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Forecasting The Number of Health Center Patient Arrivals Using Cheng's Fuzzy Time Series Method

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ABSTRACT

Forecasting is the science and art of estimating future events. Forecasting is useful in predicting events covering the short, medium and long term. In the historical data that will be taken and project it into the future so that it involves a forecast, the forecasting involvement uses the amount of data that has been taken. The number of patient arrivals at the health center has increased and decreased every month, this increase and decrease can affect the facilities provided by the health center, so this study intends to do forecasting on the number of health center patient arrivals to meet the service facilities that must be provided. This study was carried out from January 2022 to December 2023 at the Medan Amplas Health center by utilizing Cheng's Fuzzy Times Series method, therefore the results of this calculation were 70,464 patients by getting a MAPE value of 8%.

Keyword : Cheng's Fuzzy Time Series Method; Forecasting; Number of Patient

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1. INTRODUCTION

The forecasting process can be carried out by utilizing several methods including trend analysis, regression, statistical analytics, and mathematical models. The results of the forecasting process can be used in planning, decision making, and control. In general, forecasting provides important information needed to reduce risk, and increase efficiency in business processes (Helmi & Fauzan, 2023). Doing forecasting in order to know future demand needs, the thing that must be observed is the state of the environment because consumer desires change quickly (Suzuki & Denny, 2010). Forecasting is usually required to estimate what will happen in the future, so that decision makers can plan for the future or beyond (Hsb *et al.*, 2021).

This forecast predicts the number of patient arrivals at the health center. Health centers are considered as one of the forms of health provider units found in each sub-district. Health center is considered a unit in health development as a form of functional implementation, as well as the first level of organizing its activities in a health service center, integrated, and sustainable in a certain area for people living in an area (Azwar, 2001). A decision support system used in establishing rank order, choice and detection with regard to efficient alternative decisions (Widyasari *et al.*, 2019).Forecasting is useful for knowing the number of facilities that will be provided at the public health center (Husein *et al.*, 2024). Forecasting also has several kinds of methods that can be applied in estimating the future such as moving averages which require stationary data patterns, autoregressive integrated moving average (ARIMA) must have trend data in the data collection pattern, single exponential smoothing also requires stationary data patterns, Double exponential smoothing holts must have trend data patterns, trend analysis must have linear data patterns (Mahrus *et al.*, 2021). When using several data forecasting methods must have special assumptions in solving the data collection, many researchers have improved new forecasting methods whose assumptions do not require special assumptions in data collection, one example is Cheng's fuzzy time series (Nurkhasanah *et al.*, 2015). fuzzy time series is a method proposed to solve problems in forecasting when the historical data is in the form of linguistic values (Laily *et al.*, 2023). The fuzzy time series method has been proven to improve traditional methods such as handling data changes, subjective uncertainty in the data. It has the advantage of not requiring the fulfillment of assumption tests. Generally, a fuzzy set is defined as a class of numbers with less clear boundaries. Among the many fuzzy time series methods, Cheng's fuzzy time series is the one that was developed (Lestari, n.d.).

This forecasting applies historical past data with Cheng's fuzzy time series method so as to get a forecast of the number of future patient arrivals. In general, participation in the interval 0 to 1 and fuzzy logic states how far a value is wrong and how far a value is true (Kusumadewi, 2012). Of the many developments in fuzzy methods, one of them is Cheng's fuzzy time series (Sumartini & Hayati, 2017). The chen model has a weakness because it does not have a smaller weight and often emphasizes repetition, then the cheng model is improved in order to optimize the chen model which has the advantage of getting smaller weights and paying attention to repetition, by using the adapter value (Cheng *et al.*, 2008) adaptive itself is a concept and situation to a logical pattern of thought .

Cheng's fuzzy time series in determining the calculation utilizes a fuzzy logical relationship (FLR) through giving weight to all ties with reference to the same time sequence (Rizki, 2023). So that in this study, it predicts the number of patient arrivals at the Health center using Cheng's Fuzzy Times Series method at the Medan Amplas health center.

