Jurnal Mandiri IT
Vol. 14 No. 1, July (2025), pp. 48-56

ISSN 2301-8984 (Print), 2809-1884 (Online)
Published by Institute of Computer Science

Application of fuzzy time series method to determine medical equipment inventory

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A R T I C L E I N F O

Article history:

Received Jul 1, 2025
Revised Jul 9, 2025
Accepted Jul 15, 2025

Keywords:

Forecasting;
Fuzzy Time Series;
Inventory Planning;
MAPE;
Medical Equipment.

ABSTRACT

This study applied the Fuzzy Time Series (FTS) method to forecast monthly stock requirements for medical equipment at PT. Karya Metropolis. The FTS process including interval determination, fuzzification, fuzzy rule formation, and defuzzification successfully identified historical patterns in sales data and produced predictions closely aligned with actual values. Forecast results indicated the next month's needs for several items, such as 154.5 units of gauze rolls, 129 units of leukocrepe, 26.5 units of hypafix, 25 liters of 95% alcohol, 487.5 oxygen nebulizer masks, 109.5 units of Vaseline swabs, and 61 Maxter gloves. Forecast accuracy was assessed using Mean Absolute Percentage Error (MAPE), where most items showed low error rates, including gauze rolls (6.16%), Vaseline swabs (7.21%), and Maxter gloves (9.28%). However, the oxygen nebulizer mask showed a higher MAPE value of 47.28%, indicating a need for method refinement or integration with other approaches for that item. Overall, the FTS method proved effective in supporting accurate, efficient, and measurable stock planning decisions for medical supplies.

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1. INTRODUCTION

In modern business, data-driven decision-making is crucial for maintaining a competitive edge (Garcia & Adams, 2023). Forecasting and modeling help companies predict trends, identify patterns, and improve efficiency. Accurate forecasts support better market responses, while models clarify variable relationships (Sunarsi, 2023). Therefore, many organizations prioritize developing fast, relevant, and accurate models to navigate business uncertainties (Ahmad, 2024).

Medical equipment refers to devices used to prevent, diagnose, treat, and restore health conditions without involving medicinal substances (Azis et al., 2024). PT. Karya Mertopolis is a company engaged in the distribution of medical equipment in the city of Medan. This company provides medical supplies such as bandages, gauze, syringes, and similar products, primarily focusing on the distribution and sale of items used in medical care and healthcare. It offers a variety of medical instruments and devices required for various medical procedures.

Forecasting is a technique that uses both qualitative and quantitative approaches to analyze past data and predict future events (Zellner et al., 2021). In addition, forecasting helps estimate various future needs, such as the quality, quantity, and timing required to meet demand (Hayuningtyas & Sari, 2021). Forecasting is an essential tool in planning, especially in the field of economics (Chukwuma-Eke et al., 2022). In modern organizations, it helps predict future conditions, reduce uncertainty, and support more effective and efficient strategic decision-making (Setiawan, 2021). Forecasting is the process of estimating future events based on historical data

analyzed using statistical methods. Its purpose is to reduce uncertainty, support decision-making, and improve planning efficiency (Muhammad Nur et al., 2024). Forecasting is the process of estimating future events using various methods based on historical data and existing trends. This process supports decision-making and planning in various fields such as business, economics, and logistics (Yolanda et al., 2024).

Fuzzy logic is a field within artificial intelligence that mimics the human ability to make decisions based on uncertain or vague information (Wantoro et al., 2023). By converting linguistic concepts into mathematical representations, fuzzy logic enables machines to perform reasoning in a more human-like manner. It extends the concept of binary truth by allowing truth values to range between 0 and 1, thus providing a high level of accuracy when dealing with uncertainty (Hafiz & Sriani, 2023). Fuzzy logic is also capable of handling imprecise and variable data with a high degree of reliability. Its applications are wide-ranging, including system control, data categorization, prediction, and decision-making (Ritonga & Armansyah, 2025)(Muhammad Alwi Baihaqi & Sriani, 2023).

