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## IMPLEMENTATION OF THE *FUZZY TIME SERIES* METHOD FOR FORECASTING BLOOD NEEDS IN THE INDONESIAN RED CROSS (PMI) MEDAN

Rina Syafiddini Harahap<sup>1</sup>, Rakhmat Kurniawa R<sup>2</sup>

Universitas Islam Negeri Sumatera Utara

Email: : [rina0701202164@uinsu.ac.id](mailto:rina0701202164@uinsu.ac.id)<sup>1</sup>, [rakhmat.kr@uinsu.ac.id](mailto:rakhmat.kr@uinsu.ac.id)<sup>2</sup>

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### Abstract

The primary issue faced by PMI (Indonesian Red Cross) in relation to blood requirements is often associated with insufficient blood supplies to satisfy the demand of patients, particularly during emergencies or significant catastrophes such as natural calamities. Hence, it is essential to use appropriate methodologies in order to forecast blood requirements accurately and determine the quantity of blood bags required in the future. When doing forecasting calculations using fuzzy time series, the interval length is established at the start of the calculation procedure. The duration of the gap significantly affects the establishment of fuzzy associations, which in turn affects the difference in forecast computation outcomes. The investigation reveals that Group AB has the lowest Root Mean Square Error (RMSE) value of 136.90, indicating that your model demonstrates superior accuracy in predicting blood group AB in comparison to other blood groups. The RMSE score for Group O is 819.5, which suggests that your model's accuracy in predicting blood group O is lower compared to other blood groups.

**Keywords:** *PMI; Fuzzy Time Series, RMSE*

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\*Corresponding Author: Author1

### 1. INTRODUCTION

The Indonesian Red Cross, often known as PMI, is a philanthropic organisation. PMI is dedicated to provide blood donor services. The community is supplied with services swiftly and correctly, following organisational values. The organisation is known as the International Red Cross and Red Crescent. PMI regularly engages in the activity of blood donation. Blood donation is a means of rendering assistance to the community. The purpose of this action is to gather nutritious blood, therefore assisting populations in need. The citation is from Yunizar Ritonga et al. in 2023. The Indonesian Red Cross (PMI) is a national organisation in Indonesia that operates in the fields of humanitarian aid and healthcare. PMI has always adhered to fundamental ideals for the International Red Cross and Red Crescent Movement, including humanism, equality, voluntarism, independence, unity, neutrality, and independence. Currently, PMI operates a total of 33 PMI Regional branches at the

province level and around 408 PMI Branch branches at the city/district level across Indonesia. The Indonesian Red Cross does not endorse or support any certain political faction, racial group, tribe, or religious conviction. PMI does not differentiate, but rather gives priority to victims who need emergency aid for the preservation of their lives. Thus, PMI must accurately define the specific tasks that it has been assigned, such as maintaining blood transfusions, providing education and training, fostering intergenerational care for humanity, enhancing preparedness for natural disasters, and more. (Suherman, 2017). Blood is a vital component of the human body, originating from the substances that individuals ingest on a daily basis. Blood is a circulating fluid consisting of plasma, as well as red and white blood cells, which travel through the blood arteries of humans and animals. The PMI Assembly is an impartial and autonomous humanitarian organisation created with the objective of mitigating the distress of fellow individuals, irrespective of their religious, national, tribal,

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linguistic, racial, gender, group, and political affiliations. PMI City of Medan is a division of PMI that has a UTD (Blood Transfusion Unit). One of its functions is to collect blood from donors for subsequent donation to those in need, after undergoing thorough scrutiny and testing to ensure it is free from infectious illnesses (Puspitasari et al., 2022). Due to the high demand for blood in various medical settings such as hospitals, clinics, and maternity wards, it is necessary for UTDs to provide four different blood types: A, B, AB, and O. These blood types are required by individuals for surgical procedures and other medical uses. PMI's blood requirements are mostly hindered by inadequate blood reserves to satisfy the needs of patients, particularly during emergencies or significant catastrophes like natural disasters. PMI has a significant problem in consistently promoting blood donation to increase public awareness of its relevance.

