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Application of Fuzzy Time Series Chen and Cheng Methods to Forecast Profit in a State-Owned Insurance Company

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ABSTRACT

PT. Taspen (Persero) as a state-owned enterprise in the services sector needs to analyze financial performance to understand the fluctuations in quarterly profit in 2022. This study aims to compare the accuracy level of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods in predicting the profit of PT Taspen (Persero) in the period May 2023 to July 2024. The data used is monthly actual profit data that shows a fluctuating pattern with the highest peak in December 2023. The forecasting results using the Chen method show a more stable prediction pattern and tend to experience overestimation in some periods, such as November 2023 and May 2024. Meanwhile, Cheng's method produces a forecast pattern that is closer to actual data, although there is an unrealistic spike in February 2024. Based on the results of forecasting accuracy measurement, Cheng's method has a MAPE value of 0.603, MSE of 2.684, and MAE of 1,172.53, while Chen's method has a MAPE value of 0.674, MSE of 3.303, and MAE of 1,319.29. These values show that Cheng's method has a higher level of accuracy than Chen's, so it can be recommended as a more reliable method for projecting PT Taspen (Persero's profit).

Keywords: PT. Taspen (Persero), Fuzzy Time Series Chen, Fuzzy Time Series Cheng, Profit Prediction.

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1. INTRODUCTION

A business generally has the same goal, which is to impede the profit that is made as a measure of the success of a business in carrying out its activities. Profit is the amount of income from sales that has been followed by the business, and also to measure the performance of the business (Eirmaya eit al., 2016). Measuring the performance of a company, one of which can be used in insurance companies. One The insurance company in Indonesia is PT. Taspen (Persero) is a state-owned enterprise that is a subsidiary of insurance for old age savings and investment for ASN as well as a government official.

Because profit data fluctuates in certain periods, this can affect the performance of PT Taspen (Persero). So, it is necessary to carry out a forecast that will function to know the prospects of PT Taspen (Persero) and be able to predict the dividends that will be received in the future. Forecasting can help the company's ability to continue to develop its business in assessing management performance, help estimate representative profit ability in the long term, and can assess risks in investing or credit (Admirani, 2018).

Forecasting is a technique to make a value in the future by paying attention to past data and current data. The quantitative forecasting method is divided into two types of models, namely the regression model and the time series model (Aswi & Sukarna, 2006). One of the time series forecasting methods is Fuzzy Time Series (FTS). Fuzzy Time Series uses the concept of fuzzy in forecasting, data relationships, and time intervals to form fuzzy relationships. The determination of intervals has an effect on the difference in forecasting. The Fuzzy Time Series method is a forecasting method introduced by Song and Chissom (1993) using the concept of fuzzy; fuzzy logic, fuzzy sets, and linguistic variables. Vague data is explained with linguistic values (Habinuddin, 2022). Many Fuzzy Time Series methods have been developed, including the Fuzzy Time Series Chen method, and the Fuzzy Time Series Cheng method (Kusumadewi and Purnomo, 2013).

The advantage of Chen's Fuzzy Time Series method is that it uses a basic approach that is easy to understand and apply, without requiring a deep understanding of fuzzy logic. This simplicity allows for

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faster and 3rd efficient implementation in a wide range of prediction applications (Chen, 1996). Meanwhile, the advantage of Fuzzy Time Series Cheng is that it provides more accurate prediction results, especially for time series data with more complex patterns. Cheng used more sophisticated fuzzy interval determination, which allowed the model to capture more information from the data (Arnita et al., 2020).

The stages of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods are illustrated in figure 1.

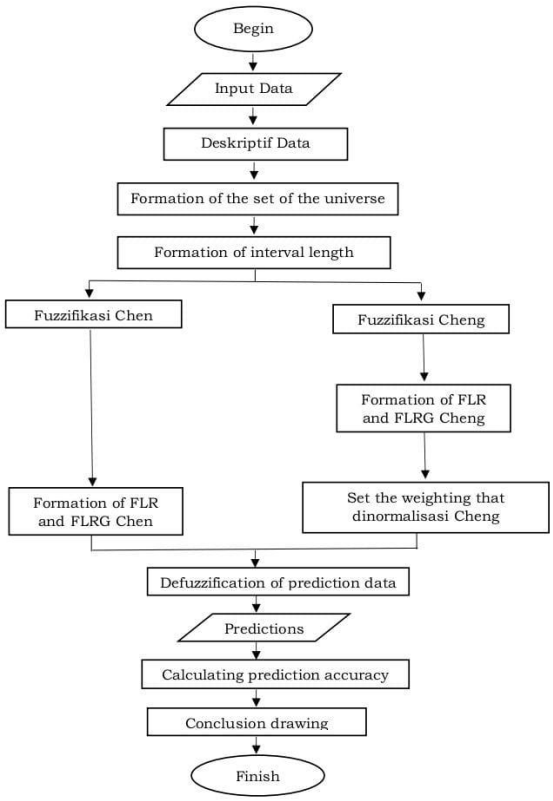

Figure 1. Illustrated method Fuzzy Time Series Chen and Fuzzy Time Series Cheng

Research using *Fuzzy Time Series* has been widely used, as has been researched by Pambudi et.al., (2018) to predict the number of fire spots as an identification of fire. The test was carried out to determine the accuracy of the prediction of the number of fire occurrences over the monthly and 10-day period.

The study by Sugumonrong et al., (2019) with gold price data for the period January 1, 2015 to December 31, 2017, obtained prediction results using *the Fuzzy Time Series method* where the average difference between the actual data and prediction data is no more than Rp. 2,850,- where the prediction uses *the fuzzy Time Series* method of *the Chen* algorithmIt is enough to use 1 data to predict the 2nd data which makes this method can be said to be accurate in predicting the price of gold.

In the study conducted by Arvie (2022), one of the methods to make predictions or forecasts was used, namely *the Fuzzy Time Series Cheng method*. The actual data used is Oil and Gas and Non-oil and Gas Import Forecasting from January 2019 to October 2021, and an import prediction process will be carried out from November 2021 to August 2024. Based on the results of the calculations that have been carried out using *Cheng's Fuzzy Time Series method*, a performance conclusion is produced that is said to be very good.

