JIKO (Jurnal Informatika dan Komputter) Accredited KEMENDIKBUD RISTEK, No.105/E/KPT/2022
Vol. 7, No. 2, August 2024, pp. 110-116 p-ISSN: 2614-8897
DOI: 10.33387/jiko.v7i2.8614 e-ISSN: 2656-1948

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

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(Received: 14 August 2024, Revised: 20 August 2024, Accepted: 26 August 2024)

Abstract

The primary issue faced by PMI (Indonesian Red Cross) about 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 to forecast blood requirements accurately and determine the quantity of blood bags required in the future. When 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 compared 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: *Fuzzy Time Series, Forecasting Blood, PMI*

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1. INTRODUCTION

The Indonesian Red Cross, often known as PMI, is a philanthropic organization. PMI is dedicated to providing blood donor services. The community is supplied with services swiftly and correctly, following organizational values. The organization is known as the International Red Cross and Red Crescent. PMI regularly engages in blood donation activities. Blood donation is a means of helping the community. The purpose of this action is to gather nutritious blood, therefore assisting populations in need. The Indonesian Red Cross (PMI) is a national organization in Indonesia that operates in the fields of humanitarian aid and healthcare [1]. 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 [2]. Blood is a vital component of the human body, originating from the substances that individuals ingest daily. 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. Blood donation is the transfer of blood from a donor to someone in need of blood. This procedure is performed by blood transfusion, often facilitated by the Blood Transfusion Unit (UTD) operated by the Indonesian Red Cross (PMI) [3]. The PMI Assembly is an impartial and autonomous humanitarian organization created to mitigate the distress of fellow individuals, irrespective of their religious, national, tribal, 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 [4]. Due to the high demand for blood in various medical settings such as hospitals, clinics, and maternity wards, UTDS must 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.

Fuzzy-based models use multivalued logic, which enables reasoning in the presence of ambiguity. Even in more elementary models that include the fundamental principles of fuzzy logic, these attributes persist, therefore offering a potent means of representation. Fuzzy Time Series (FTS) models provide a representation that is achieved by a straightforward technique, hence improving its interpretability [5]. 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 [6]. 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, to successfully and efficiently accomplish the desired aim [7]. The use of fuzzy logic in assessment decision-making is based on subjective criteria and has the potential to restrict students' opportunities. An effective quality assessment system may improve individual performance and guarantee equitable ratings. Implementing explicit guidelines may enhance precision and uniformity while reducing the influence of personal interpretation within the evaluation team [8].

Proposed the notion of fuzzy time series, which utilizes fuzzy sets of real numbers for data in the prediction process. The primary distinction between fuzzy time series (FST) and conventional time series is the data used. The FST uses fuzzy sets created from real numbers to represent values, which are associated with pre-defined universe sets [9]. The fuzzy time series (FST) is a prediction approach that uses fuzzy sets as the foundation for its calculating procedure. This approach employs a prognostic system that discerns patterns from past data 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 [10]. Time series forecasting is a highly research-driven discipline that finds practical applications in several domains, including finance, process and quality control, energy consumption, water demand, epidemiology, and more [11]. Categorizes the forecast period into three distinct groups: 1. Short-term prediction refers to a forecast made for less than three months. 2. Medium-term prediction refers to making forecasts for a duration ranging from three months to three years. Long-term prediction refers to making predictions over a period beyond three years [12].

Incorporates data from prior research, including a study that uses the fuzzy time series approach to forecast the demand for crucial raw elements in food goods at Kedai Dampizza. This approach utilizes historical data as a reference point to determine the classifications of essential input raw materials. The program underwent testing on many web browsers, resulting in an error rate of 3.83%. The objective is to augment the inventory of the Dampizza shop while minimizing instances of scarcity or surplus [13]. The project primarily centers on using the fuzzy time series approach and genetic algorithms to forecast the water requirements in Malang City. This research utilizes data collected between 2008 and 2013 and employs a real-coded chromosomal representation together with genetic operators. The method achieves optimal performance by obtaining the best parameters, resulting in a forecast with a minimal error value of 2.266776% [14].

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, 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 [15]. 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

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

2.1 Research Framework

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:

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.

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.

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

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.

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.

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.

Interview

The communication process is interactive between researchers and parties related to Indonesia's Reddest City, Medan, to get relevant information related need for blood in the PMI, using the 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.