2

2

2

Fuzzy logic is capable of interpreting mathematical computations to articulate uncertainties or vagueness in the form of language variables. The concept may be seen as an extension of the traditional assembly theory, integrating both qualitative and quantitative methodologies. (Nasution & Prakarsa, 2020). Fuzzy logic is a notion that extends Boolean logic by including partial truth values. This reasoning has an ambiguous value that falls somewhere in the middle of the spectrum between good and wrong, as well as black and white. Fuzzy logic is very valuable for resolving situations that include a certain level of ambiguity. When striving to achieve a certain objective, the issue at hand serves as the foundation for decision-making. This involves selecting among numerous offered choices for resolving the problem, in order to successfully and efficiently accomplish the desired aim. (Furqan et al., 2020). Chen (1996) proposed the notion of fuzzy time series, which utilises fuzzy sets of real numbers for data in the prediction process. The primary distinction between fuzzy time series (FST) and conventional time series is in the nature of the data used. The FST uses fuzzy sets created from real numbers to represent values, which are associated with pre-defined universe sets (Istiqara et al., 2018). The fuzzy time series (FST) is a prediction approach that use fuzzy sets as the foundation for its calculating procedure. This approach employs a prognostic system that discerns patterns from past data in order to forecast future data. The Fuzzy Time Series is a data prediction tool that is based on fuzzy concepts. In simple terms, a fuzzy set may be defined as a group of integers that have imprecise bounds. (Muhammad et al., 2021).

Interval lengths are established at the start of the calculation procedure in fuzzy time series prediction calculations. The choice of the interval length greatly influences the creation of fuzzy associations, which in turn affects the differences in predictive computations. Hence, in order to ensure precision, it is necessary to accurately construct the fuzzy connection, which entails determining the

appropriate lengths of intervals. An approach for calculating the duration of an effective interval is the average-based fuzzy time series technique. The citation is from Elfajar et al., 2017. The PMI City of Medan operates a Blood Transfusion Unit (UTD) that collects blood from donors and redistributes it to those in need. Nevertheless, the need for blood is sometimes linked to inadequate reserves, particularly in times of emergency or significant catastrophes. PMI should persist in promoting blood donation and enhancing public awareness of its significance. Fuzzy logic, a notion that extends Boolean logic, is useful for addressing situations that include ambiguity. Fuzzy logic is a valuable tool for problem-solving since it allows for the selection of several options to effectively achieve objectives.

## 2. RESEARCH METHOD

### Research Framework

A research framework is a structure or design used to organize the flow and components related to research as follows.

#### Planning

In this methodology the author conducted research using two techniques, namely quantitative and qualitative. Quantitative techniques involve analyzing historical data and producing numbers in the form of *time series data*. The following planning process clarifies the qualitative and quantitative research stages. The steps taken are as follows:

##### a. Observation

In the context of this research, observation refers to the process of observing and analyzing blood demand data at the Indonesian Red Cross in Medan City. This observation became the basis for applying the *Fuzzy Time Series method* and forecasting blood needs at the Indonesian Red Cross in Medan City. Observation embodies the data collection method used is direct observation at the Indonesian Red Cross in Medan City. The purpose of this observation is to obtain data regarding conditions and sales needed in this research.

##### b. Interview

Interviews are a data collection method used to obtain information related to existing problems. At the same time, to obtain data on blood needs at the Indonesian Red Cross in Medan City. By using this interview technique, the author was able to obtain direct information from related parties at the Indonesian Red Cross in Medan City regarding blood needs, and their views on the implementation of the proposed forecasting method. The author interviewed Mr Yogi, one of the officers at the Indonesian Red Cross in Medan City. Data collected through interviews will be a valuable source of information in this research.

##### c. Sample

Sample refers to a part of the total object that is the focus of research. In this case, the sample consists of receipt data (blood bags), supply data (blood bags), and demand data (blood bags) for blood groups A, B, AB and O per month in the last 5 years to date.

### Needs Analysis

#### a. Data collection technique

Data collection techniques are procedures or methods used to collect relevant and valid information or data for research or other analytical purposes.

#### b. Literature review

In literature study, the author collects and reads scientific publications, journal articles, books and research reports related to the topic under study. Then carry out a critical analysis of the literature, identify relevant findings or arguments, and compare and synthesize the information obtained. Apart from that, information was also collected regarding the *Fuzzy Time Series logic method*.

#### c. Observation

The meaning of observation in this context is the activity of directly observing blood needs activities at the Indonesian Red Cross in Medan City. This observation involves collecting data regarding blood demand patterns, trends, fluctuations, and factors that influence blood demand in PMI. During observations, the *Fuzzy Time Series method* was used to forecast blood needs.

#### d. Interview

Through the communication process interactive between researchers and parties related to Indonesia's Reddest City, Medan, with objective For get relevant information related need blood in the PMI , using Fuzzy Time Series method in the analysis . In context This is an interview done with one PMI officers who have knowledge and experience related need blood .