2. RESEARCH METHOD

2.1 Research Stages

This study utilizes a quantitative type of approach to research by collecting data that can be measured with mathematics. The type of data utilized is secondary data which is obtained through monthly patient visits. The research was conducted from January 2022 to December 2023 with the amount of data conducted for 24 months on the Medan amplas puskesmas patient visit data every month. Data analysis is carried out every month from the number of patient visits, the visit data studied starts from patient visit data, starting from general examination services, elderly examination services, child examiners, dental and oral services, Lung TB, and Immunizations. This study was carried out in a number of stages including:

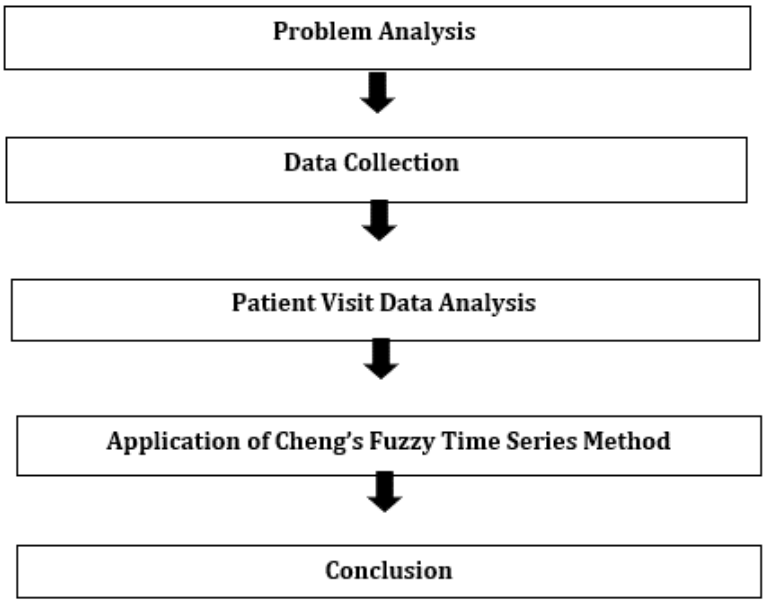

Figure 1. Research Model

3.2Stages of Applying The Fuzzy Time Series Cheng's Method

This research uses the Cheng fuzzy time series method, the research uses this method because the time series method is for use in short-range forecasting using previous data in order to estimate future data. In general, fuzzy can be said to be an equal restriction on the class of numbers if U is a universal set so that the membership function is:

$$A_i = \mu_{A_i}(u_i) \,|u_i + \cdots + \mu_{A_p}(u_p) \,|u_p \qquad (1)$$

Where $\mu_A(u_i)$ is the degree of membership of (u_i) to A_i and $\mu_A(u_i) \epsilon [0,1]$ and $1 \leq i \leq p$.

By giving weight to each relationship based on the same time sequence, Cheng's fuzzy time series utilizes Fuzzy Logical Relationship (FLR) to determine the calculation. There are several steps involved in completing Cheng's fuzzy time series forecasting, namely (Fahmi & Sudarno, 2015):

1. Determine The Universes of the actual data
$$U = [d_{min}, d_{max}] \quad (2)$$
2. Using Interval Width using frequency distribution
   a. Find the range value
   $$R = [d_{min} - d_{max}] \quad (3)$$
   b. Find the number of class intervals using the struges equation
   $$K = 1 + 3{,}322 \times \log n \quad (4)$$
   c. Finding the width of the interval
   $$I = \frac{\text{Range data (R)}}{K} \quad (5)$$
   d. Find the center value (m)
   $$m_1 = \frac{\text{Batas atas} + \text{Batas bawah}}{2} \quad (6)$$
3. Fuzzyfication of Data
   Define the fuzzy set A_1 and then fuzzyfy it to the actual data being analyzed. Assuming $A_1, A_2, A_3, \dots, A_t$ is a fuzzy set with linguistic values, so the definition of the fuzzy set on the universe of speech U is:
$$A_1 = \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \cdots + \frac{0}{u_p}$$
$$A_2 = \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \frac{0}{u_4} + \cdots + \frac{0}{u_p}$$
$$A_3 = \frac{0}{u_1} + \frac{0{,}5}{u_2} + \frac{1}{u_3} + \frac{0{,}5}{u_4} + \cdots + \frac{0}{u_p}$$
$$\dots$$
$$A_p = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \cdots + \frac{0{,}5}{u_{p-1}} + \frac{0}{u_p} \quad (7)$$
4. Referring to the actual data create a Fuzzy Logical Relationship (FLR) table. FLR is connoted by $A_i \rightarrow A_j$.
5. Define fuzzy logical relationship group (FLRG)
6. The standardized weighting matrix (W^) is multiplied by (m_1) to determine the defuzzified forecasting value and the forecasting result value, thus Forecasting results:
$$F_i = W_{i1}(m_1) + W_{i2}(m_2) + \cdots + W_{ip}(m_p) \quad (8)$$