In this study, Chen's Fuzzy Time Series and Cheng's Fuzzy Time Series methods were used because they both offer different approaches to handling data. The chen method is known to be efficient and simple for data with stable patterns, while the cheng method has the advantage of handling more complex data through adaptive fuzzy interval determination. By comparing these two methods, the study aims to find out which method is the most accurate in predicting profits.

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Based on this background, this study was conducted to apply the Fuzzy Time Series Chen and Fuzzy Time Series Cheng methods in predicting the profit of PT. Taspen (Persero), and compared the accuracy level of the two methods with the title **"The Use of the Fuzzy Time Series Chen and Fuzzy Time Series Cheng Methods to Predict Profit at PT. Taspen (Persero)".**

2. RESEARCH METHOD

2.1 Fuzzy Time Series Chen

Chen (1996) developed the Fuzzy Time Series based on Song and Chissom (1993) with simple operations, the development of the Fuzzy Time Series method has complex matrix operations, and has a very large influence on the Fuzzy Time Series method, there are various models, namely the Song, Chissom, Chen and Lee models. The Fuzzy Time Series process of interval length will be determined first because the length of the interval will affect the prediction results, so the formation of a fuzzy relationship (FLR) will be appropriate.

The initial step in Fuzzy Time Series analysis is the formation of a universal set (U). In forming a universal set (U), the smallest (minimum) and largest (maximum) data from PT Taspen's profit data are required.Below will be explained the steps of the Fuzzy Time Series method using the Chen Algorithm:

Step 1. The formation of the set of the universe (U).

$$U = [D_{min} - D_1 \; ; \; D_{max} + D_2] \quad (1)$$

With
D_1 dan D_2 : Any number of positives
D_{min} : Smallest data from historical data
D_{max} : The largest data of historical data

Step 2. Interval formation

Dividing the set of the universe into intervals of equal distance. To find out the many intervals, you can use the Sturges formula as follows: (2)

$$K = 1 + 3{,}322\log(n)$$

With,
n : amount of historical data (observations)

After the number of intervals is obtained, then determine the length of the interval using the following formula. (3)

$$I = \frac{D_{max} - D_{min}}{Jumlah\ Interval}$$

So that it forms a number of linguistic values to represent a fuzzy set at intervals formed from the set of the universe (U). (4)

$$U = \{u_1, u_2, \dots, u_i\}$$

U : From the semen of Himpuna
u_i : the magnitude of the interval in , for $Ui = 1, 2, \dots, p$

Step 3. Define a *fuzzy* set

A fuzzy set is a class or group of objects with a continum of the degree of membership. Suppose U is a set of universes, with U=$\{u1,u2,\dots,ui\}$where ui is the possible value of U, then the linguistic variable Ai with respect to U can be formulated as follows.

$$A_i = \frac{\mu A_i(u_1)}{u_1} + \frac{\mu A_i(u_2)}{u_2} + \cdots + \frac{\mu A_i(u_k)}{u_k} \quad (5)$$

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The fuzzy set Ai has a membership function, namely μAi, so that $\mu A_i : U \rightarrow [0,1]$.If ,u-i. is a member of Ai, then $\mu A_i(u_i)$ is the degree of membership , u_i. to Ai (Brata, 2016).
The results of the membership degree are obtained from the following rules.

1. If the historical data of , F_t is included in , u_i then the value of the degree of membership for , u_i is 1, and , u_{i+1} is 0.5 and if it is not , u_i and , u_{i+1}it is declared zero.
2. If the historical data of , F_t. is included in , u_i, $1 \leq i \leq n$ then the value of the degree of membership for u_i. is 1, for u_{i-1} and , u_{i+1} is 0.5 and if it is not u_i, u_{i-1} and , u_{i+1} it is declared zero.
3. If the historical data of , F_t is included in , u_i., then the value of the degree of membership for , u_i. is 1, and , u_{i-1}. is 0.5 and if it is not , u_i. and , u_{i-1}. it is declared zero.

Step 4. Fuzzification of historical data
This stage determines the membership value of each fuzzy set of historical data. The input data is received and the system determines the value of its membership function and converts numerical variables (non-fuzzy variables) into linguistic variables (fuzzy variables). In other words, fuzzification is the grouping of numerical numbers in the corresponding fuzzy set. The membership function gives meaning or defines linguistic expressions into numbers that can be manipulated. Fuzzification obtains a value and combines it with membership functions to generate a fuzzy value. Fuzzification is the process of determining an input number for each fuzzy group.

Step 5. Defining *Fuzzy Logic Relations* (FLR)
Define FLR and create groups according to time. In the fuzzified data, 2 consecutive fuzzy sets A_i or fuzzy sets at time , $(t-1)$. and , A_j. fuzzy sets at time t can be expressed as FLR or relations , $A_i \rightarrow A_j$. Next is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with fuzzy set which has the same $(t-1)$. For example, if FLR is formed from $A_1 \rightarrow A_2$, $A_1 \rightarrow A_1$, $A_1 \rightarrow A_3$, $A_1 \rightarrow A_1$then FLRG is formed, namely $A_1 \rightarrow A_1, A_2, A_3$.

Step 6. Defining Fuzzy Logic Relations Group (FLRG)
Next is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with a fuzzy set that has the same , $(t-1)$. For example, if FLR is formed from $A_1 \rightarrow A_2$, $A_1 \rightarrow A_1$, $A_1 \rightarrow A_3$, $A_1 \rightarrow A_1$, then FLRG is formed, namely $A_1 \rightarrow A_1, A_2, A_3$

Step 7. Forecasting and Defuzzification
Suppose $F_t \rightarrow A_1, A_2, A_t$ then the equation to find the final forecast value is as follows.

$$\hat{F}_t = \frac{\sum_{i=1}^{k} m_i}{k} \tag{6}$$

With

$\hat{F}_t$: deifuzziifiication
m_i : the middle value of A_i

Defuzzification of the value of the previous data, F-t. is Chen's Fuzzy Time Series method which has several rules that must be observed to make a forecast. The following are the rules:

1. If the fuzzification value of data to t is , A_j then there is a fuzzy set that has no fuzzy logical relationship, such as , $A_j \rightarrow \emptyset$, whose maximum value of the membership function of , A_f. is at the interval , u_i., then the middle value , u_i. is , m_i. so that it can be seen that the result of the forecast , F_{t-1}. is m_i.
2. If the fuzzification value of the data to t is A_i. where there is only one FLR in the FLRG, such as , $A_i \rightarrow A_j$. with A_i. and , A_j. is a fuzzy set whose maximum value is the membership function of A_j. is at the interval u_j, then the middle value of u_j. is u_j., so that the forecast result F_{t-1}. is m_j.

