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The Application of Fuzzy Time Series Method for Web-Based Prediction of Household Chemical Product Sales Stock

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Abstract

The seasonal and trend factors of the market demand greatly influence the sales of household chemical products. Therefore, PT. XYZ company requires an accurate sales prediction system to optimize production and inventory. This research aims to develop a web-based sales prediction system for household chemical products using fuzzy time series method. This method considers the factors that influence sales and generates a prediction model that can assist the company in decision-making. This method allows the use of uncertain and unstructured variables in the prediction. The research collected historical sales data of household chemical products from January to December 2023 through interviews, observations, and literature studies. The system was designed using a structured approach and PHP programming language. The Fuzzy Time Series method was used for decision-making. The accuracy of the Fuzzy Time Series method for sales data from January to December 2020 was calculated through program simulation and manual methods, resulting in an accuracy rate of 13.71%. The application provides information on the sales of each product, with the hope that users can reduce the accumulation of stock every month.

Keywords: *Fuzzy Time Series, Prediction, Household Chemical Products, Sales, Web-Based*

1. Introduction

PT. XYZ is a private company that produces high-quality industrial household chemical products for customers. As a household chemical company, PT. XYZ needs to have a deep understanding of market trends and customer demand. Stock accumulation due to uncertain profit in the previous month and the lack of an accurate sales prediction system are challenges that can affect the company's profit and loss calculations. It is necessary to identify stock levels and develop a sales prediction system to reduce business risks. The objective of this research is to develop a web-based sales prediction system that helps the company determine the production quantity and stock inventory by predicting the demand for products in the previous month. Forecasting is a technique to predict future values based on historical or past data. The forecasting process is crucial in decision-making, as the effectiveness of decisions often depends on factors that cannot be predicted at the time the decision is made [1].

Fuzzy Time Series is a forecasting method that utilizes the concept of fuzzy sets to connect the universe set with actual data in its basic forecasting process [2]. This method uses fuzzy sets as a representation of actual data derived from real numbers in the universe set. By using fuzzy sets as a substitute for historical data, the forecasting process can be done with a limited amount of data [3]. A study conducted in 2020 titled "Application of Fuzzy Time Series Method for Web-Based Sales Prediction at CV. Agva Kota Pasuruan" found that changes in consumer demand for a product can cause inventory to become unstable, making it difficult for store owners to determine the appropriate stock of goods. This study used the fuzzy time series method with the average formula to calculate intervals and fuzzy sets. The results of testing with the fuzzy time series method obtained a manual calculation system with an error rate of 2.28% [4]. In 2023, a study titled "Forecasting the Amount of Flour Sales at UD. Citra Pekanbaru Using Fuzzy Time Series" found that businesses face challenges with uncertain demand for goods, resulting in shortages or excess inventory of flour at certain times. Therefore, a fuzzy time series prediction system was created to identify variables related to sales forecasting. The accuracy of the fuzzy time series method was calculated based on sales data through program simulation and manual calculation the accuracy value was 18.68% [5]. To improve efficiency and accuracy in predicting product stock, there are several methods used, one of which is using the fuzzy time series method. This method utilizes fuzzy logic concepts to predict the amount of stock by analyzing historical data patterns and using that information to project data in the future. Thus, the fuzzy time series method can help optimize product stock management [6], [7], [8].

The fuzzy time series method is an approach to analyzing uncertain systems. In this method, fuzzy set theory is used to calculate data patterns with tolerance for uncertainty. Unlike conventional forecasting methods, the application of fuzzy time series method does not require stationary assumptions. This method can be used in planning the production quantity of household chemical products based on demand, remaining stock, and stock shortages [9]. The fuzzy time series method is used to determine the level of product sales by involving the determination of intervals based on average sales, which is then used to forecast product sales [10]. The fuzzy time series method also

has the ability to identify the percentage of buyer interest in a product over a certain period of time [11], and can be used to analyze fluctuating time series data patterns [12]. Based on previous research references, the fuzzy time series method is a method that utilizes fuzzy logic to model the relationship between factors that affect production stock, such as season, trend, promotion, and other factors.

2. Research Methods

2.1. Data Collection Methods

The data collection process is carried out through several methods, including direct observation to obtain demand data, interviews with relevant competent parties, and literature studies involving the collection of references from various sources such as books, articles, journals, papers, and websites.