Where F_1 is the forecasting result, with:
$$F_{ij} = \frac{W_{ij}}{\sum_{j=1}^{p} W_{ij}} \quad (9)$$

The value of (F_1) is the middle value of u_i, or determined by m_1, if the fuzzyfication result of the i-th period is A_1 and A_i has no FLR value in FLRG with the situation $A_i \rightarrow \emptyset$, A_i, where the maximum value of the membership degree (Irawan, 2014).

7. Mean Absolute Percentage Error (MAPE) can be used to determine the accuracy of the forecasting results, with the formula:
$$MAPE = \frac{\sum_{t=1}^{n} \frac{X_t - F_t}{X_t}}{n} \times 100\% \quad (10)$$

Then the forecasting accuracy can be calculated by
$$\text{forecasting accuracy} = 100\% - MAPE \quad (11)$$

is a lot of data, where X_t is the actual data for the tth period, F_t is the value of the forecasting results for the tth period, n is a lot of data.

Table 1. weighting

c	Results
$< 10\%$	Very Good
$10\% - 20\%$	Good

$> 20\%$	Good Enough

In the weighting table, it is done for research results because if a model has superior performance if the MAPE value is less than 10% and has good value if the MAPE value is in the range of 10% to 20%.

3. RESULTS AND DISCUSSION

he number of patients visiting the Amplas puskesmas every month for 2 years or equal to 24 months is the data examined in this study. The table below displays the amount of patient arrival data.

Table 2. Data on the number of patient arrivals

Year	Month	Number of Patient	Year	Month	Number of Patient
2022	January	2680	2023	January	2784
	February	2357		February	2308
	March	2998		March	2620
	April	2763		April	2039
	May	2499		May	3301
	June	2857		June	2814
	July	2666		July	3343
	August	2988		August	3665
	September	3356		September	3587
	October	2847		October	3386
	November	2985		November	3085
	Desember	2370		Desember	3071

The table above displays the number of patient arrivals at the health center every month, with the smallest number of patient arrivals in April 2023 totaling 2,039 patients and data on the largest number of patient arrivals in August 2023 totaling 3,665 patients. After knowing the actual data, then make the descriptive data below:

Table 3. Descriptive Statistics on the Arrival Number of Patients at the Health Center

Statistic Descriptive	Results
Total Data (n)	24
Maximum Value	3665
Minimum Value	2039
Average	2852

After determining the descriptive value, the next process is to process the data using Cheng's Fuzzy Time Series method as follows:

1. Determine The Universes of the actual data

$$U = [2.039,\ 3.665]$$

2. Using Interval Width using frequency distribution
   a. Find the range value

$$R = [3.665 - 2.039] = 1.626$$

   b. Find the number of class intervals using the struges equation

$$K = 1 + 3{,}322 \times \log n$$
$$= 1 + 3{,}322 \times \log 24$$
$$= 5{,}585 \approx 6$$

   c. Finding the width of the interval

$$I = \frac{\text{Range(R)}}{K}$$
$$= \frac{1626}{5{,}585}$$
$$= 291{,}137$$

After knowing the number of class intervals of 6 classes and the interval width of 291.137. So that it can be known the value of u_1 to u_2 which is from the universe set u_1 with the middle value (m), found is in the table below.

Tabel 4. Universal Set Interval

u_i	Lower Limit	Upper Limit	Center Value (m)
u_1	2.039	2.330,137	2.184,57
u_2	2.330,137	2.621.274	2.457,71
u_3	2.621, 274	2.912,411	2.766,85
u_4	2.912,411	3.203,548	3.062,48
u_5	3.203,548	3.494,685	3.349,11
u_6	3.494,685	3.785,822	3.640,25

In the table above, the values of u_1 to u_6 can be recognized from the upper limit to the lower limit. The lower limit value is generated from the lower limit value at $u_1$plus the value of the interval width above and so on until the lower limit value of u_6. The center value is also obtained in equation (6) above.