Fuzzy Time Series (FTS) is a forecasting method that applies fuzzy logic principles, where time series values are represented using fuzzy sets(Arisandi & Hafid, 2024). This approach was first introduced by Song and Chissom in 1993 to forecast student enrollment at the University of Alabama. The method works by identifying patterns in historical data and using those patterns to make future projections (Rahmawati et al., 2021)(Yudha & Putri, 2024). Fuzzy Time Series (FTS) is a forecasting method that uses fuzzy logic to handle uncertain and imprecise data (Lucas et al., 2022). It transforms numerical data into linguistic forms, allowing for more flexible analysis of historical patterns. This method is suitable for various fields such as economics, inventory management, and decision-making systems (Ipan et al., 2022). Fuzzy Time Series is a flexible method that can be used to predict both stationary and non-stationary time series data. It is effective in handling uncertainty and is suitable for various fields with inconsistent data patterns (Komaria et al., 2023).

Previous studies had several limitations. First, the sales data of antibiotic drugs used were unstructured and non-linear, making the application of the Fuzzy Time Series (FTS) Model Lee challenging. Forecasting with this method is also subject to uncertainty due to unpredictable external factors such as changes in health policies or market trends, which cannot be fully modeled by the FTS approach. Additionally, limitations in the availability and quality of historical data may reduce forecasting accuracy, as this method heavily relies on past data. Although the forecasting results showed favorable Mean Absolute Percentage Error (MAPE) values, discrepancies between predictions and actual data were still observed at certain points, indicating the model's limited ability to capture data fluctuations comprehensively. Furthermore, previous research only used a single forecasting method without comparison, making it difficult to conclude whether the method was the most optimal for the case studied (Listyaning Pangestu et al., 2024).

This research offers an advantage by not only focusing on forecasting but also aiming to support decision-making in the management of medical equipment inventory more effectively. By applying the Fuzzy Time Series method to historical demand data, this study seeks to produce accurate predictions of future inventory needs. The forecasting results are expected to help the company make better decisions in stock management, minimize the risk of shortages or overstock, improve operational efficiency, and ensure sustainable product availability.

The study by (Sari et al., 2023). showed that the Fuzzy Time Series Chen Model accurately predicted medical supply needs with only a 4% error rate, proving it to be a simple, reliable, and effective tool for procurement planning. The study by (Zufria et al., 2024) on fish sales prediction using the Fuzzy Time Series method showed excellent results, with an AFER value of 0.09412% based on 475 data points from January 2022 to July 2023. Program testing was also conducted using Black Box Testing. The study by (Nasution & Sriani, 2023) resulted in a forecasting system for grocery sales at UD. Ridho Dolok Masihul, which was deemed feasible for use. The system is expected to help the owner accurately determine future stock levels, thereby avoiding losses or decreased income. (Hamdani et al., 2020) developed a web-based sales forecasting system using the Fuzzy Time Series method with 2.28% accuracy, aimed at minimizing monthly stock accumulation at CV. Agva Pasuruan.

Conventional forecasting methods are less effective in handling fluctuating and non-linear medical demand data. Therefore, this study adopts the Fuzzy Time Series approach, as it is

capable of managing uncertainty and irregular data patterns, allowing for more adaptive and accurate forecasting of medical stock needs at PT. Karya Mertopolis.

2. RESEARCH METHOD

This flowchart serves as a guide for developing a system based on the Fuzzy Time Series (FTS) method to ensure it meets functional requirements. By illustrating key stages such as historical data retrieval, fuzzification, fuzzy rule formation, and defuzzification, the flowchart helps developers understand the overall system workflow. Additionally, it acts as an essential reference for team communication, user requirement validation, and system evaluation and testing to ensure accurate and efficient forecasting.