2.2. System Development Method

The system development method used in this case is the Waterfall Model. The stages of the waterfall model are as follows:

a. Research Variables
The variables used are the remaining stock variable and stock shortage variable as input variables, and the monthly sales quantity variable as the output variable.

b. Analysis
The analysis stage of this system involves analyzing the problem, analyzing system requirements, and applying the fuzzy time series method. The Fuzzy Time Series method by Chen (1996)[13] is as follows:
Step 1: Determining the Universe of Discourse.

$$U = [D_{min} - D1\ ;\ D_{max}\ +\ D2] \quad (1)$$

with,
Dmin = minimum data
Dmax = maximum data
D1 and D2 are arbitrary positive numbers determined by the researcher.
Step 2 : Formation of Intervals
To form intervals, first determine the number of interval classes and the length of intervals.

1) Number of Intervals

$$n = 1 + 3{,}322 \log N \quad (2)$$

2) Interval Length

$$p = \frac{[(D_{max} + D2) - (D_{min} -\ D1)]}{n} \quad (3)$$

From these results, we obtain the partition of the universe of discourse according to the length of the intervals.

3) Intervals of The Universe of Discourse

$$\begin{aligned} u_1 &= (D_{min} - D_1\ ;\ D_{min} -\ D_1 + p) \\ u_2 &= (D_{min} - D_1 + p\ ;\ D_{min} -\ D_1 + 2p) \\ &\cdot \\ &\cdot \\ u_n &= (D_{min} - D_1 + (K-1)\,p\ ;\ D_{min} -\ D_1 + np) \end{aligned} \quad (4)$$

Step 3: Formation of Fuzzy Sets.

$$\begin{aligned} A_1 &= \left\{ {}^{1}/_{u_1} + {}^{0{,}5}/_{u_2} + {}^{0}/_{u_3} + \cdots {}^{0}/_{u_p} \right\} \\ A_2 &= \left\{ {}^{0{,}5}/_{u_1} + {}^{1}/_{u_2} + {}^{0{,}5}/_{u_3} + \cdots {}^{0}/_{u_p} \right\} \\ &\cdot \\ &\cdot \\ A_p &= \left\{ {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0}/_{u_3} + \cdots {}^{0{,}5}/_{u_{p-1}} , {}^{1}/_{u_p} \right\} \end{aligned} \quad (5)$$

Step 4: Fuzzy Logic Relations (FLR)
It is necessary to consider the fuzzy value Ai of the time series data for each day from 1 to n. FLR can be expressed as $Ai\ Aj$, where Ai is the left-side set or the previous observation F(t-1), and Aj is the right-side set or the subsequent observation after the previous data $F(t)$ in the time series data.
Step 5: Formation of Fuzzy Logical Relationship Group (FLRG)
After obtaining the results of Fuzzy Logic Relations (FLR), we can form Fuzzy Logical Relationship Groups (FLRG) by grouping each FLR that has the same left-side (t-1). The following is the grouping or FLRG obtained based on the FLR results.
Step 6: Forecasting
If there are fuzzy logic relationship groups Ai → Ai, Aj, ..., Ap, then the forecast value Ft will correspond to Ai, Aj, ..., Ap. The equation is as follows:

$$F_{t=} \frac{\mathrm{m1} +\ \mathrm{m2} + \cdots + \mathrm{mn}}{n} \quad (6)$$

c. Design
The system design is carried out using an object-oriented approach, and its modeling involves the use of Use Case Diagram.

d. Development
Implementing the Fuzzy Time Series method into the PHP programming language using a MySQL database.

e. Testing

Functional testing using Black Box testing and validity testing using the Mean Absolute Percentage Error (MAPE) method to assess the accuracy of the calculation results [14][15].

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{X_t - F_t}{X_t}\ X\ 100\%\right| \quad (7)$$

3. Results and Discussion

3.1. Application of Fuzzy Time Series

The data in this study is the household chemical product data in Table 1, which is the monthly data of PT. XYZ from January 2023 to December 2023.

Table 1: Product Data

Month	Quality
January	174
February	172
March	220
April	211
May	218
June	131
July	163
August	177
September	202
October	151
November	155
December	151

Step 1: Determining the Universe of Discourse using formula (1).

$$U = [D_{min} - D_1 ; D_{max} + D_2]$$
$$= [131 - 0 ; 220 + 0]$$
$$= [131 ; 220]$$

Step 2: Formation of Intervals.
Determining the number of intervals using formula (2).

$$n = 1 + 3{,}322 \log N$$
$$= 1 + 3{,}322 \log (12)$$
$$= 4{,}5850 \text{ (dibulatkan menjadi 5)}$$

Determining the interval length using formula (3).

$$p = \frac{p = [(D_{max} + D2) - (D_{min} - D1)]}{n}$$
$$= \frac{[(220 + 0) - (131 - 0)]}{5}$$
$$= 17{,}8$$

Fuzzy intervals of the fuzzy Universe of Discourse using formula (4) with results as shown in Table 2.