3. Data Fuzzyfication

$A_p$fuzzy set with actual data from the number of intervals of 6 class intervals. Where the fuzzy membership values include [0,1]. here is the fuzzy set:

$$A_1 = \frac{1}{u_1} + \frac{0,5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6}$$
$$A_2 = \frac{0,5}{u_1} + \frac{1}{u_2} + \frac{0,5}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6}$$
$$A_3 = \frac{0}{u_1} + \frac{0,5}{u_2} + \frac{1}{u_3} + \frac{0,5}{u_4} + \frac{0}{u_5} + \frac{0}{u_6}$$
$$A_4 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0,5}{u_3} + \frac{1}{u_4} + \frac{0,5}{u_5} + \frac{0}{u_6}$$
$$A_5 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0,5}{u_4} + \frac{1}{u_5} + \frac{0,5}{u_6}$$
$$A_6 = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0,5}{u_5} + \frac{1}{u_6}$$

For the fuzzyfication stage, it is carried out based on the previous interval, where the data will be converted into linguistic values A_n That's A_1 to A_6.

Table 5. Fuzzyfication Data

Year	Month	Number of Patient	Fuzzyfication	Year	Month	Number of Patient	fuzzyfication
	January	2680	A_3		January	2784	A_3
	February	2357	A_2		February	2308	A_1
	March	2998	A_4		March	2620	A_2
	April	2763	A_3		April	2039	A_1
	May	2499	A_2		May	3301	A_5
2022	June	2857	A_3	2023	June	2814	A_3
	July	2666	A_3		July	3343	A_5
	August	2988	A_4		August	3665	A_6
	September	3356	A_5		September	3587	A_6
	October	2847	A_3		October	3386	A_5
	November	2985	A_4		November	3085	A_4
	Desember	2370	A_2		Desember	3071	A_4

In table 5, it can be seen that the results of fuzzyfication on the arrival of puskesmas patients for January 2022 are 2,680 patients, grouped in the interval [2,621,274; 2,912,411] where the set data formed u_3 has a membership degree of 1 in the A_3 set, so the fuzzyfication data is in A_2.

4. Establishment of FLR and FLRG

To obtain the FLR value by identifying based on data from month to month that has been fuzzified before. Written with the notation $A_n \rightarrow A_m$. The following is the result of the FLR formation process on patient arrivals.

Table 6. Fuzzy Logic Relationship (FLR) Result

Year	Month	FLR	Year	Month	FLR
2022	January	$A_3 \rightarrow A_2$	2023	January	$A_2 \rightarrow A_3$
	February	$A_2 \rightarrow A_4$		February	$A_3 \rightarrow A_1$
	March	$A_4 \rightarrow A_3$		March	$A_1 \rightarrow A_2$
	April	$A_3 \rightarrow A_2$		April	$A_2 \rightarrow A_1$
	May	$A_2 \rightarrow A_3$		May	$A_1 \rightarrow A_5$
	June	$A_3 \rightarrow A_3$		June	$A_5 \rightarrow A_3$
	July	$A_3 \rightarrow A_3$		July	$A_3 \rightarrow A_5$
	August	$A_3 \rightarrow A_4$		August	$A_5 \rightarrow A_6$
	September	$A_4 \rightarrow A_5$		September	$A_6 \rightarrow A_6$
	October	$A_5 \rightarrow A_3$		October	$A_6 \rightarrow A_5$
	November	$A_3 \rightarrow A_4$		November	$A_5 \rightarrow A_4$
	Desember	$A_4 \rightarrow A_2$		Desember	$A_4 \rightarrow A_4$

In table 6 it can be seen that in January 2022 and February 2022 both have fuzzyfications namely A_3 and A_2, so FLR can be obtained namely $A_3 \rightarrow A_2$

Furthermore, the formation of FLRG is obtained from the results of FLR by grouping it with the same membership and repeating it can be made into one group. The number of parts of the same group in FLRG is in the following table.