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3. When the fuzzification values of the data to t are A_i and A_j. have multiple FLRs and FLRGs, such $A_1 \rightarrow A_{j1}, A_{j2}, \dots, A_{jk}$, with $A_{j1}, A_{j2}, \dots, A_{jk}$. is a fuzzy set then the maximum value of the membership function of $A_{j1}, A_{j2}, \dots, A_{jk}$is at the intervals $u_{j1}, u_{j2}, \dots, u_{jk}$ and $m_{j1}, m_{j2}, \dots, m_{jk}$, so that the result of the forecast is F_{t-1} as follows:

$$F_t = \frac{m_{j1}, m_{j2}, \dots, m_{jk}}{k} \quad (7)$$

With,
k : the number of middle values

To find the middle value (m_i) in the interval of the fuzzy set, the following equation can be used:

$$m_i = \frac{upper\ limit + lower\ limit}{2} \quad (8)$$

2.2 Fuzzy Time Series Cheng

Cheng's method has a slightly different way of determining intervals, using FLR by including all relationships and giving weights based on the same sequence and looping of FLRs (Tauryawati & Irawan, 2014). The following are the stages of forecasting time series data using FTS Cheng:

Step 1. The formation of a set of universes (U).

$$U = [D_{min}, D_{max}] \quad (9)$$

with,
D_{min} : Smallest data from historical data
D_{max} : The largest data of historical data

Step 2. Interval formation

Using frequency distribution, with the following steps:
Define the range.

$$R = D_{max} - D_{min} \quad (10)$$

with,
R : range

Determine the number of class intervals using the sturges equation.

$$K = 1 + 3{,}322\log(n) \quad (11)$$

Specify the width of the interval.

$$I = \frac{Range\ data(R)}{number\ of\ \ intervals} \quad (12)$$

Find the middle value

$$m_i = \frac{lower\ limit + upper\ limit}{2} \quad (13)$$

with
i : Lots of *fuzzy* sets

Step 3. Defining *Fuzzy* Sets

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A fuzzy set is formed by looking at the number of different frequencies, then at the first most frequency it is divided into h intervals of the same time. Next, the second most frequency is divided over $i-1$of the same interval, the interval at the third most frequency is divided into $i-2$ of the same interval. This is done up to intervals with undivided frequencies.

Step 4. Fuzzification of Historical Data

Define the fuzzy set A_i. and perform fuzzification on the actual observed data. Suppose $A_1, A_2, \dots, A_p$ is a fuzzy set that has the linguistic value of a linguistic variable, the definition of the fuzzy set $A_1, A_2, \dots, A_p$ in U is as follows:

$$\begin{aligned} A_1 &= \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \cdots + \frac{0}{u_p} \\ A_2 &= \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \cdots + \frac{0}{u_p} \\ A_3 &= \frac{0}{u_1} + \frac{0{,}5}{u_2} + \frac{1}{u_3} + \cdots + \frac{0}{u_p} \\ &\vdots \\ A_p &= \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \cdots + \frac{0{,}5}{u_{p-1}} + \frac{1}{u_p} \end{aligned} \tag{14}$$

with, $u_i (i = 1,2, \dots, p)$ is an element of the set of the universe $(U)$and a number marked with the symbol "/" which expresses the degree of membership of $\mu_{A_i}(u_i)$ against A_i $(i = 1,2, \dots, p)$where the value is $0, 0{,}5$ atau 1.

Step 5. Define and create a Fuzzy Logic Relations (FLR) table

FLR can be denoted by $A_i \rightarrow A_j$ where $A_i$is called the *current state* and A_j is called the *next state*.

Step 6. Determining the weight of FLR relations into a Fuzzy Logic Relations Group (FLRG)

Enter all relationships and give weights based on the same order and loop. FLRs that have the same *current state* (A_i) are combined into a single group into the form of a weighting matrix. Suppose there is a sequence of the same FLR

$(t = 1)\ A_1 \rightarrow A_1$, given weight 1

$(t = 2)\ A_2 \rightarrow A_1$, given weight 1

$(t = 3)\ A_1 \rightarrow A_1$, given a weight of 2

$(t = 4)\ A_1 \rightarrow A_1$, given a weight of 3

With,

t : time.

Then the weights obtained in the FLR relation are entered into the form of a weighting matrix (W) whose equation is written as follows:

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1p} \\ w_{21} & w_{22} & \dots & w_{2p} \\ \vdots & \vdots & w_i & \vdots \\ w_{p1} & w_{P2} & \dots & w_p \end{bmatrix} \tag{15}$$

with,

W : weighting matrix

w_i : matrix weights in the first row and the -i column -j with i $i = 1,2, \dots, p$; $j = 1,2, \dots, p$

Step 7. Transfer the FLRG weight into the form of a standardized weighting matrix (W^*)

The equation is written as follows:

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$$W^* = \begin{bmatrix} w_{11}^* & w_{12}^* & \cdots & w_{1p}^* \\ w_{21}^* & w_{22}^* & \cdots & w_{21}^* \\ \vdots & \vdots & w_i & \vdots \\ w_{p1}^* & w_{p2}^* & \cdots & w_{pp}^* \end{bmatrix} \quad (16)$$

with,

W^* : Standardized weighting matrix with $w_i^* = \frac{w_i}{\sum_{j=1}^{p} w_i}$

Step 8. Determining the forecasting value specification

To generate the forecast value, the standardized weighting matrix (W^*)is multiplied by (m_i). Finding the middle value (m_i) at the interval of a fuzzy set can use Equation (5). So that the calculation of the prediction becomes: (17)

$$F_i = w_{i1}^* (m_1) + w_{i2}^* (m_2) + \cdots + w_{ip}^* (m_p)$$

with,

F_i : Forecast results

If the fuzzification value of the -i period is -A_i. and A_i. does not have FLR in the FLRG with the condition $A_i \rightarrow \emptyset$, where the maximum value of the degree of membership is in the interval u_i., then the forecast value (F_i) is the middle value of the interval u_i., or defined by m_i.

