namely:

Request : consists of 2 fuzzy sets, namely low and high
Inventory : consists of 2 fuzzy sets, namely few and many
Production : consists of 2 fuzzy sets, namely less and more

2. Implication function application rules
Inference is the process of translating fuzzy statements into mathematical logic [16], reasoning using fuzzy input and fuzzy *r*ules to produce fuzzy output [17]. In the Fuzzy Mamdani method, the implication function used is min [18].

$$min\left(\mu_{sf}(x_i), \mu_{kf}(x_i)\right)$$

3. Composition of rules
To combine the output values use the Max. The Max function can generate a new fuzzy set by taking the maximum value to modify the fuzzy [19].

$$\max\left(\mu_{sf}(x_i), \mu_{kf}(x_i)\right)$$

4. Defuzzification
The defuzzification process is a mathematical operation performed on the resulting form of the membership function [20]. The defuzzification technique is the center of area or centroid [21]. In this development the centroid method used to calculate the crisp value by selecting the center point of the fuzzy area [22], [26].

3. RESULT AND DISCUSSION

The completion of the manual calculation process using the Mamdani Fuzzy Logic Application which has 4 stapes, namely:

Step 1: Determine the related variables in the process to be determined and the appropriate fuzzification function [23].

In this case there are 3 variables to be modeled, namely:

a) The demand variable (x) (Pmt), consists of 2 *fuzzy sets,* namely HIGH and LOW. Based on the largest and smallest demand data in 2020, the membership function is formulated as follows:
Blood Type O, Pouch Request:

$$\mu_{Pmt\ LOW}(x) = \begin{cases} 1 & ; \quad x < 93 \\ \dfrac{572 - x}{572 - 93} & ;93 \le x \le 572 \\ 0 & ; \quad x > 572 \end{cases}$$

$$\mu_{Pmt\ HIGH}(x) = \begin{cases} 0 & ; \quad x < 93 \\ \dfrac{x - 93}{572 - 93} & ;93 \le x \le 572 \\ 1 & ; \quad x > 572 \end{cases}$$

If it is known that the demand in January 2021 is 297 sacks, then:

$$\mu_{PmtLOW}(297) = \frac{572 - x}{479} = \frac{572 - 297}{479} = \frac{275}{479} = 0{,}574$$

$$\mu_{Pmt\ HIGH}(297) = \frac{x - 93}{479} = \frac{297 - 93}{479} = \frac{186}{479} = 0{,}425$$

b) Inventory variable (y) (Psd), consists of 2 *fuzzy sets* , namely LITTLE, and MANY. Based on the largest and smallest inventory data in 2020, the membership function is formulated as follows:
Blood Type O, Pouch Supplies:

$$\mu_{Psd\ LITTLE}(y) = \begin{cases} 1 & ; \quad y < 4 \\ \dfrac{149 - y}{149 - 4} & ;4 \le y \le 149 \\ 0 & ; \quad y > 149 \end{cases}$$

$$\mu_{Psd\ LOTS}(z) = \begin{cases} 0 & ; \quad y < 4 \\ \dfrac{y-4}{149-4} & ;4 \le y \le 149 \\ 1 & ; \quad y > 149 \end{cases}$$

If it is known that the inventory for January 2021 is 116 sacks, then:

$$\mu_{Psd\ LITTLE}(116) = \frac{149-y}{149-4} = \frac{149-116}{145} = \frac{33}{145} = 0{,}227$$

$$\mu_{Psd\ LOTS}(116) = \frac{y-4}{149-4} = \frac{116-4}{145} = \frac{186}{479} = 0{,}772$$

c) The production variable (z)(Prd), consists of 2 *fuzzy sets* , namely LESS and MORE. Based on the largest and smallest production data in 2020, the membership function is formulated as follows:

Production Blood Type O Pouch:

$$\mu_{Prd\ LESS}(z) = \begin{cases} 1 & ; \quad z < 195 \\ \dfrac{491-z}{491-195} & ;195 \le z \le 491 \\ 0 & ; \quad z > 491 \end{cases}$$

$$\mu_{Prd\ MORE}(z) = \begin{cases} 1 & ; \quad z < 195 \\ \dfrac{z-195}{491-195} & ;195 \le z \le 491 \\ 0 & ; \quad z > 491 \end{cases}$$

Step 2: Application of the implication function

After determining the membership function of the variables, fuzzy logic rules are formed. Based on the existing data, the following rules can be formed. The rule used is the MIN rule on the implication function:

Type O blood bag

[$R1$] IF demand is LOW, and supply is LOTS, then the production of blood bags is LESS

$$\propto -predikat_1 = \left(\mu_{Pmt\ LOW}(297), \mu_{Psd\ LOTS}(116)\right)$$
$$= \min(0{,}574\ ; 0{,}772) = 0{,}574$$

[*R2*] IF demand is LOW, and supply is LITTLE, then the production of blood bags is LESS

$$\propto -predikat_2 = \left(\mu_{Pmt\ LOW}(297), \mu_{Psd\ LITTLE}(116)\right)$$
$$= \min(0{,}574\ ; 0{,}227) = 0{,}227$$

[$R3$] IF demand is HIGH, and supply is LOTS, then produce MORE blood bags

$$\propto -predikat_3 = \left(\mu_{PmtHIGH}(297), \mu_{PsdLOTS}(116)\right)$$
$$= \min(0{,}425\ ; 0{,}772) = 0{,}425$$

[$R4$] IF demand is HIGH, and supply is LITTLE, then produce MORE blood bags

$$\propto -predikat_4 = \left(\mu_{PmtHIGH}(297), \mu_{PSD\ LITTLE}(116)\right)$$
$$= \min(0{,}425\ ; 0{,}227) = 0{,}227$$

Step 3: Composition between rules

Application of the function of each rule, the Max method is used to perform the composition between all the rules. To determine the value of z*, it is done by dividing the area into 3 parts with each area, namely $A_1, A_2\ dan\ A_3$. Then it will look for the value of a_1 and a_2.

$$\frac{z-195}{491-195} = 0{,}425 \Rightarrow z = (0{,}425 \times 296) + 195 = 320{,}8$$

$$\frac{z-195}{491-195} = 0{,}574 \Rightarrow z = (0{,}574 \times 296) + 195 = 364{,}9$$

Thus the membership function obtained for the results of this composition is:

$$\mu(z) = \begin{cases} 0{,}425 & ; \quad z < 320{,}8 \\ \dfrac{z - 195}{491 - 195} & ; 320{,}8 \le z \le 364{,}9 \\ 0{,}574 & ; \quad x > 364{,}9 \end{cases}$$

Step 4: Defuzzification

The last step in fuzzy defuzyfication is to calculate the results of the research results [24]. For that, the first step that must be done is to calculate the moment for each area.

$$M_1 = \int_0^{320{,}8} 0{,}425z\, dz = M_1 = \frac{0{,}425\, z^2}{2} = 0{,}2125x320{,}8^2 = 21868{,}936$$

$$M_2 = \frac{z^3}{3x296} - \frac{195\, z^2}{2x296}\Big|_{320{,}8}^{364{,}9}$$

$$= \left(\frac{364{,}9^3}{888} - \frac{195x364{,}9^2}{592}\right) - \left(\frac{320{,}8^3}{888} - \frac{195x320{,}8^2}{592}\right)$$

$$= \left(\frac{48587168{,}45}{888} - \frac{25964641{,}95}{592}\right) - \left(\frac{33014374{,}91}{888} - \frac{20067964{,}8}{592}\right)$$