Table 7. FLRG weighting

Group	Relationship	Total
A_1	A_2 (1), A_5 (1)	2
A_2	A_1 (1), A_3 (2), A_4 (1)	4
A_3	A_1 (1), A_2 (2), A_3 (2), A_4 (2), A_5 (1)	8
A_4	A_2 (1), A_3 (1), A_4 (1), A_5 (1)	4
A_5	A_3 (2), A_4 (1), A_5 (1)	4
A_6	A_5 (1), A_6 (1)	2

Table 7 is the FLRG weighting process for each group. In determining a grouping can be obtained from the number of FLRs. Suppose there are 2 groups A_1, namely $A_1 \rightarrow A_2$ and $A_1 \rightarrow A_5$ have a lot of weight on $A_1 \rightarrow A_2$ because in the FLR table there is only 1 in common so it has a weight of 1, as well as in $A_1 \rightarrow A_5$ because there is only 1 similarity so it has a weight of 1. The same applies to the next weighting.

5. Calculating the Prediction Accuracy Value

After weighting, the calculation is carried out by multiplying the middle value using a standardized weight matrix, using the formula in equation (8). So the calculation is done as follows:

$$F_i = W_{i1}\hat{}(m_1) + W_{i2}\hat{}(m_2) + \cdots + W_{ip}\hat{}(m_p)$$

$$F_1 = W_2(m_2) + W_5(m_5)$$
$$= \frac{1}{2}\ (2.184{,}57) + \frac{1}{2}(3.349{,}11)$$
$$= 2.912$$

$$F_2 = W_1(m_1) + W_3(m_3) + W_4(m_4)$$
$$= \frac{1}{4}(2.184{,}57) + \frac{2}{4}(2.776{,}85) + \frac{1}{4}(3.062{,}48)$$
$$= 2.700$$

$$F_3 = W_1\ (m_1) + W_2\ (m_2) + W_3\ (m_3) + W_4\ (m_4) + W_5(m_5)$$
$$= \frac{1}{8}(2.184{,}57) + \frac{2}{8}(2.457{,}71) + \frac{2}{8}(2.776{,}85) + \frac{2}{8}(3.062{,}48) + \frac{1}{8}(3.640{,}25)$$
$$= 2.807$$

$$F_4 = W_2\ (m_2) + W_3\ (m_3) + W_4\ (m_4) + W_5\ (m_5)$$
$$= \frac{1}{4}(2.457{,}71) + \frac{1}{4}(2.776{,}85) + \frac{1}{4}(3.062{,}48) + \frac{1}{4}(3.640{,}25)$$
$$= 2.989$$

$$F_5 = W_3(m_3) + W_4(m_4) + W_6(m_6)$$
$$= \frac{2}{4}(2.776{,}85) + \frac{1}{4}(3.062{,}48) + \frac{1}{4}(3.640{,}25)$$
$$= 3.064$$

$$F_6 = W_5(m_5) + W_6(m_6)$$
$$= \frac{1}{2}(3.349{,}11) + \frac{1}{2}(3.640{,}25)$$
$$= 3.495$$

So that the above calculations to determine predictions on fuzzyfication, predictions on fuzzyfication are attached in table 8.

Table 8. Prediction Result on teh Number of Patient Arrivals

year	Month	Number of Patient	Fuzzyfication	Predicted Value
2022	January	2.680	A_3	2.807
	February	2.357	A_2	2.700
	March	2.998	A_4	2.989
	April	2.763	A_3	2.807
	May	2.499	A_2	2.700
	June	2.857	A_3	2.807
	July	2.666	A_3	2.807
	August	2.988	A_4	2.989
	September	3.356	A_5	3.064
	October	2.847	A_3	2.807
	November	2.985	A_4	2.989
	Desember	2.370	A_2	2.700
2023	January	2.784	A_3	2.807
	February	2.308	A_1	2.912
	March	2.620	A_2	2.700
	April	2.039	A_1	2.912
	May	3.301	A_5	3.064
	June	2.814	A_3	2.807
	July	3.343	A_5	3.064
	August	3.665	A_6	3.495
	September	3.587	A_6	3.495
	October	3.386	A_5	3.064
	November	3.085	A_4	2.989
	Desember	3.071	A_4	2.989

From table 8, the results of the prediction of the number of arrivals of puskesmas patients in December 2022 were 2,700 patients, as well as in December 2023 as many as 2,989 patients These results are obtained based on FLR and weighting.