2.3 Forecasting Accuracy

Forecasting is the goal of time series analysis. The forecasting method has the goal of getting optimal forecast results without having a large error rate. If the error rate that has been obtained is smaller, the result of a forecast will be closer to the actual value (Wei, 2006). In this study, the accuracy of the forecast will be calculated using *Mean Absolute Percentage Error* (MAPE), *Mean Squared Error* (MSE), and *Mean Absolute Error* (MAE).

1. *Mean Absolute Percentage Error* (MAPE)

MAPE is the average of the overall percentage of error (difference) between actual data and predictive data (Sukerti, 2015). Systematically MAPE is shown as follows (Makridakis, eit al., 1999). (18)

$$MAPE = \frac{100\%}{n} \sum_{t=1}^{n} \left| \frac{F_t - \hat{F}_t}{F_t} \right|$$

with,

n : Lots of data

F_t : Observation data at time t

$\hat{F}_t$: data of forecasting results at time t

The interpretation of the MAPE value is shown in the following table (Lewis, 1982).

Table 1. Interpretation of MAPE Values

MAPE (%)	Interpretasi
< 10	Highly Accurate Predictions
$10 - 20$	Good predictions
$20 - 50$	Decent predictions
> 50	Inaccurate predictions

2. *Mean Squared Error* (MSE)

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MSE is a calculation used in measuring the average of the squares obtained between the difference between the expected value and the output value of the prediction. The lower the value obtained from the MSE calculation, the more accurate the prediction results will be considered (Wiranto, Setiawan, Nuryaman, & Usman, 2003). Systematically MSE is shown as follows (Makridakis et.al, 1982).

$$MSE = \frac{\sum(Yi - \hat{Y}i)^2}{n} \quad (19)$$

With,

n : Lots of data
Y_i : Actual value of data i
$\hat{Y}_i$: Predictive value of data i

3.*Mean Absolute Error* (MAE)
MAE is one of the methods used to measure the accuracy of forecasting models. The MAE value shows the absolute average error between the forecast/prediction results and the real value (Subagyo, 1986). In terms of the MAE formula, it is explained as follows.

(20)

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |F_i - Y_i|$$

With,

n *: Lots of data*
F_i *: The value of the application results to i i*
Y_i *: the actual value to i*

3. RESULTS AND DISCUSSION

A. PT Taspen's Profit Forecasting Using *Fuzzy Time Series Chen*

The steps for forecasting PT Taspen's profit using the Fuzzy Time Series Chem method are as follows:

Step 1. Determine the set of the universe (*U*) from historical data.

The initial step of Fuzzy Time Series analysis is the formation of a set of universes (*U*). In the formation of the universe set (*U*), it requires the smallest (minimum) data and the largest data (maximum) from PT Taspen's profit data. Minimum profit value in the month (D_{min}) January 2024, which is Rp. 2.451.700.000 while the maximum profit value in December 2023 is (D_{max}) IDR 106.516.180.000. In this study, the author determined the value for *D1 to be 0.17 and the value for D2 was 0.22.* Furthermore, after obtaining the values and determining the values $D_{min}D_{max}$ *of D1 and D2, the next step is to form a set of universes (U*) as in equation (1). The following is the set of the universe (*U*) that is formed.

$$\begin{aligned} U &= [D_{min} - D_1 \,; D_{max} + D_2] \\ &= [2.451.700.000 - 0{,}17 \,; 106.516.180.000 + 0{,}22] \\ &= [2.451.530.000; 106.516.400.000] \end{aligned}$$

Step 2. Determining the number of intervals (m)

The next step is to determine the number of intervals or the number of interval classes of the entire set of the universe (U) using the following equation (2).

$$\begin{aligned} K &= 1 + 3{,}322 \log(15) \\ &= 1 + 3{,}907 \\ &= 4{,}907 \approx 5 \end{aligned}$$

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Based on these results, 5,001 is obtained for the number of intervals rounded up to 5 intervals. Then the set of the universe (*U*) will be partitioned into 5 intervals into $u_1, u_2, u_3, \ldots, u_5$. by searching the Length of each interval using the following equation (3):

$$I = \frac{D_{max} - D_{min}}{K}$$
$$= \frac{106.516{,}18 - 2.451{,}70}{5}$$
$$= 20.812.896.000$$

The results of the 5 intervals formed and the middle values in each of these intervals are presented in the following table:

Table 2. Interval of Universe Aggregate (U) Profit of PT Taspen (Persero)

Intervals (u_i)	**Middle value** (m_i)
$u_1 = [2.451.530.000; 23.264{,}426]$	**12.857.978.000**
$u_2 = [23.264.426.000; 44.077.322.000]$	**33.670.874.000**
$u_3 = [44.077.322.000; 64.890.218.000]$	**54.483.770.000**
$u_4 = [64.890.218.000; 85.703.144.000]$	**75.296.681.000**
$u_5 = [85.703.144.000; 106.516.010.000]$	**96.109.577.000**

Step 3. Identifying *Fuzzy sets*

The *range of fuzzy* sets is used to derive the value of each *fuzzy set* that is formed. The minimum value is that it will have a membership degree of 1 and be a value of . $(D_{min})2.451.700.000\ A_1$. This is because the value is defined in the association so that it has a membership degree of 1. $2.451.700.000\ u_1 fuzzy\ A_1$. Then the value is A_1 added with the value of the fuzzy range so that a value of A_2 that is 28.467.820.000. By applying the same step, the value of which is the maximum value will be obtained, namely $A_5(D_{max})106.516.180.000$ With Membership Degree of 1. The values of the fuzzy set will form the membership degree curve that is used to find the membership value of each data in the *fuzzy* set. The curve of the membership value formed can be seen in the following figure:

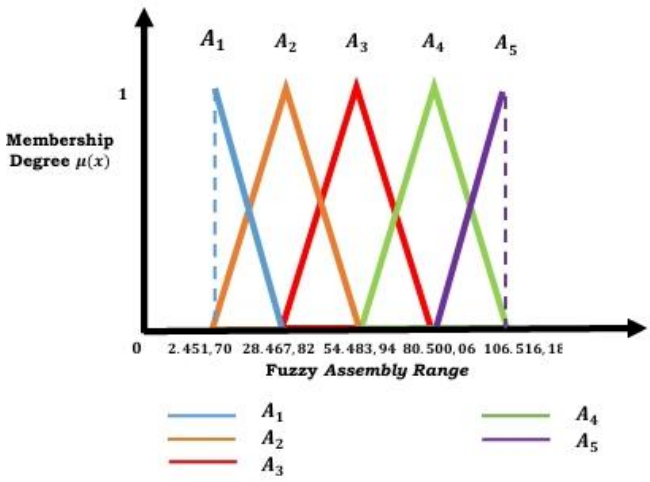

Figure 2. Fuzzy Profit Association of PT Taspen (Persero)

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Figure 1 above shows that the membership degree curve of the formed fuzzy set values is a representation of the triangle curve. In this study, the linguistic value represented is $A_1, A_2, A_3, \ldots, A_5$ on top of which each has a range of profit values. Suppose is a linguistic value that represents the range of profit values of A_1 2.451.700.000 until. 28.467.820.000. Then, is the linguistic value A_2 which represents the range of profit values from 28.467.820.000 until 54.483.940.000 and so on.

Step 4. Determine the membership of each data

The calculation of the membership value of each data refers to the curve formed in Figure 12. For example, for the calculation of the value of the degree of membership, the first profit data of PT Taspen (Persero), namely April 2022 data, is $x =$ 16.837.410.000 When the value of $x =$ 16.837.410.000 be on the following triangular curve:

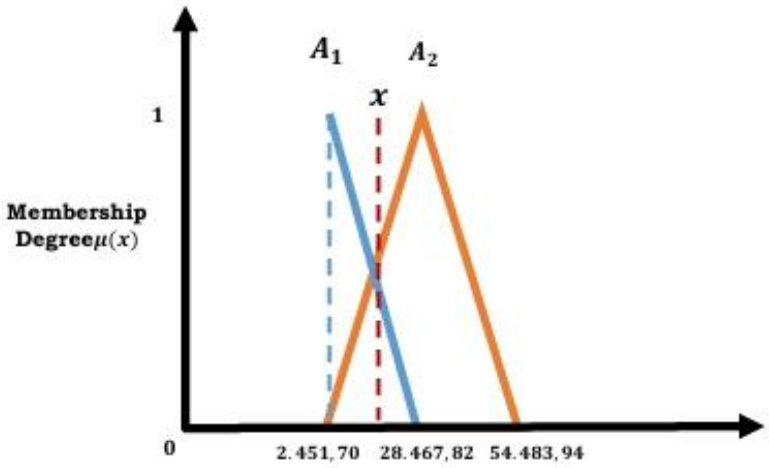

Figure 3. Membership Degree Triangle Curve

Based on the triangular curve of the fuzzy set A_1 above, it can be seen that the value $x =$ 16.837.410.000 is on the right side of the curve. Thus, based on the curve, the following values are obtained:

$b =$ 2.451.700.000
$c =$ 28.467.820.000

Due to the x located on $b < x < c$ so that for the calculation of the value of membership $x =$ 16.837,41 on the fuzzy set triangle curve A_1 obtained as follows:

$$\mu_{x_1}(x) = \frac{c - x}{c - b} = \frac{28.467.820.000 - 16.837.410.000}{28.467.820.000 - 2.451.700.000} = 0{,}44$$

Based on the triangular curve of the fuzzy set A_2 above, it can be seen that the value $x =$ 16.837.410.000 is on the right side of the curve. Thus, based on the curve, the following values are obtained:

$a =$ 2.451.700.000
$b =$ 28.467.820.000
$c =$ 54.483.940.000

Due to the x located on $a < x < b$ so that for the calculation of the value of membership $x =$ 16.837,41 on the fuzzy set triangle curve A_1 obtained as follows:

$$\mu_{x_1}(x) = \frac{x - a}{b - a} = \frac{16.837.410.000 - 2.451.700.000}{28.467.820.000 - 2.451.700.000} = 0{,}55$$

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Step 5. Determining the fuzzification of PT Taspen (Persero) profit data
For example, for PT Taspen (Persero)'s profit data for April 2023, namely $x = 16.837{,}41$. The data is located in a fuzzy set A_1 and A_2 with the value of each membership $0{,}44$ and $0{,}55$. The determination of data fuzzification is obtained by looking for the maximum membership value. Based on the maximum membership value, namely $A_1 < A_2$, then the results of the data fuzzification in May 2023 are $x = 16.837.410.000$ was A_1or it can be categorized as very low. The results of the fuzzification of PT Taspen (Persero)'s profit data are presented in the following table:

Table 3. Fuzzification of PT Taspen (Persero) Profit Data

Period (t)	Profit Date	Fuzzification	FLR
May-23	16.837,41	A_1	NA
Jun-23	46.094,88	A_3	$A_1 \rightarrow A_3$
Jul-23	35.576,21	A_2	$A_3 \rightarrow A_2$
Aug-23	41.923,17	A_2	$A_2 \rightarrow A_2$
Sep-23	82.351,57	A_4	$A_2 \rightarrow A_4$
Oct-23	65.025,61	A_4	$A_4 \rightarrow A_4$
Nov-23	97.805,04	A_5	$A_4 \rightarrow A_5$
Dec-23	106.516,18	A_5	$A_5 \rightarrow A_5$
Jan-24	2.451,70	A_1	$A_5 \rightarrow A_1$
Feb-24	5.654,92	A_1	$A_1 \rightarrow A_1$
Mar-24	10.394,33	A_1	$A_1 \rightarrow A_1$
Apr-24	8.732,71	A_1	$A_1 \rightarrow A_1$
May-24	14.711,99	A_1	$A_1 \rightarrow A_1$
Jun-24	22.606,17	A_1	$A_1 \rightarrow A_1$
Jul-24	19.202,57	A_1	$A_1 \rightarrow A_1$