$$= (54715{,}2797 - 43859{,}1924) - (37178{,}3501 - 33898{,}5891)$$

$$= 10856{,}0873 - 3279{,}761 = 7576{,}3263$$

$$M_3 = \frac{0{,}574z^2}{2}\Big|_{364{,}9}^{491}$$

$$= 0{,}287 \times 491^2 - 0{,}287x364{,}9^2$$

$$= 69190{,}247 - 38214{,}626 = 30975{,}621$$

$$A_1 = 320{,}8\,.\,0{,}425 = 136{,}34$$

$$A_2 = 0{,}425 + 0{,}574\frac{\alpha_2 - \alpha_1}{2}$$

$$A_2 = 0{,}425 + 0{,}574\frac{364{,}9 - 320{,}8}{2}$$

$$A_2 = 0{,}999x22{,}05 = 22{,}027$$

$$A_3 = (491 - 364{,}9)\, 0{,}574 \; A_3 = 126{,}1\,.\,0{,}574$$

$$A_3 = 72{,}3814$$

$$Z = \frac{M_1 + M_2 + M_3}{A_1 + A_2 + A_3} Z$$

$$= \frac{21868{,}936 + 7576{,}3263 + 30975{,}621}{136{,}34 + 22{,}027 + 72{,}3814}$$

$$Z = \frac{60421{,}8833}{230{,}7484} = 261{,}8517 \approx 262$$

So from the Mamdani fuzzy application on the results of the manual calculation of blood type O with a demand of 297 bags and a supply of 116 bags, the total production to be produced in January 2019 is 262 bags. With the same steps, in February 2019 with a demand for 402 sacks and a supply of 129 sacks, the total production to be produced in January 2019 was 232 sacks.

Step 5: Calculation of *Mean Precentage Error (MPE)*

After the testing process is carried out, then the correctness of the test is calculated using the Mamdani fuzzy logic method. At the calculation stage, the truth value uses the mean percent error value known as the Mean Percentage Error (MPE) [25]. In performing calculations using *Mean Precentage Error (MPE),* production data from Indonesian Red Cross Deli Serdang Regency is used , $\alpha_t$while production data $\tilde{\alpha}_t$is based on *fuzzy* Mamdani. The calculation results can be seen in table 3.

Table 3. Calculation of MPE

No	Month	α_t (production)	$\tilde{\alpha}_t$ (fuzzy)	Error	$\left\lvert\frac{(\alpha_t - \tilde{\alpha}_t)}{\alpha_t}\right\rvert \times 100\%$
1	19-Jan	271	262	9	3.32103

2	19-Feb	242	232	10	4.13223
		MPE			3.72663

Based on the test results for forecasting blood bag production with Mamdani *fuzzy logic* in January and February 2022, it can be seen that the data that meets the demand with a percentage value of 96.2733%. With the average percentage error of the Mamdani method is 3.72663 %. Therefore, the truth level of Mamdani *fuzzy calculation* is 96.2733%. So it can be concluded that the application of the Mamdani *fuzzy method* can be used to predict the supply of blood bags that must be predicted by Indonesian Red Cross Deli Serdang Regency.

Using the same steps, we can get results for forecasting blood types A, B, and AB in January and February 2020.

Table 4. Forecasting Results of the Number of Blood Bags in January 2020

Month	Variable	Blood Bag			
		O	A	B	AB
Jan-2020	Request	297	74	248	63
	Supply	116	146	142	44
	Production	262	126	177	56

Table 5. Results of Forecasting the Number of Blood Bags in February 2020.

Month	Variable	Blood Bag			
		O	A	B	AB
Feb-2020	Request	402	223	267	77
	Supply	129	117	122	29
	Production	232	163	229	58

4. CONCLUSION

The application of fuzzy logic with fuzzy Mamdani is effectively applied in predicting the number of blood bags per month to help Indonesian Red Cross Deli Serdang Regency minimize the possibility of a shortage or excess of blood bags with an average percentage error of the Mamdani method of 3.72663%. Based on the results of calculating the amount of blood bag production using the *Fuzzy* Mamdani method, when compared with the manual method, the results will be more accurate if using other applications such as Matlab for further research.

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