Furthermore, from table 8, it can be seen in the form of a graph comparing the actual data and the estimated data on the total arrival of puskesmas patients.

6. Accuracy of Prediction Results

The accuracy of the prediction results of the number of arrivals of health center patients can be calculated by comparing predicted data and actual data, we can determine the accuracy of the prediction results of the number of arrivals of health center patients. This can be done by looking for errors in the data. The more likely the prediction data is used, the lower the error rate in the projected data. Mean Absolute Percentage Error (MAPE) can be used as a determinant of how accurate the prediction results are.

Table 9. Accuracy of Prediction Results for the Number of Patient Arrivals at the Health Center

Year	Month	Number Of Patient	Fuzzyfication	Predicted Value	$\lvert X_t - F_t \rvert$	$\left\lvert \frac{X_t - F_t}{X_t} \right\rvert$
2022	January	2.680	A_3	2.807	127	0,047
	February	2.357	A_2	2.700	343	0,145
	March	2.998	A_4	2.989	9	0,003
	April	2.763	A_3	2.807	44	0,016
	May	2.499	A_2	2.700	201	0,08
	June	2.857	A_3	2.807	50	0,161
	July	2.666	A_3	2.807	141	0,053
	August	2.988	A_4	2.989	1	0,0003

	September	3.356	A_5	3.064	292	0,087
	October	2.847	A_3	2.807	40	0,014
	November	2.985	A_4	2.989	4	0,0013
	Desember	2.370	A_2	2.700	330	0,139
	January	2.784	A_3	2.807	23	0,008
	February	2.308	A_1	2.912	604	0,262
	March	2.620	A_2	2.700	80	0,0306
	April	2.039	A_1	2.912	873	0,428
	May	3.301	A_5	3.064	237	0,072
2023	June	2.814	A_3	2.807	7	0,002
	July	3.343	A_5	3.064	279	0,083
	August	3.665	A_6	3.495	170	0,046
	September	3.587	A_6	3.495	92	0,0256
	October	3.386	A_5	3.064	322	0,096
	November	3.085	A_4	2.989	96	0,03
	Desember	3.071	A_4	2.989	82	0,026
Total		69.369				1,8558

Based on table 9, it can be seen that the value of the calculation on the actual data to achieve the forecasting value, the accuracy of the forecasting results can be calculated using the Mean Absolute Percentage Erroe (MAPE) in equation 10, then:

$$\text{MAPE} = \frac{\sum_{t=1}^{n} \frac{X_t - F_t}{X_t}}{n} \times 100\%$$
$$= \frac{1{,}8558}{24} \times 100\%$$
$$= 7{,}7\%$$

When a mathematical model has superior performance if it has a MAPE value of less than 10% and when it has a MAPE value in the range of 10% to 20% it is said to have a good performance value. Therefore, the accuracy of the forecasting results or can be said to be a prediction can be calculated using equation 11, as follows:

$$\text{forecasting accuracy} = 100\% - \text{MAPE}$$
$$= 100\% - 8\%$$
$$= 92{,}3\%$$

Then an error value of 7.7% can be obtained and the accuracy of the forecasting results of the number of patient arrivals at the health center obtained a value of 92.3%.

4. CONCLUSION

The application of the fuzzy time series Cheng method to the implementation of the total forecast of patient arrivals at the Amplas health center produces a very good prediction value with the results of a MAPE value of less than 10% with a research MAPE value of 7.7% and has a forecasting accuracy of 92.3%. So, the number of arrivals of puskesmas patients who are predicted to visit the Medan Amplas puskesmas using the fuzzy time series cheng method is 33,166 patients in 2022, and in 2023 as many as 36,298 patients. The total number of predictions in 2022 to 2023 has a patient visit of 70,464 patients, while the value of the number of patient arrivals in the actual data is 69,369 patients. Therefore, it is estimated that there will be an increase in the number of patient arrivals at the sandpaper puskesmas from 2022 to 2023 by 1,095 patients.

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