Step 6. Defining Fuzzy Logic Relations Group (FLRG)
The next stage is the formation of FLRG using FLR which has LHS (Left Hand Side) or FLR with fuzzy set which has $(t-1)$ the same in the profit of PT Taspen (Persero). The FLRG obtained is as follows:

Table 4. FLRG Profit Data of PT Taspen (Persero)

FLRG	
$A_1 \rightarrow$	A_1, A_3
$A_2 \rightarrow$	A_2, A_4
$A_3 \rightarrow$	A_2
$A_4 \rightarrow$	A_4, A_5
$A_5 \rightarrow$	A_5

Step 7. Forecasting and Defuzzification
The next stage is forecasting and defuzzification which describes the process of converting the results of fuzzy logic relations (FLR) into quantitative values or actual predictions. After processing, the overall results of PT Taspen (Persero) profit data forecasting using the fuzzy time series method were obtained as follows:

Table 5. Overall Profit Data Forecasting of PT Taspen (Persero)

Period	Profit	Divination
May-23	16.837,41	NA
Jun-23	46.094,88	90.606,7
Jul-23	35.576,21	45.303,3

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Aug-23	41.923,17	153.045
Sep-23	82.351,57	153.045
Oct-23	65.025,61	246.703
Nov-23	97.805,04	246.703
Dec-23	106.516,18	138.961
Jan-24	2.451,70	138.961
Feb-24	5.654,92	90.606,7
Mar-24	10.394,33	90.606,7
Apr-24	8.732,71	90.606,7
May-24	14.711,99	246.703
Jun-24	22.606,17	90.606,7
Jul-24	19.202,57	90.606,7

B. PT Taspen Profit Forecasting Using *Cheng's Fuzzy Time Series*

Step 1. The formation of the set of the universe (*U*). The first step in calculating fuzzy time series using Cheng is to form a universal set. In this case, the author sets D1 to 3 and D2 to 5.
The first step in calculating fuzzy time series with cheng is to form a set of universes.
In this case, the author specifies D1 as 3 and D2 as 5. The calculation is as follows:

$$U = [D_{min} ; D_{max}]$$
$$= [2.451.700.000 ; 106.516.180.000]$$

Step 2. Interval formation

The next step for the fuzzy time series cheng method is to form a class interval as follows:
Define the range.

$$R = 106.516.180.000 - 2.451.700.000$$
$$= 104.064.480.000$$

Determine the number of class intervals using the sturges equation.

$$I = \frac{Range\ (R)}{(k)}$$
$$= \frac{104.064.480.000}{5}$$
$$= 20.812.896.000$$

Find the middle value

Table 6. Central Value of PT Taspen (Persero) Profit Data

Lower Limit	Upper Limit	Middle Value
	2.448.700.000	
2.448.700.000	23.261.596.000	12.855.148.000
23.261.596.000	44.074.492.000	33.668.044.000
44.074.492.000	64.887.388.000	54.480.940.000
64.887.388.000	85.700.284.000	75.293.836.000
85.700.284.000	106.513.180.000	96.106.732.000

Step 3. Define a *fuzzy* set

The frequency with the first most number is divided into i the same interval to represent a more detailed degree of membership. The second most frequency is then divided into $i - 1$ interval, and the third most frequency becomes $i - 2$ intervals, and so on. This process continues to be carried out gradually

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until the remaining frequencies no longer allow for further division, resulting in a fuzzy representation that is proportional and reflects the data distribution more accurately.
This process continues to be carried out gradually until the remaining frequencies no longer allow for further division.

Table 7. Central Value of PT Taspen (Persero) Profit Data

Fuzzification	Categori
A_1	Very Low
A_2	Low
A_3	Intermediate
A_4	Tall
A_5	Very High

Step 4. Fuzzification of historical data
Every fuzzy set A_i has a membership function $\mu A_i(u)$ that maps each element $u \in U$ into the degree of membership in the range $[0,1]$ according to its linguistic meaning, such as "low", "medium", or "high". The next step is to define fuzzy sets A_1,A_2,…,A_n in the universe of discourse U, which represent the linguistic values of a linguistic variable. Each fuzzy set A_i has a membership function μA_i(u) that maps each element u∈U into a membership degree in the range [0,1], according to its linguistic meaning, such as "low", "medium", or "high". This process is then continued with fuzzification, which is converting the actual observed data into the form of membership degree values for each A_i, so that the deterministic crisp data can be represented in a fuzzy form that reflects uncertainty and ambiguity more realistically.

Step 5. Define and create a Fuzzy Logic Relations (FLR) table
This FLR represents the logical relationship between two fuzzy sets based on the time sequence of the fuzzified data. The next step in the Fuzzy Time Series method is to form a Fuzzy Logical Relationship (FLR) symbolized by A_i→A_j, where A_i is called the current state and A_j is called the next state. This FLR represents a logical relationship between two fuzzy sets based on the time sequence of the fuzzified data. That is, if at time t the data is in the fuzzy set A_i, and at time t+1 the data is in the fuzzy set A_j, then the FLR relationship A_i→A_j is formed. This relationship is the basis for building a prediction model, because it reflects the pattern of changes in variable values over time in a linguistic form that has been transformed fuzzy.