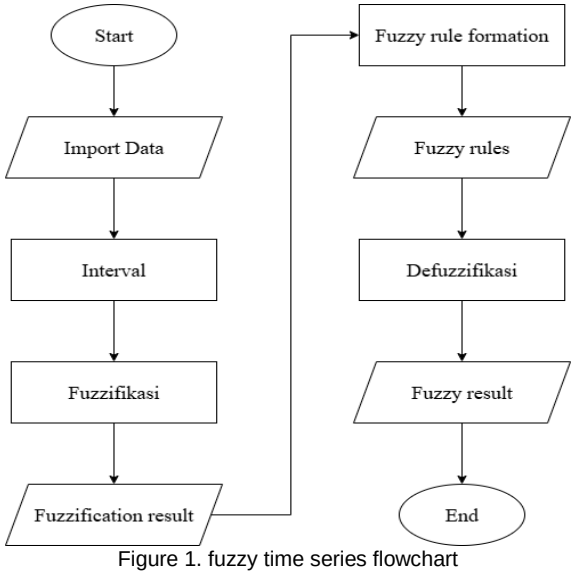

Figure 1. fuzzy time series flowchart

Data

This study collects sales data of seven types of medical supplies over the course of one year to be analyzed using the Fuzzy Time Series method. The aim is to forecast future demand for medical supplies, enabling more efficient and timely stock procurement while minimizing the risk of shortages or overstocking.

Table 1. Medical device data

Month	Rolled Gauze 80 yards X 80cm Fei Medika	Leukocrepe 6 Inch	Hypafix 10cm X 5m New	Alkohol 95% @ 20l	Gea Adult Oxygen Nebulizer Mask	Vaseline Swab 10x10 Winner	Maxter Gloves No. 7
1	150	100	30	20	500	100	60
2	130	90	25	18	450	95	55
3	140	110	28	22	480	98	58
4	160	120	35	25	520	110	62
5	155	100	27	21	490	100	50
6	145	95	26	19	470	98	49
7	170	130	40	27	330	115	64
8	165	125	34	24	380	108	60
9	150	105	29	23	195	102	55
10	160	115	31	26	120	107	59
11	155	110	30	22	500	104	52
12	170	135	36	28	540	118	66

Determining the Interval

At this stage, the sales data of each medical item is divided into several intervals. The purpose of this interval determination is to group the data into proportional classes, making it easier to convert numerical values into linguistic forms (such as A1, A2, A3, A4). This step serves as a

crucial foundation for the fuzzification process and the formulation of fuzzy time series rules, ensuring that the analysis results are more accurate and reflective of actual conditions.

Table 2. Interval

Tool Name	Interval	Range	*Fuzzy* Set
Rolled Gauze 80 yards X 80cm Fei Medika	1	[130 - 139]	A1
	2	[140 - 149]	A2
	3	[150 - 159]	A3
	4	[160 - 170]	A4
Leukocrepe 6 Inch	1	[90 - 100]	A1
	2	[101 - 111]	A2
	3	[112 - 122]	A3
	4	[123 - 135]	A4
Hypafix 10cm X 5m New	1	[25 - 28]	A1
	2	[29 - 32]	A2
	3	[33 - 36]	A3
	4	[37 - 40]	A4
Alkohol 95% @ 20l	1	[18 - 20]	A1
	2	[21 - 23]	A2
	3	[24 - 26]	A3
	4	[27 - 29]	A4
Gea Adult Oxygen Nebulizer Mask	1	[120 - 224]	A1
	2	[225 - 329]	A2
	3	[330 - 434]	A3
	4	[435 - 540]	A4
Vaseline Swab 10x10 Winner	1	[95 - 100]	A1
	2	[101 - 106]	A2
	3	[107 - 112]	A3
	4	[113 - 118]	A4
Maxter Gloves No. 7	1	[49 - 53]	A1
	2	[54 - 58]	A2
	3	[59 - 63]	A3
	4	[64 - 68]	A4

Fuzzification

This stage involves the fuzzification process, which transforms numerical sales data into linguistic values (A1–A4) based on predefined intervals. The purpose is to simplify numerical data into linguistic categories for use in fuzzy logic. This step is essential in determining time-based relationships for accurate and efficient forecasting using the fuzzy time series method.