Table 2: Interval of Fuzzy Sets

No	Interval (u)	Midpoint value (m)
1	[131;148,8]	139,9
2	[148,8;166,6]	157,7
3	[166,6;184,4]	175,5
4	[184,4; 202,2]	193,3
5	[202,2; 220]	211,1

Step 3: Fuzzy Set Formation
The formation of fuzzy sets is done using formula (5).

$$A_1 = \left\{1/u_1 + 0{,}5/u_2 + 0/u_3 + 0/u_4 + 0/u_5\right\}$$
$$A_2 = \left\{0{,}5/u_1 + 0{,}1/u_2 + 0{,}5/u_3 + 0/u_4 + 0/u_5\right\}$$
$$A_3 = \left\{0/u_1 + 0{,}5/u_2 + 1/u_3 + 0{,}5/u_4 + 0/u_5\right\}$$
$$A_4 = \left\{0/u_1 + 0/u_2 + 0{,}5/u_3 + 1/u_4 + 0{,}5/u_5\right\}$$
$$A_5 = \left\{0/u_1 + 0/u_2 + 0/u_3 + 0{,}5/u_4 + 1/u_5\right\}$$

The results of data fuzzification in Table 3 are denoted in linguistic numbers as follows.

Table 3: Fuzzification

Month	Quality	Fuzzification
January	174	A3
February	172	A3
March	220	A5
April	211	A5
May	218	A5
June	131	A1
July	163	A2
August	177	A3
September	202	A4
October	151	A2
November	155	A2
December	151	A2

Step 4: Fuzzy Logical Relationship (FLR), the results are as shown in Table 4.

Table 4 : The result of Fuzzy Logic Relationship (FLR)

Month	Quality	FLR
January	174	-
February	172	A3 → A3
March	220	A3 → A5
April	211	A5 → A5
May	218	A5 → A5
June	131	A5 → A1
July	163	A1 → A2
August	177	A2 → A3
September	202	A3 → A4
October	151	A4 → A2
November	155	A2 → A2
December	151	A2 → A2

Step 5: Fuzzy Logical Relationship Group (FLRG) as shown in table 5.

Table 5: Fuzzy Logical Relationship Group (FLRG)

Grup	Fuzzy Logical Relationship Group
1	→ A2
2	→ A2, A3
3	→ A3, A4, A5
4	→ A2
5	→ A1, A5

Step 6: Forecasting.
Forecasting is done using formula (6). Table 6 shows the results of the forecast for the next 3 months from January to March 2024.

Table 6: Forecasting Results

Period	FLRG	Forecasting
Januari 2023	A2 → A2, A3	166,6
Februari 2023	A3 → A3, A4, A5	193,3
Maret 2023	A3 → A3, A4, A5	157,7

3.1. System Design

Figure 1 represents a use case diagram depicting the interaction between the admin and the user.

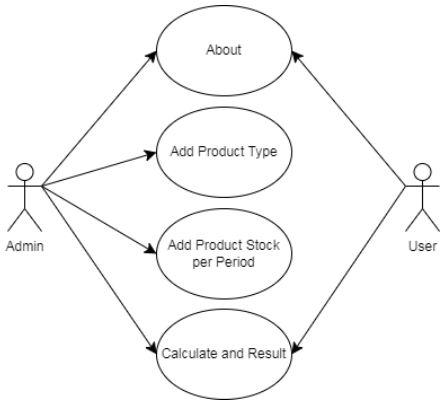

Fig. 1: Usecase

As an admin, you have full access to all features and functions within the system. This system allows the admin to view information about

the application, add product types, add product stock, perform calculations, and view the results. On the other hand, users have limited access to some features and functions within the system. Users can view information about the application, perform calculations, and view the results.

4. Implementation

4.1. System Implementation

System implementation is the process of creating a system to predict the sales of household chemical products.

1. Login Page
   The admin's initial page of the application can only be accessed after the user enters their username and password on the login page. Upon successful login, the user will be redirected to the main page of the application. Figure 2 shows the appearance of the login page.