Table 8. FLR Profit Data of PT Taspen (Persero)

CS	NS	COUNTA of NS
A_1	A_1	7
	A_3	1
A_2	A_2	1
	A_4	1
A_3	A_2	1
A_4	A_1	1
	A_4	1
A_5	A_1	1
	A_5	1

Based on the Fuzzy Logical Relationship (FLR) table provided, it can be seen that each Current State (CS) has one or more Next State (NS) that appear based on the frequency of their occurrence (COUNTA of NS). For example, CS A_1 has two NS namely A_1 as many as 7 times and A_3 as many as 1 time, indicating that from state A_1, the system tends to remain in A_1 but also has the possibility of moving to A_3. CS A_2 has NS A_2 and A_4, each once, indicating the existence of variations in movement

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in both directions. CS A_3 only moves to A_2 once, while CS A_4 has two possibilities, namely remaining in A_1 and moving to A_4, each once.

Step 6. Determining the weight of FLR relations into a Fuzzy Logic Relations Group (FLRG)

The next step is to input all the fuzzy logical relationships (FLRs) that have been formed and assign weights based on the order and frequency of occurrence of the same relationship. FLRs that have the same current state (A_i) will be grouped into one Fuzzy Logical Relationship Group (FLRG), then organized into a weighting matrix. Each repeated relationship A_i → A_j will have its occurrences counted and used as the basis for assigning weights. Every relationship $A_i \rightarrow A_j$ that are repeated will be calculated in the number of occurrences and used as the basis for giving weight, So that relationships that appear more often will have greater weight than those that rarely occur.

Table 9. Profit Data Weighting Matrix of PT Taspen (Persero)

	A_1	A_2	A_3	A_4	A_5
A_1	7	0	1	0	0
A_2	0	1	0	1	0
A_3	0	1	0	0	0
A_4	1	0	0	1	0
A_5	1	0	0	0	1

Step 7. Transfer the FLRG weight into the form of a standardized weighting matrix (*W**)

The next step is to transfer the weights from the Fuzzy Logical Relationship Group (FLRG) into a standardized or normalized weighting matrix. This process is done by dividing each value in the initial weighting matrix row by the total number of values in that row, resulting in a proportional weight value in the range of 0 to 1. This normalization aims to convert absolute frequencies into transition probabilities from a current state (A_i) to various possible next states (A_j).

This process is done by dividing each value in the initial weighting matrix row by the total number of values on that row, resulting in a proportional weight value that is in the range of 0 to 1.

Table 10. Standardized Matrix of PT Taspen (Persero) Profit Data

	A_1	A_2	A_3	A_4	A_5
A_1	0,875	0	0,125	0	0
A_2	0	0,5	0	0,5	0
A_3	0	1	0	0	0
A_4	0,5	0	0	0,5	0
A_5	0,5	0	0	0	0,5

The matrix above shows the normalized result of the previous weighting matrix, where each value in a row represents the probability of transition from the current state (A_i) to the next state (A_j). For example, in row A_1, the value of 0.875 in column A_1 and 0.125 in column A_3 indicates that from state A_1, there is an 87.5% probability of remaining in A_1 and a 12.5% probability of moving to A_3. Row A_2 has a balanced probability distribution, 0.5 for A_2 and A_4, respectively. Meanwhile, A_3 only has a full probability (1.0) of moving to A_2. Similarly, A_4 shows an equal probability of moving to A_4 or A_5 (0.5 each), and A5 has a balanced probability of moving to A_1 or remaining in A_5.

Step 8. Determining the defuzification of the forecast value

The next stage is forecasting and defuzzification, which describes the process of converting the results of fuzzy logic relations (FLRs) into quantitative values or actual predictions. Defuzzification is performed by taking the midpoint of each interval of the fuzzy set, which reflects the best estimate of the fuzzified data. If a fuzzy set has no relation (a single FLR), then forecasting is performed using the midpoint of that set.

Defuzzification is performed by taking the middle value of each *fuzzy* set interval, which reflects the best estimate of the data that has been fuzzified. If a fuzzy set has no relation (single FLR), then the

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forecasting is done using the middle value of that set. After processing, the overall results of PT Taspen (Persero) profit data forecasting using the *fuzzy time series cheng* method were obtained as follows:

Table 11. Overall Forecasting of the Cheng Method of PT Taspen (Persero) Profit Data

Period	Profit	Divination
May-23	16.837,41	*NA*
Jun-23	46.094,88	33.670,444
Jul-23	35.576,21	54.484,94
Aug-23	41.923,17	54.484,94
Sep-23	82.351,57	37.649,718
Oct-23	65.025,61	37.649,718
Nov-23	97.805,04	54.484,94
Dec-23	106.516,18	54.484,94
Jan-24	2.451,70	18.059,572
Feb-24	5.654,92	18.059,572
Mar-24	10.394,33	18.059,572
Apr-24	8.732,71	18.059,572
May-24	14.711,99	18.059,572
Jun-24	22.606,17	18.059,572
Jul-24	19.202,57	18.059,572

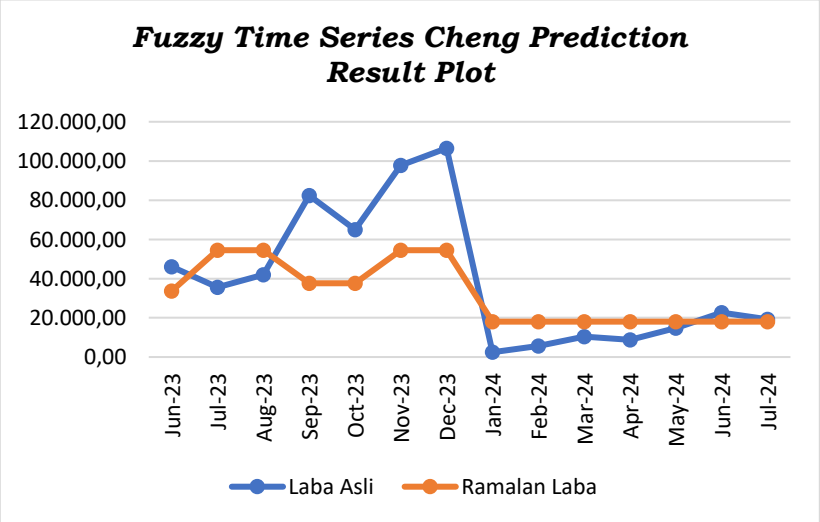

Figure 4. Fuzzy Time Series Cheng Prediction Result Plot Profit PT Taspen (Persero)

C. Measurement of the Accuracy of PT Taspen's Profit Forecasting

In this section, an evaluation was carried out on the accuracy of PT Taspen's profit forecasting results using *the Fuzzy Time Series Chen* and *Fuzzy Time Series Cheng methods* through three error measures, namely *Mean Absolute Percentage Error* (MAPE), *Mean Squared Error* (MSE), and *Mean Absolute Error* (MAE).