Table 3. Fuzzification

Month	Rolled Gauze 80 yards X 80cm Fei Medika	Leukocrepe 6 Inch	Hypafix 10cm X 5m New	Alkohol 95% @ 20l	Gea Adult Oxygen Nebulizer Mask	Vaseline Swab 10x10 Winner	Maxter Gloves No. 7
1	A3	A1	A2	A1	A4	A1	A3
2	A1	A1	A1	A1	A4	A1	A2
3	A2	A2	A1	A2	A4	A1	A2
4	A4	A3	A3	A3	A4	A3	A3
5	A3	A1	A1	A2	A4	A1	A1
6	A2	A1	A1	A1	A4	A1	A1
7	A4	A4	A4	A4	A3	A4	A4
8	A4	A4	A3	A3	A3	A3	A3
9	A3	A2	A2	A2	A1	A2	A2
10	A4	A3	A2	A3	A1	A3	A3
11	A3	A2	A2	A2	A4	A2	A1
12	A4	A4	A3	A4	A4	A4	A4

The data presented in the table is the result of the fuzzification process, where numerical sales data of medical supplies has been converted into fuzzy values (A1–A4) based on predefined intervals. This output serves as a crucial foundation for forming fuzzy logical relationships, which are then used to forecast future demand. With data in fuzzy form, changes over time can be more systematically analyzed within the fuzzy time series framework.

Determination of Rules

This stage involves the formation of fuzzy logical relationships by analyzing the transition patterns of fuzzy values over time, such as A2 → A3. These patterns are constructed based on the results of the fuzzification process to forecast the values for the following month. The more data analyzed, the stronger and more accurate the resulting rules become, thereby improving the quality of predictions using the fuzzy time series method.

Table 4. Rules

Rolled Gauze 80 yards X 80cm Fei Medika	Leukocrepe 6 Inch	Hypafix 10cm X 5m New	Alkohol 95% @ 20l	Gea Adult Oxygen Nebulizer Mask	Vaseline Swab 10x10 Winner	Maxter Gloves No. 7
(3 → 1)	(1 → 1)	(2 → 1)	(1 → 1)	(4 → 4)	(1 → 1)	(3 → 2)
(1 → 2)	(1 → 2)	(1 → 1)	(1 → 2)	(4 → 4)	(1 → 1)	(2 → 2)
(2 → 4)	(2 → 3)	(1 → 3)	(2 → 3)	(4 → 4)	(1 → 3)	(2 → 3)
(4 →3)	(3 → 1)	(3 → 1)	(3 → 2)	(4 → 4)	(3 → 1)	(3 → 1)
(3 → 2)	(1 → 1)	(1 → 1)	(2 → 1)	(4 → 4)	(1 → 1)	(1 → 1)
(2 → 4)	(1 → 4)	(1 → 4)	(1 → 4)	(4 → 3)	(1 → 4)	(1 → 4)
(4 → 4)	(4 → 4)	(4 → 3)	(4 → 3)	(3 → 3)	(4 → 3)	(4 → 3)
(4 → 3)	(4 → 2)	(3 → 2)	(3 → 2)	(3 → 1)	(3 → 2)	(3 → 2)
(3 → 4)	(2 → 3)	(2 → 2)	(2 → 3)	(1 → 1)	(2 → 3)	(2 → 3)
(4 → 3)	(3 → 2)	(2 → 2)	(3 → 2)	(1 → 4)	(3 → 2)	(3 → 1)
(3 → 4)	(2 → 4)	(2 → 3)	(2 → 4)	(4 → 4)	(2 → 4)	(1 → 4)

Defuzzification

The defuzzification stage converts fuzzy prediction results (such as A1–A4) into quantitative values by taking the midpoint of the corresponding interval. The goal is to produce concrete numerical predictions to support decision-making, such as stock planning or procurement. This is the final step in the fuzzy time series method, following interval determination, fuzzification, and rule formation.

The defuzzification formula in the Fuzzy Time Series method uses the midpoint of the predicted interval. The formula is:

$$Prediction = \frac{Lower\ limit + Upper\ limit}{2}$$

Description:
Lower limit: initial value of the fuzzy interval
Upper limit: final value of the fuzzy interval

Defuzzification is the final stage in the fuzzy time series method, converting symbolic prediction results (such as A1–A4) into real numerical values. This process is essential to bridge fuzzy logic with practical needs, such as procurement planning and inventory management.