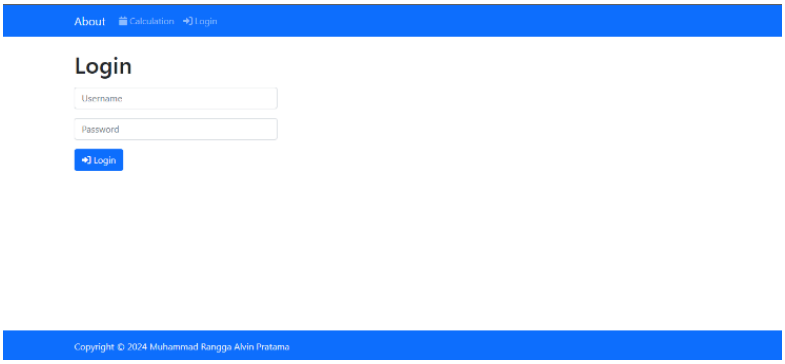

Fig. 1: Login page

2. Home Page
   The home page in Figure 3 is the initial page displayed after the admin successfully logs into the system.

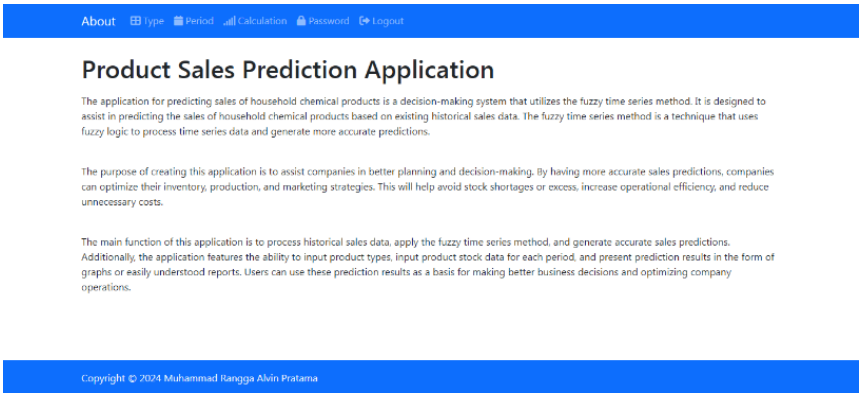

Fig. 2: Homepage

3. Product Type Input
   Figure 4 represents the page used to add product types.

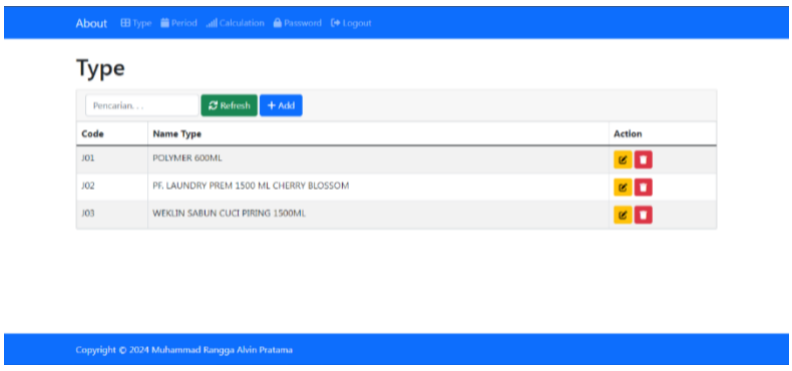

Fig. 3: Product category page

4. Product Stock Input
   The form shown in Figure 5 is used to add, edit, and delete product stock data that will be used in sales prediction or forecasting calculations.

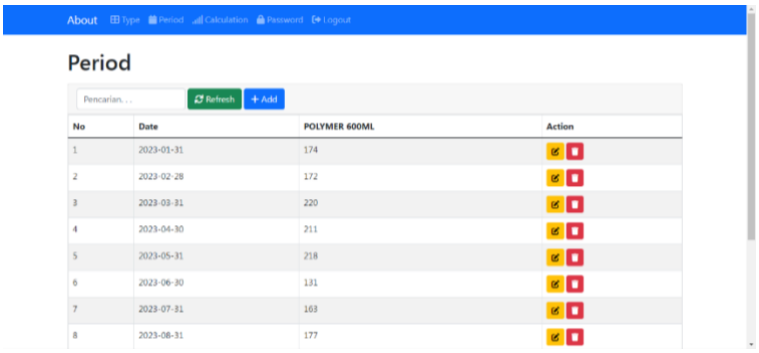

Fig. 4: Product stock page

5. Prediction Page
   The calculation page uses the fuzzy time series method implemented by converting it into the PHP language. On this page, users can enter the data period and prediction period to be calculated using the fuzzy time series method. The calculation page, as shown in Figure 6, is used to perform prediction calculations based on product type, start date, end date, and the desired period.