#### e. Documentation Study

Documentation study is the process of collecting , accessing , and analyzing document or relevant notes with need blood in the PMI , with use Fuzzy Time Series method . In context this , study documentation involve collection as document like reports , historical data or notes from receipt , supply , and demand blood , as well other related documents with activity need blood at PMI Medan City

### Planning

#### a. Forecasting/Prediction (*forecasting*)

Forecasting/prediction (*forecasting*) is an attempt to project or predict what might happen in the future. The forecasting process based on variables connected forecasting with a series of related historical data with request upcoming .

#### b. *Fuzzy Time Series Logic*

this step , the author apply Fuzzy Time Series method for do forecasting / prediction to the data that has been collected at stage previously . This process involve series steps from method *fuzzy time series* developed by Chen:

1. Step 1: Define set universe
2. Step 2: Shaping universe talk (U) for determine universe the conversation use formula
3.  $U = [D_{min} - D1, D_{max} + D2]$   
...( 3.1)
4. Step 3: interval formation is carried out with share range mark talks become a number of segment with uniform length . To determine the number of intervals required, you can use the following formula:  
**Sum of intervals =  $1+3.33 \log(n)$**   
...( 3.2)
5. After the number of intervals is found, the next step is to determine the length of the interval using a formula  
**Intervals length =  $D_{max} - D_{min}$**   
...( 3.3)
6. Step 4: Defining fuzzy sets and fuzzification of historical data
7. Step 5: Determine connection fuzzy logic (FLR) and Groups Fuzzy Logic Relations (FLRG)
8. Step 6: Calculate forecasting / defuzzification.

### Testing

In the context of testing, there are several approaches that can be taken to test the validity and performance of a model or system that uses the *Fuzzy Time Series method* . Testing aims to ensure that the model or system developed can provide accurate and reliable results in different situations.

### Discussion Plan

When determining blood supply, problems often arise due to unpredictable fluctuations in blood demand. This causes PMI to experience problems in supply, with sometimes experiencing a shortage or excess of blood supply at certain times. A shortage of supplies indicates high demand for hospitals or other units, but the blood stock at PMI may be inadequate. On the other hand, an excess of blood supply indicates low demand for blood from hospitals or other units, but the stock at PMI may be more sufficient. This problem is also faced by PMI Medan City.

### Fuzzy Time Series Flowchart

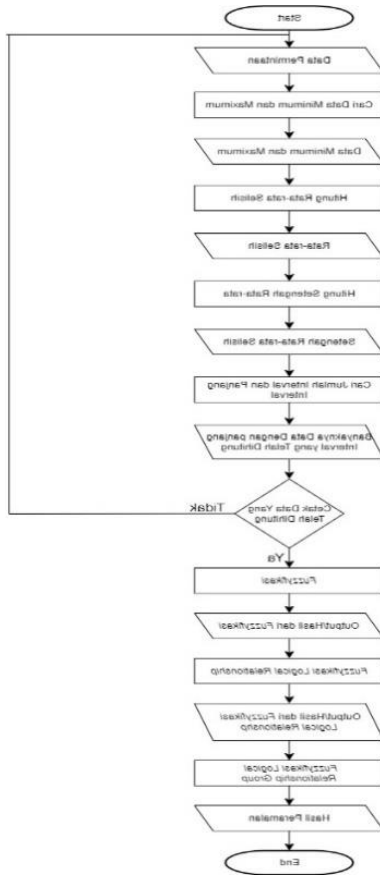


Figure 1 Research Framework

### 3. RESULT AND DISCUSSION

#### Results Analysis Request Data

Table 4. 1 Demand data blood

YEAR	A	B	AB	O
2021	12868	15668	3610	22261
2022	15549	19089	4387	27092
2023	17995	21578	4979	30456

#### Statistics Descriptive

Table 4. 2 Descriptive Statistics						
	N	Minimum	Maximum	Mean	Std. Deviation	Variance
A	3	12868	17995	15470.67	2564.397	6576134.333
B	3	15668	21578	18778.33	2967.223	8804410.333
AB	3	3610	4979	4325.33	686.580	471392.333
O	3	22261	30456	26603.00	4119.326	16968847.000
Valid N (listwise)	3					