Table 12. Accuracy of Forecasting Method Cheng Profit Data of PT Taspen (Persero)

Error Absolute Chen	*Error Absolute Cheng*
3.769,27	1.222,16
4.511,80	1.424,44
.727,13	1.908,73

	1.122,20	1.561,77
	.693,80	4.701,85
	1.677,79	2.375,89
	1.898,36	.320,10
	.445,19	.031,24
	.509,67	.607,87
	.951,76	.404,65
	.212,35	.665,24
	.873,97	.326,86
	1.991,41	.347,58
	.000,51	.546,60
	.404,11	1.143,00
MAPE	0,674	0,603
MSE	3.303	2.684
MAE	1.319,29	1.172,53

In particular, the MAPE value of Cheng's method shows that the forecast relative error to the actual value is smaller, so Cheng's method is more reliable and worthy of consideration in projecting PT Taspen (Persero's profit).

4. CONCLUSION

Based on the results of the description that has been discussed in the previous chapter, it can be concluded:

1. Based on the results of the analysis, Cheng's Fuzzy Time Series method resulted in a higher level of accuracy in PT Taspen (Persero's) profit forecasting than Chen's Fuzzy Time Series method, as indicated by the lower MAPE, MSE, and MAE values. The cheng method is also better able to follow the fluctuating trend of actual profit so that it can be a more reliable approach to projecting PT Taspen's profit.
2. The results of this study show that the cheng method has the potential to be applied in financial planning and decision-making. For further research, it is recommended to develop this method by combining other Fuzzy Time Series methods.

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REFERENCES

Perusahaan. *Jurnal Penelitian Ilmu Dan Teknologi,* 10(1), 19–31.

Adilah, S. N., & Mardhotillah, B. (2023). Peramalan Nilai Tukar Petani Subsektor Hortikultura Menggunakan ARIMA. Multi Proximity: *Jurnal Statistika Universitas Jambi,* 2(2), 2023.

Arnita, Afnisah, N., & Marpaung, F. (2020). A Comparison of the Fuzzy Time Series Methods of Chen, Cheng and Markov Chain in Predicting Rainfall in Medan. *Journal of Physics: Conference Series,* 1462(1).

Agustin, M. D., Yufantria, F., & Ameraldo, F. (2022). Pengaruh Fraud Hexagon Theory Dalam Mendeteksi Kecurangan Laporan Keuangan (Studi Kasus Pada Perusahaan Asuransi Yang Terdaftar Di Bursa Efek Indonesia Periode 2017-2020). *Journals of Economics and Business*, *2*(2), 47–62.

Arief Nurdini, & Anita. (2022). Analisis Peramalan Permintaan Tempe Gmo 450 Gram Dengan Menggunakan Metode Regresi Linear. *Jurnal Ilmiah Teknik*, *1*(2), 131–142.

Arvie, D. (2022). Peramalan Import Migas dan Non-migas Menggunakan Metode Fuzzy Time Series Model Cheng. *JATISI (Jurnal Teknik Informatika Dan Sistem Informasi),* 9(4), 3519–3528.

Aswi, & Sukarna. (2006). *Analisis Deret Waktu Analisis Deret Waktu. January,* 303.

Dwi Antoni, I., & Findawati, Y. (2024). Implementasi Logika Fuzzy Untuk Menentukan Jumlah Produksi Roti Menggunakan Metode Tsukamoto. *Smatika Jurnal*, *14*(01), 61–70.

Ermaya, A. Y., Priatna, H., & Alfiani, H. (2016). Pengaruh Penjualan Bersih dan Biaya Produksi terhadap Laba Bersih (Studi Kasus pada PT. Aneka Tambang (Persero), Tbk.). *Jurnal Ilmiah Akuntansi,* 7(2), 20–26.

Habinuddin, E. (2022). Penerapan Fuzzy Time Series Untuk Memprediksi Curah Hujan Kota Bandung. *Jurnal Digit,* 12(2), 115.

Handayani, A. S., & Wibowo, A. (2021). Analisis Pengaruh Pemilihan Jumlah Variabel Linguistik Membership Function pada Metode Fuzzy Simple Additive Weighting (FSAW) untuk Perankingan Penerimaan Beasiswa Bagi Siswa Kurang Mampu (Studi Kasus : Sekolah Dasar Negeri Petompon 02 Semarang). *Jurnal Masyarakat Informatika*, *12*(1), 19–28.

Hasibuan, S., Asdi, Y., & Nazra, A. (2024). Peramalan Harga Minyak Mentah Dunia Menggunakan Metode Fuzzy Time Series Logika Singh. *Jurnal Matematika UNAND*, *13*(1), 66–74.

Pambudi, R. A., Setiawan, B. D., & Wijoyo, S. H. (2018). Implementasi Fuzzy Time Series untuk Memprediksi Jumlah Kemunculan Titik Api. *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer (J-PTIIK) Universitas Brawijaya,* 2(11), 4767–4776.

Purwanto, R. H. (2015). Aspek Hukum Asuransi Antara Berdasarkan Prinsip Utmost Good Faith Sesuai Dengan Uu No.40/2014 Tentang Pengasuransian. *Jurnal Pro Hukum*, *IV*(1), 33–39.

Sugumonrong, D. P., Handinata, A., & Tehja, A. (2019). Prediksi Harga Emas Menggunakan Metode Fuzzy Time Series Model Algoritma Chen. Informatics Engineering Research And Technology, 1(1), 48–54.