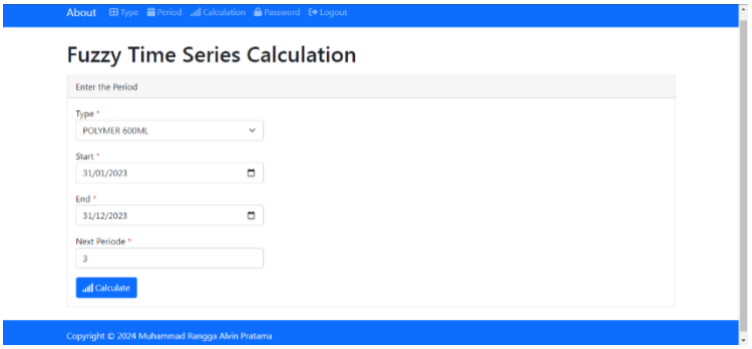

Fig. 5: Calculation page

6. Results
   The display in Figure 7 shows the calculation results in the form of a table and a graph, according to the specified period.

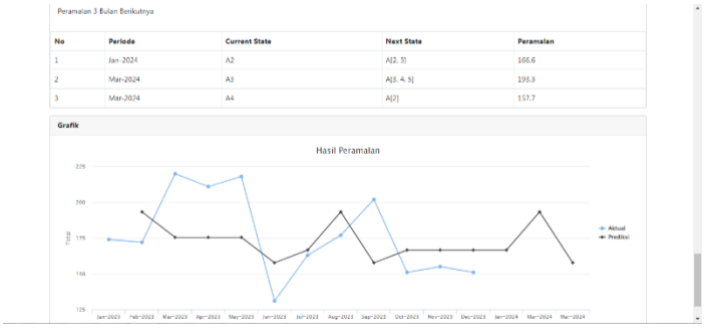

Fig. 6: Calculation result page

4.2. Testing

The system testing is conducted in two stages: functional testing using black box testing and validity testing. Functional testing is performed on the admin login form, accessing the homepage, inputting product types, inputting product stock, and accessing the prediction page with successful test results. Validity testing is done using MAPE (Mean Absolute Percentage Error) by using formula (7). Table 7 represents the calculation results of MAPE.

Table 7: The result of MAPE

Periode	Kualitas	Prediksi	PE Absolut
Jan-2023	174		
Feb-2023	172	193,3	0,1238
Mar-2023	220	175,5	0,2023
Apr-2023	211	175,5	0,1682
Mei-2023	218	175,5	0,195
Jun-2023	131	157,7	0,2083
Jul-2023	163	166,6	0.0221
Agust-2023	177	193,3	0.0921

Sep-2023	202	157,7	0.2193
Okt-2023	151	166,6	0.1033
Nov-2023	155	166,6	0.0748
Des-2023	151	166,6	0.1033
		Jumlah	**1,508**

Calculation of MAPE

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{X_t - F_t}{X_t} X\ 100\%\right|$$

$$= \frac{1{,}51}{11} X\ 100\%$$

$$= 13{,}71\ \%$$

From Table 7, the MAPE value obtained is 13.71%. Therefore, the forecasting using the fuzzy time series method indicates that the forecasting results are good.

5. Conclusion

The research conducted has successfully achieved the research objectives in developing a web-based sales prediction system using the fuzzy time series method. This system is used to determine the production quantity and stock inventory by predicting the product demand in the previous month. The results of the system testing in terms of functionality show that the data is accepted and processed successfully. Additionally, the validity testing using Mean Absolute Percentage Error (MAPE) indicates that the forecasting system using the fuzzy time series method produces an error rate of 13.71%, which can be categorized as a good forecasting result.

References

[1] I. S. Synthia Catur Wahyuni, Deni Arifianto, "Peramalan Jumlah Penduduk Miskin Di Pulau Jawa Menggunakan Metode Fuzzy Time Series Chen," *Smart Teknol.*, vol. 3, no. 5, pp. 133–139, 2022.

[2] S. Lestari and S. Yurinanda, "Prediksi Pajak Pertambahan Nilai pada Penyediaan Jasa dengan Metode Fuzzy Time Series Model Chen," *Euler J. Ilm. Mat. Sains dan Teknol.*, vol. 11, no. 2, pp. 267–281, 2023, doi: 10.37905/euler.v11i2.22724.