Documentation Study

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

Planning

Forecasting/Prediction (*forecasting*)

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

Fuzzy Time Series Logic

In this step, the author applies the Fuzzy Time Series method for forecasting/prediction to the data that has been collected at the stage previously. This process involves a series of steps from the method fuzzy time series developed by Chen:

Step 1: Define set universe

Step 2: Shaping universe talk (U) to determine the universe the conversation uses a formula

U = [Dmin – D1, Dmax + D2] … (3.1)

Step 3: interval formation is carried out with share range mark talks become several segments 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)

After the number of intervals is found, the next step is to determine the length of the interval using a formula

Intervals length = Dmax – Dmin ... (3.3)

Step 4: Defining fuzzy sets and fuzzification of historical data

Step 5: Determine the connection between fuzzy logic (FLR) and group fuzzy Logic Relations (FLRG)

Step 6: Calculate forecasting/defuzzification.

Testing

In the context of testing, several approaches 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, 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 bloodstock at PMI may be inadequate. On the other hand, an excess 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

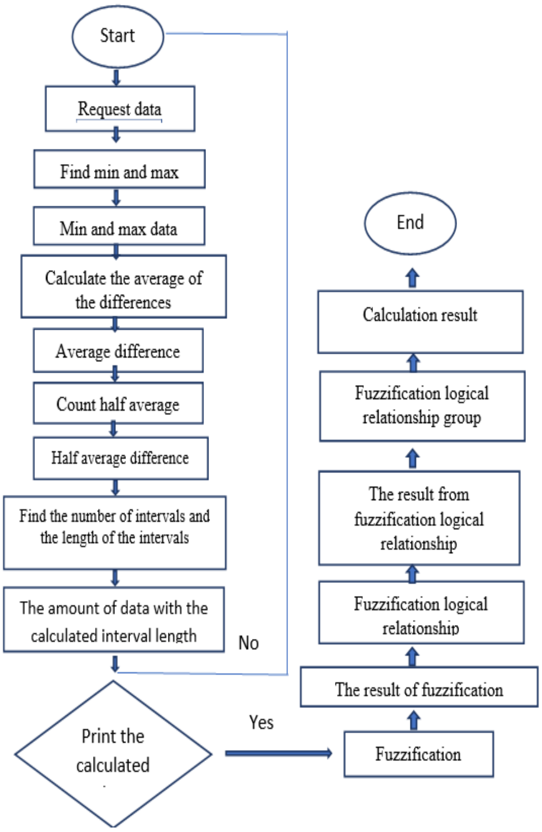

Figure 1. Research Framework

3. RESULT AND DISCUSSION

3.1 Results Analysis Request Data

The demand for blood from the Indonesian Red Cross in the Medan region increases almost every year, as shown in Table 1.

Table 1. Demand data blood

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

3.2 Statistics Descriptive

Based on the request for blood data for 3 years, then analyzed descriptively as the results are shown in Table 2.

Table 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	3					

3.3 Determine the number of fuzzy intervals (n_intervals).

The number of fuzzy intervals determines how detailed the fuzzy category you want to use. For example, 5 intervals can be given categories such as "Very Low", "Low", "Medium", "High", and "Very High". Here We use 5 intervals, using 5 intervals in fuzzy time series helps identify trends and patterns in time series data in an informative way However still simple. This is possible to understand How the amount of donor blood changed from time to time in easy fuzzy categories interpreted.

Calculates fuzzy intervals for every group of blood based on data. With the use function create-intervals, we can calculate fuzzy intervals for every group of blood based on available data. The implementation results using R Studio are shown in Figure 2.

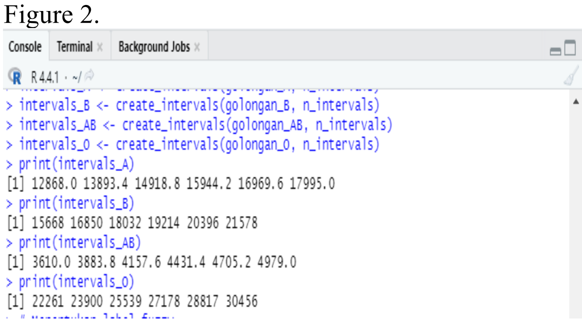

Figure 2. Interval Fuzzy Time Series

Determine the limit maximum and minimum

Determine the limit maximum and minimum of request data for every group blood, minimum maximum data already There is previously in the descriptive statistics table previously. So that at this stage it is divided based on the minimum and maximum of each blood type as shown in Table 3.

Table 3. Limit Data

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

Determine interval width

$$interval\ width = \frac{maximum\ limit - minimum\ limit}{number\ of\ intervals}$$

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

BLOOD GROUP A

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

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

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

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

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

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

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

Group O intervals

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

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. The results of fuzzy labels are shown in Figure 3 and Figure 4.