Table 4. 2 Descriptive Statistics

#### Fuzzy Time Series Predictions

```
RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
data_permintaan
1 library(dplyr)
2 library(tidyverse)
3
4 # data jumlah permintaan per tahun per golongan darah
5 tahun <- c(2021, 2022, 2023)
6 golongan_A <- c(12868, 15549, 17995)
7 golongan_B <- c(15668, 19089, 21578)
8 golongan_AB <- c(3610, 4387, 4979)
9 golongan_O <- c(22261, 27092, 30456)
10
11 # Mengubah data menjadi data frame
12 data_permintaan <- data.frame(
13   Tahun = tahun,
14   golongan_A = golongan_A,
15   golongan_B = golongan_B,
16   golongan_AB = golongan_AB,
17   golongan_O = golongan_O
18 )
```

	Tahun	Golongan_A	Golongan_B	Golongan_AB	Golongan_O
1	2021	12868	15668	3610	22261
2	2022	15549	19089	4387	27092
3	2023	17995	21578	4979	30456

Figure 4. 1 Calculation of quantity data request per year

#### Creating Fuzzy Intervals

Function This on duty For share range data value becomes some of the same intervals big . This is necessary For set boundaries for every fuzzy categories (e.g. , “ Low ”, “Medium”, “High”).

```
RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
data_permintaan
20 # Membuat interval fuzzy
21 create_intervals <- function(data, n) {
22   min_val <- min(data)
23   max_val <- max(data)
24   interval_size <- (max_val - min_val) / n
25   intervals <- seq(min_val, max_val, by = interval_size)
26   return(intervals)
27 }
28
29 n_intervals <- 5
30
31 intervals_A <- create_intervals(golongan_A, n_intervals)
32 intervals_B <- create_intervals(golongan_B, n_intervals)
33 intervals_AB <- create_intervals(golongan_AB, n_intervals)
34 intervals_O <- create_intervals(golongan_O, n_intervals)
35
36 print(intervals_A)
37 print(intervals_B)
38 print(intervals_AB)
39 print(intervals_O)
40
```

Figure 4. 2 Function For create fuzzy intervals.

Determine number of fuzzy intervals ( n\_intervals ).

The number of fuzzy intervals determines how much detailed the fuzzy category you want to use . For example , 5 intervals can be give category such as “Very Low ”, “ Low ”, “Medium”, “High”, “Very High”. Here We using 5 intervals, Using 5 intervals in fuzzy time series helps identify trends and patterns in time series data with informative way However still

simple . This is possible We For understand How amount donor blood changed from time to time in easy fuzzy categories interpreted .

Calculates fuzzy intervals for every group blood based on data. With use function create\_intervals , us can calculate fuzzy intervals for every group blood based on available data .

```

R4.4.1 ~ /
> intervals_B <- create_intervals(golongan_B, n_intervals)
> intervals_AB <- create_intervals(golongan_AB, n_intervals)
> intervals_O <- create_intervals(golongan_O, n_intervals)
> print(intervals_A)
[1] 12868.0 13893.4 14918.8 15944.2 16969.6 17995.0
> print(intervals_B)
[1] 15668 16850 18032 19214 20396 21578
> print(intervals_AB)
[1] 3610.0 3883.8 4157.6 4431.4 4705.2 4979.0
> print(intervals_O)
[1] 22261 23900 25539 27178 28817 30456
    
```

Figure 4. 3Interval Fuzzy Time Series

a. Determine limit maximum and minimum of request data every group blood group blood , minimum maximum data already There is previously in the descriptive statistics table previously .

BLOOD TYPE	MINIMUM	MAXIMUM
A	12868	17995
B	15668	21578
AB	3610	4979
O	22261	30456

b. Determine interval width

$$lebar\ interval = \frac{batas\ maksimum - batas\ minimum}{jumlah\ interval}$$

- Interval 1: "Very Low "
- Interval 2: " Low "
- Interval 3: "Medium"
- Interval 4: "High"
- Interval 5: "Very High"

BLOOD GROUP A

$$lebar\ interval = \frac{17995 - 12868}{5} = \frac{5127}{5} = 1025,4$$

Group A intervals

- $\mu_1 = [12868.0, 13893.4]$
- $\mu_2 = [13893.4, 14918.8]$
- $\mu_3 = [14918.8, 15944.2]$
- $\mu_4 = [15944.2, 16969.6]$
- $\mu_5 = [16969.6, 17995.0]$