[3] M. Muhammad, S. Wahyuningsih, and M. Siringoringo, "Peramalan Nilai Tukar Petani Subsektor Peternakan Menggunakan Fuzzy Time Series Lee," *Jambura J. Math.*, vol. 3, no. 1, pp. 1–15, 2021, doi: 10.34312/jjom.v3i1.5940.

[4] A. I. Hamdani, Y. Agus Pranoto, and N. Vendyansyah, "Penerapan Metode Fuzzy Time Series Untuk Prediksi Penjualan Berbasis Web Pada CV. AGVA Kota Pasuruan," *JATI (Jurnal Mhs. Tek. Inform.*, vol. 4, no. 1, pp. 35–41, 2020, doi: 10.36040/jati.v4i1.2433.

[5] Andres and Erlin, "Peramalan Jumlah Penjualan Tepung Pada UD. Citra Pekanbaru Menggunakan Fuzzy Time Series," *J. Mhs. Apl. Teknol. Komput. dan Inf.*, vol. 4, no. 3, pp. 128–134, 2022, [Online]. Available: www.bps.go.id

[6] M. Ula, B. -, D. Yulisda, B. -, and A. Bintoro, "Application of the Fuzzy Time Series Model in Clothing Material Stock Forecasting," *J. Sist. Inf. dan Ilmu Komput. Prima(JUSIKOM PRIMA)*, vol. 6, no. 1, pp. 56–61, 2022, doi: 10.34012/jurnalsisteminformasidanilmukomputer.v6i1.2862.

[7] C. Mashuri *et al.*, "Sistem Inventory Manajemen Dengan Metode Safety Stock," *Semin. Nas. SAINSTEKNOPAK Ke-5 LPPM UNHASY TEBUIRENG JOMBANG 2021*, pp. 1–9, 2021.

[8] R. K. Pratama, A. A. Karim, and C. D. P. Hertadi, "Perencanaan Stok Pengaman dan Titik Pemesanan Ulang dengan Metode Time Series pada Perusahaan Furniture Di Kalimantan," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 2, no. 3, pp. 200–211, 2023, doi: 10.55826/tmit.v2i3.256.

[9] N. H. Pajriati, E. Kurniati, and D. Suhaedi, "Penerapan Metode Average Based Fuzzy Time Series Lee Untuk Peramalan Harga Emas Di PT. X," *J. Ris. Mat.*, vol. 1, no. 1, pp. 73–81, 2021, doi: 10.29313/jrm.v1i1.221.

[10] Yehoshua, Kustanto, and V. R. Tri, "Prediksi Penjualan Produk Promo PT. Unilever, Tbk Menggunakan Metode Fuzzy Time Series," *J. Inf. Politek. Indonusa Surakarta*, vol. 6, pp. 51–57, 2020.

[11] A. Taufiq, E. Yulianingsih, and ..., "Peramalan jumlah penjualan kendaraan menggunakan metode fuzzy time series studi kasus pt. Astra Internasional tbk-tso Cabang Palembang (Auto 2000 Plaju)," *Bina Darma …*, pp. 298–306, 2019.

[12] M. Risnawati, W. Syafmen, and B. Mardhotillahs, "jurnal Prediksi Penjualan Emas di PT. Pegadaian Area Jambi Menggunakan Fuzzy Time Series Cheng," *J. Ekon. Dan Stat. Indones.*, vol. 3, no. 1, pp. 70–84, 2023, doi: 10.11594/jesi.03.01.06.

[13] F. Chellai, "Forecasting using Fuzzy Time Series," no. July, pp. 1–19, 2022, doi: 10.13140/RG.2.2.32910.23367.

[14] I. Nabillah and I. Ranggadara, "Mean Absolute Percentage Error untuk Evaluasi Hasil Prediksi Komoditas Laut," *JOINS (Journal Inf. Syst.*, vol. 5, no. 2, pp. 250–255, 2020, doi: 10.33633/joins.v5i2.3900.

[15] M. B. S. Junianto, "Fuzzy Inference System Mamdani dan the Mean Absolute Percentage Error (MAPE) untuk Prediksi Permintaan Dompet Pulsa pada XL Axiata Depok," *J. Inform. Univ. Pamulang*, vol. 2, no. 2, p. 97, 2017, doi: 10.32493/informatika.v2i2.1511.