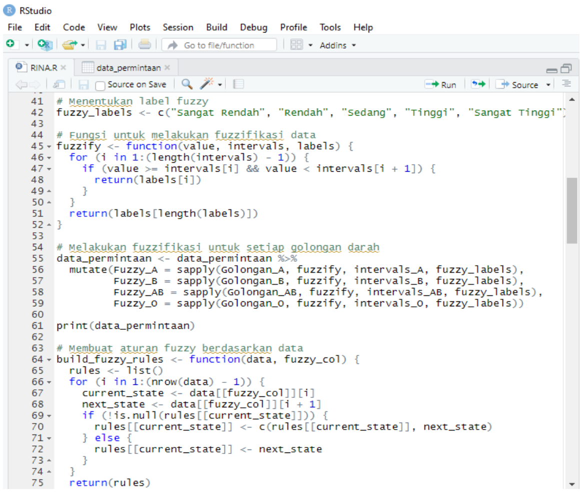

Figure 3. Fuzzy Labels

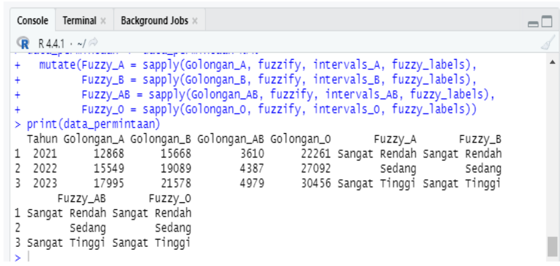

Figure 4. Fuzzy Label Interval for request data

Conversion of every data value to 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"

Fuzzy Label Intervals

Based on the results of the interval calculations for each blood type, the intervals for each blood type are shown in Table 4.

Table 4. Fuzzy Label Intervals for request data

Year	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

Make Data-Driven Fuzzy Rules

Make fuzzy rules based on the transition between fuzzy categories in data. Make fuzzy rules based on the transition between Fuzzy categories in data work to catch temporal patterns in time series data. These fuzzy rules are Then used for predict future value based on past fuzzy categories.

Perform predictive analysis using fuzzy rules.

The make function for predicting the next fuzzy category based on fuzzy rules has been made. After identifying all the fuzzy relationships, group these relationships into fuzzy relationship groups (FLRG) to simplify predictions. The results are shown in Table 5.

Table 5. Prediction Based on Fuzzy Rules

Blood type	FLRG
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

Do Prediction for Year Next

Use function predictions to estimate fuzzy number categories donor for the 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, and O. Shown in Table 6.

Table 6. Prediction Results in 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

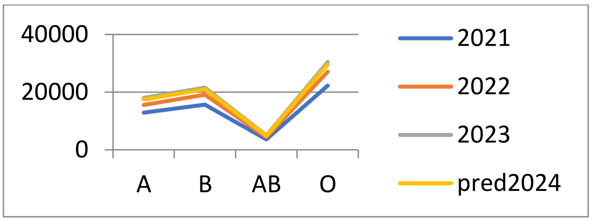

Figure 6. blood type prediction result diagram

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

3.6. Count Accuracy

Count accuracy predictions for every group's blood and display it Table 7.

Table 7. 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%

3.7 Results Analysis

Type AB has an MAE and MSE that break arrived displays bids, a large MSE, and a moderate MAPE, indicating predictions Enough accurate However There is a variation that is a must noticed. Type -O has more MAPE high, as well as more MAPE big, showing that predictions for group low O blood are accurate compared to others.

Based on the research results, it can be concluded that the demand for blood types in 2024 is very high as shown in Table 8.

Table 8. Prediction results amount requested 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

Group AB has the lowest RMSE value which is 136.90, which shows that your model is more accurate in predicting group AB blood compared with group blood. Group O has the highest RMSE value which is 819.5, which shows that your model is lacking accuracy in predicting group O blood compared with group blood.

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 can 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.

4. Conclusion

The use of the Fuzzy Time Series (FTS) technique in forecasting blood requirements at the Indonesian Red Cross (PMI) Medan has shown its efficacy in anticipating future demand. The research emphasised the significance of selecting suitable interval durations to establish precise fuzzy connections, which have a substantial effect on the prediction results. The study findings demonstrated that Group AB had the lowest RMSE value compared to other blood groups, suggesting that the FTS model yielded the most precise predictions for this particular group. Nevertheless, the accuracy of the model differed across different blood groups, with Group O exhibiting the greatest RMSE value, indicating a poorer level of prediction accuracy.

The study also showed that by using the FTS technique, PMI Medan can effectively oversee its blood supply, hence minimising occurrences of shortages or surpluses. This is especially vital during crises or important events when the need for blood might vary in an unpredictable manner. Overall, the research highlights the effectiveness of Fuzzy Time Series in dealing with time series data that contains inherent uncertainties, making it a helpful tool for predicting outcomes in important domains such as blood supply management.

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