3. RESULTS AND DISCUSSIONS

This stage is the process of predicting the medical supply needs for the following month based on data that has undergone the previous steps: interval determination, fuzzification, rule formation, and defuzzification. The prediction is derived from the defuzzified value of the most recent fuzzy result, obtained through the pattern of relationships between previous months. The goal is to estimate the required quantity accurately, enabling more precise and efficient procurement in line with the demand patterns observed over the past year.

The following is the medical supply data for December 2024, which serves as the basis for predicting the needs for the following month. This data is the main reference in the final stage of the fuzzy time series method determining the fuzzy value for December, applying the established rules, and performing defuzzification to obtain a more accurate and targeted quantitative prediction for January 2025.

Table 5. December 2024 data

Tool Name	Actual Value
Rolled Gauze 80 yards X 80cm Fei Medika	170
Leukocrepe 6 Inch	135
Hypafix 10cm X 5m New	36
Alkohol 95% @ 20l	28
Gea Adult Oxygen Nebulizer Mask	540
Vaseline Swab 10x10 Winner	118

Tool Name	Actual Value
Maxter Gloves No. 7	66

The next step is the fuzzification process for the December 2024 data. This fuzzification aims to convert numerical values into linguistic representations in the form of fuzzy sets, such as A1, A2, A3, and A4, based on the previously defined intervals. By grouping the data into fuzzy categories, quantitative data can be analyzed more flexibly and logically. This process is crucial as it forms the basis for creating fuzzy rules and generating predictions for the next period. The fuzzification result for December will serve as the main reference in determining the fuzzy value used to forecast the needs for January 2025.

Table 6. December 2024 data fuzzification

Tool Name	Actual Value	Fuzzification
Rolled Gauze 80 yards X 80cm Fei Medika	170	A4
Leukocrepe 6 Inch	135	A4
Hypafix 10cm X 5m New	36	A3
Alkohol 95% @ 20l	28	A4
Gea Adult Oxygen Nebulizer Mask	540	A4
Vaseline Swab 10x10 Winner	118	A4
Maxter Gloves No. 7	66	A4

After obtaining the fuzzification result for December 2024, the next step is to predict the needs for January 2025. This process uses fuzzy logical relationships formed from the patterns of previous months. The fuzzy value for December will be matched with the existing rules to determine the fuzzy prediction for January. Once the fuzzy prediction is obtained, defuzzification is carried out to convert it into a numerical value that can be used as a reference for planning the procurement of medical supplies. Thus, this process plays an important role in ensuring that the needs at the beginning of the year are met accurately and efficiently.

Table 7. January 2025 sales forecast

Tool Name	Actual Value	Fuzzifikasi	Prediction
Rolled Gauze 80 yards X 80cm Fei Medika	170	A4	A3
Leukocrepe 6 Inch	135	A4	A4
Hypafix 10cm X 5m New	36	A3	A1
Alkohol 95% @ 20l	28	A4	A3
Gea Adult Oxygen Nebulizer Mask	540	A4	A4
Vaseline Swab 10x10 Winner	118	A4	A3
Maxter Gloves No. 7	66	A4	A3

After obtaining the fuzzy prediction result for January 2025, the next step is defuzzification. Defuzzification is the process of converting fuzzy values (such as A1, A2, A3, or A4) into concrete numerical values. This is done by calculating the average of the lower and upper bounds of the interval corresponding to the predicted fuzzy value. The purpose of defuzzification is to produce an exact number that can serve as a more accurate basis for planning medical supply needs and can be applied in decision-making, particularly in the procurement process for January 2025.