BLOOD GROUP B

$$lebar\ interval = \frac{21578 - 15668}{5} = \frac{5910}{5} = 1182$$

Group B intervals

- $\mu_1 = [15668, 16850]$
- $\mu_2 = [16850, 18032]$
- $\mu_3 = [18032, 19214]$
- $\mu_4 = [19214, 20396]$

$$\mu_5 = [20396, 21578]$$

BLOOD GROUP AB

$$lebar\ interval = \frac{4979 - 3610}{5} = \frac{1369}{5} = 273,8$$

Group AB interval

- $\mu_1 = [3610.0, 3883.8]$
- $\mu_2 = [3883.8, 4157.6]$
- $\mu_3 = [4157.6, 4431.4]$
- $\mu_4 = [4431.4, 4705.2]$
- $\mu_5 = [4705.2, 4979.0]$

BLOOD GROUP AB

$$lebar\ interval = \frac{30456 - 22261}{5} = \frac{8195}{5} = 1639$$

Group O intervals

- $\mu_1 = [22261, 23900]$
- $\mu_2 = [23900, 25539]$
- $\mu_3 = [25539, 27178]$
- $\mu_4 = [27178, 28817]$
- $\mu_5 = [28817, 30456]$

c. Determining Fuzzy Labels

Defines the fuzzy labels that will be used For categorize data. Defining fuzzy labels is very important in fuzzy time series because help in:

```

RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function Addins
RINAR x data_permintaan x
41 # Menentukan label fuzzy
42 fuzzy_labels <- c("Sangat Rendah", "Rendah", "Sedang", "Tinggi", "Sangat Tinggi")
43
44 # Fungsi untuk melakukan fuzzifikasi data
45 fuzzify <- function(value, intervals, labels) {
46   for (i in 1:(length(intervals) - 1)) {
47     if (value >= intervals[i] && value < intervals[i + 1]) {
48       return(labels[i])
49     }
50   }
51   return(labels[length(labels)])
52 }
53
54 # Melakukan fuzzifikasi untuk setiap golongan darah
55 data_permintaan <- data_permintaan %>%
56   mutate(Fuzzy_A = sapply(golongan_A, fuzzify, intervals_A, fuzzy_labels),
57          Fuzzy_B = sapply(golongan_B, fuzzify, intervals_B, fuzzy_labels),
58          Fuzzy_AB = sapply(golongan_AB, fuzzify, intervals_AB, fuzzy_labels),
59          Fuzzy_O = sapply(golongan_O, fuzzify, intervals_O, fuzzy_labels))
60
61 print(data_permintaan)
62
63 # Membuat aturan fuzzy berdasarkan data
64 build_fuzzy_rules <- function(data, fuzzy_col) {
65   rules <- list()
66   for (i in 1:(nrow(data) - 1)) {
67     current_state <- data[[fuzzy_col]][i]
68     next_state <- data[[fuzzy_col]][i + 1]
69     if (!is.null(rules[[current_state]])) {
70       rules[[current_state]] <- c(rules[[current_state]], next_state)
71     } else {
72       rules[[current_state]] <- next_state
73     }
74   }
75   return(rules)
    
```

Figure 4. 4Fuzzy Labels

```

R4.4.1 ~ /
+ mutate(Fuzzy_A = sapply(golongan_A, fuzzify, intervals_A, fuzzy_labels),
+        Fuzzy_B = sapply(golongan_B, fuzzify, intervals_B, fuzzy_labels),
+        Fuzzy_AB = sapply(golongan_AB, fuzzify, intervals_AB, fuzzy_labels),
+        Fuzzy_O = sapply(golongan_O, fuzzify, intervals_O, fuzzy_labels))
> print(data_permintaan)
Tahun golongan_A golongan_B golongan_AB golongan_O Fuzzy_A Fuzzy_B
1 2021 12868 15668 3610 22261 Sangat Rendah Sangat Rendah
2 2022 15549 19089 4387 27092 Sedang Sedang
3 2023 17995 21578 4979 30456 Sangat Tinggi Sangat Tinggi
Fuzzy_AB Fuzzy_O
1 Sangat Rendah Sangat Rendah
2 Sedang Sedang
3 Sangat Tinggi Sangat Tinggi
    
```

Figure 4. 5Fuzzy Label Interval for request data

Conversion every data value to in fuzzy form based on predefined intervals determined:

- Blood Type A:**

- Year 2021 (12868): Located in the interval 1 → "Very Low "
- Year 2022 ( 15549 ): Located in interval 3 → "Medium"
- Year 2023 ( 17995 ): Located in interval 5 → "Very High"
- **Blood Type B:**
  - Year 2021 ( 15668 ): Located in the interval 1 → "Very Low "
  - Year 2022 ( 19089 ): Located in interval 3 → "Medium"
  - Year 2023 ( 21578 ): Located in interval 5 → "Very High"
- **Blood Type AB:**
  - Year 2021 ( 3610 ): Located in the interval 1 → "Very Low "
  - Year 2022 ( 4387 ): Located in interval 3 → "Medium"
  - Year 2023 ( 4979 ): Located in interval 5 → "Very High"
- **Blood Type O:**
  - Year 2021 ( 22261 ): Located in the interval 1 → "Very Low "
  - Year 2022 ( 27092 ): Located in interval 3 → "Medium"
  - Year 2023 ( 30456 ): Located in interval 5 → "Very High"

**Table 4. 3**Fuzzy Label Intervals for request data

YE AR	A	B	AB	O
2021	12868 VERY LOW	15668 VERY LOW	3610 VERY LOW	22261 VERY LOW
2022	15549 CURRENTLY	19089 CURRENTLY	4387 CURRENTLY	27092 CURRENTLY
2023	17995 VERY HIGH	21578 VERY HIGH	4979 VERY HIGH	30456 VERY HIGH

d. **Make Data -Driven Fuzzy Rules**  
Make fuzzy rules based transition between fuzzy categories in data. Make fuzzy rules based transition between Fuzzy categories in data work For catch temporal patterns in time series data. These fuzzy rules Then used For predict future value based on past fuzzy categories .

e. **Do Prediction Based on Fuzzy Rules**  
Make function For predict next fuzzy category based on fuzzy rules have been made . After identifying all the fuzzy relationships, group these relationships into fuzzy relationship groups (FLRG) to simplify predictions.

Blood type	FLRG
------------	------

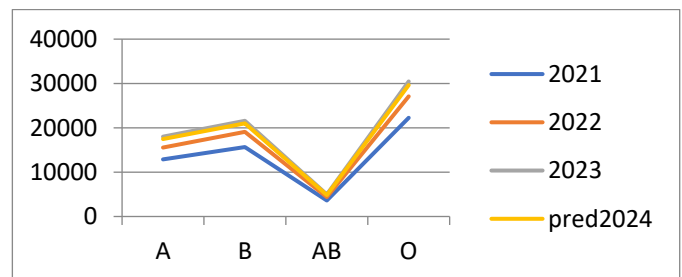
Author, et. al, Title Written Times ... 6

A	FLRG 1 : Very Low → Medium
	FLRG 2 : Medium → Very High
B	FLRG 1 : Very Low → Medium
	FLRG 2 : Medium → Very High
AB	FLRG 1 : Very Low → Medium
	FLRG 2 : Medium → Very High
O	FLRG 1 : Very Low → Medium

f. **Do Prediction For Year Next**  
Use function predictions For estimate fuzzy number categories donor For year next . Based on the results, it is predicted that in 2024 the number of blood requests will be in the very high category for all blood types, namely A, B, AB, O

**S Table 4. 4**Prediction Results group blood

Group blood	2024 Predictions	Category
A	17,482	Very high
B	20,987	Very high
AB	4,842	Very high
O	29,637	Very high



Based on results predictions that in 2024 the number request every group blood experience decline from year previously i.e. 2023 though still in very high category

g. **Count Accuracy**  
Count accuracy predictions For every group blood and display it .

**Table 4. 5**Accuracy table predictions with RMSE

BLOOD TYPE	MSE	MAE	MAPE
A	7365796	2714	15%
B	8014561	2831	13%
AB	443556	666	13%
O	14799409	3.847	12%

h. **Results Analysis**

- Type AB has a MAE and MSE that brake arrived doslnys bids , a large MSE , and a moderate

MAPE , indicating predictions Enough accurate However There is variation is a must noticed .

- Type -O has more MAPE high , as well as more MAPE big , shows that predictions For group low O blood accurate compared to others.

Based on the research results, it can be concluded that:

Prediction results amount request blood in 2024

Group blood	2024 Predictions	Category
A	17,482	Very high
B	20,987	Very high
AB	4,842	Very high
O	29,637	Very high

1. Group AB has the lowest RMSE value that is 136.90 , shows that your model is more accurate in predict group AB blood is compared with group blood other .

2. Group O has the highest RMSE value that is 819.5 , shows that your model is lacking accurate in predict group O blood compared with group blood other .

The PMI is able to provide data in less time to facilitate the implementation of deposits in the blood demand data so that the PMI can have more effective blood demand calculation data against its predictions.

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