- Rolled Gauze 80 yards X 80cm Fei Medika = A3

$$A3 = \frac{150 + 159}{2} = \frac{309}{2} = 154{,}5$$

- Leukocrepe 6 Inci = A4

$$A4 = \frac{123 + 135}{2} = \frac{258}{2} = 129$$

- Hypafix 10cm X 5m New = A1

$$A1 = \frac{25 + 28}{2} = \frac{53}{2} = 26{,}5$$

- Alkohol 95% @ 20l = A3

$$A3 = \frac{24 + 26}{2} = \frac{50}{2} = 25$$

- Gea Adult Oxygen Nebulizer Mask

$$A4 = \frac{435 + 540}{2} = \frac{975}{2} = 487{,}5$$

- Vaseline Swab 10x10 Winner = A3

$$A3 = \frac{107 + 112}{2} = \frac{219}{2} = 109{,}5$$

- Maxter Gloves No. 7 = A3

$$A3 = \frac{59 + 63}{2} = \frac{122}{2} = 61$$

Based on the defuzzification results obtained earlier, the predicted values for medical supply needs in January 2025 will be presented in a table. This tabular presentation aims to provide a clearer, more structured, and easily understood overview of the final results of the forecasting process using the fuzzy time series method. The table will include the names of the medical supplies, the predicted fuzzy values, the intervals used, and the defuzzified numerical values as estimates of the needs for the following month.

Table 8. Defuzzification results

Tool Name	Defuzzification
Rolled Gauze 80 yards X 80cm Fei Medika	154,5
Leukocrepe 6 Inch	129
Hypafix 10cm X 5m New	26,5
Alkohol 95% @ 20l	25
Gea Adult Oxygen Nebulizer Mask	487,5
Vaseline Swab 10x10 Winner	109,5
Maxter Gloves No. 7	61

The following table presents a summary of the MAPE (Mean Absolute Percentage Error) values for each medical supply item analyzed using the fuzzy time series method. This presentation aims to provide an overview of the forecasting accuracy compared to actual data, serving as a reference for making more precise and efficient decisions in the procurement of medical supplies.

Table 9. MAPE Value of Medical Devices

Tool Name	MAPE
Rolled Gauze 80 yards X 80cm Fei Medika	6,16%
Leukocrepe 6 Inch	18,55%
Hypafix 10cm X 5m New	14,01%
Alkohol 95% @ 20l	14,72%
Gea Adult Oxygen Nebulizer Mask	47,28%
Vaseline Swab 10x10 Winner	7,21%
Maxter Gloves No. 7	9,28%

4. CONCLUSION

Based on the results of the research and the implementation of the Fuzzy Time Series (FTS) method on medical supply sales data at PT. Karya Metropolis, it can be concluded that this method is effective in forecasting monthly stock requirements. The FTS process which includes interval determination, fuzzification, fuzzy rule formation, and defuzzification is capable of identifying historical data patterns and generating predictions that closely match actual values. Therefore, FTS can serve as a reliable tool in making more accurate, efficient, and measurable decisions regarding the procurement of medical supplies.

Based on the forecasting results using the Fuzzy Time Series method, the predicted medical supply needs for the following month are as follows: gauze roll at 154.5 units, leukocrepe at 129 units, hypafix at 26.5 units, 95% alcohol at 25 liters, oxygen nebulizer masks at 487.5 units, vaseline swabs at 109.5 units, and maxter gloves at 61 units. The accuracy of the forecast was evaluated using MAPE (Mean Absolute Percentage Error), where most items showed low MAPE values, such as gauze roll (6.16%), vaseline swab (7.21%), and maxter gloves (9.28%), indicating a low prediction error. However, the oxygen nebulizer mask showed the highest MAPE at 47.28%, suggesting that the method may need to be reviewed or combined with another approach for that

particular item. Overall, the Fuzzy Time Series method has proven to be quite effective in supporting inventory forecasting of medical supplies at PT. Karya Metropolis.

To improve the accuracy of medical device predictions in the future, especially when the MAPE value remains relatively high, several strategies can be considered. These strategies include exploring hybrid methods that combine Fuzzy Time Series with other algorithms (such as Neural Networks or ARIMA), optimizing the parameters of the applied algorithms, and adding more diverse predictor variables to better capture demand patterns.

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