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Comparison of Fuzzy Time Series Markov Chain and Fuzzy Time Series Lee in North Sumatra Import Value Forecasting

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Abstract

North Sumatra is a province that carries out import activities in other provinces to complement the shortage of goods in North Sumatra. Every month based on data from the Central Bureau of Statistics (BPS) of North Sumatra, the import value of North Sumatra constantly fluctuates. So a method is needed to show the increase or decrease in the value of North Sumatra in the next period. The method is forecasting, where forecasting is an activity that predicts something in the future, intending to get information in the next period as a decision or decision in the future. Many forecasting methods can be used, but this study uses fuzzy time series Markov Chain and fuzzy time series Lee methods. These two methods aim to obtain the best forecasting method based on the minor mean absolute percentage error (MAPE) and mean square error (MSE). In this study, the data is on the value of imports in North Sumatra taken from the Central Statistics Agency (BPS) of North Sumatra. The test results on forecasting the import value of North Sumatra show that the fuzzy time series Markov Chain is better than the Fuzzy Time series Lee based on the smallest MAPE and MSE values. The MAPE fuzzy time series Markov Chain value is 7.7467%, and the MSE value is 176,748,587. Meanwhile, Lee's fuzzy time series has a MAPE of 10.014% and an MSE value of 2,387,874,804.

INTRODUCTION

Import is the goods or commodities transaction from abroad to customs (domestic country) carried out legally and typically needs to mix customs hands between sender and recipient [1]. Based on data from the North Sumatra Central Statistics Agency (BPS). From January 2014 to September 2021, North Sumatra imports experienced change or every data fluctuation the month. Because there are value data fluctuations in North Sumatra imports, the government of North Sumatra will be challenged to take some decisions or actions in the coming period. So we needed to use data forecasting to get and analyze data patterns to be formed in the next period.

Forecasting is the prediction about something events to happen in the future [2]. Forecasting aims to get information for the next period and come as a reference in taking action or decisions on the next Century. Forecasting is distinguished into two methods: qualitative and quantitative. One qualitative forecasting method is a time series or analysis streak time. Fuzzy

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Time Series that combines logic fuzzy with analysis time series. Fuzzy time series is a method forecast used with the principle fuzzy. Pattern data from historical fuzzy time series will be used For project data for the next period.

Fortune telling requires accurate results data forecasting for count accuracy or size data forecasting. Several methods, such as the mean absolute percentage error (MAPE) and mean square error (MSE), can be used. MAPE is a percentage of overall data mean error between the result data forecast and actual data. MSE is the sum of all square errors on each period shared with amount period forecasting.

In the research conducted by Mustika [8], when comparing forecasting inflation data in Indonesia with the use method, Cheng's fuzzy time series and the fuzzy time series Markov Chain said that the fuzzy time series Markov Chain has results forecasting best compared to Cheng's fuzzy time series. On the other hand, Arnita [10], when comparing Chen's fuzzy time series and Lee's fuzzy time series on predictions price gold, said that Lee's fuzzy time series model is better than the Chen model with generated errors fuzzy time series Lee smaller compared to with Chen's fuzzy time series.

Based on the description above, the fuzzy time series Markov Chain is better than method Cheng's fuzzy time series and Lee's fuzzy time series is better than Chen's. So writer wants to see and compare the second method between the fuzzy time series Markov Chain and Lee's fuzzy time series using the same data, namely value data North Sumatra imports to get the method best based on value absolute mean percentage error (MAPE) and mean square error (MSE) smallest between fuzzy time series Markov Chain and Lee's fuzzy time series.

METHOD

The research type is applied research with a quantitative research approach description. Quantitative research description is research conducted in numbers, and results can be interpreted as a description.

Required data in this research is value data import province of North Sumatra obtained from the central body statistics (BPS) for the province of North Sumatra. The data type used in conducting research, namely: Secondary data. Secondary data is obtained or collected by the person doing the research from the source.

The research procedure was used as a base for systematically and efficiently carrying out research with steps. The steps used in this study are:

1. Collect Data

The data used is the value North Sumatra imports obtained from the Central Bureau of Statistics of North Sumatra.

2. Stage Data Processing

a. Fuzzy Time Series Markov Chain

*The fuzzy time series Markov chain introduced by Tsaur at the time foresees mark swap Taiwan curr*ency with the US. The objective merger's second method is to obtain the most significant opportunity from matrix opportunity transitions used in the chain Markov.

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Following are the steps in the forecasting method *fuzzy time series Markov chain*.

1. Determine set U universe
   Determine set universe U is a step initially formulated _ with
   $$U = [D_{\min} - Z_1; D_{maks} + Z_2]$$
   With
   D_{min} = data minimum value, D_{maks} = data maximum value, Z_1, Z_2 is the corresponding positive number
   Z_1, Z_2 are two numbers appropriate and determined by the researcher.
2. Defining Multiple Sets Fuzzy
   To determine many set fuzzy, use the formula average-based length. The following are stages in many sets formed fuzzy:
   a. Determine the length of the U interval
   $$R = D_{maks} + Z_2 - D_{\min} - Z$$
   With Z_1 and Z_2 is any positive number
   b. Calculates the average value difference (*lag) absolute* with the use of equality
   $$mean = \frac{\sum_{t=1}^{N-1} |(D_{t+1}) - D_t|}{N-1}$$
   With N is the amount of data and D_t is the data at the moment t.
   c. Then determine the basis interval with the use of equality.
   $$K = \frac{mean}{2}$$

Table 1Base Intervals

Reach	Base
0-1	0.1
1,1-10	1
11-100	10
101-1000	100
1001-10000	1000
10001-100000	10000

   d. Then determine many sets of Fuzzy with equality.
   $$n = \frac{R}{K}$$
   e. Furthermore, look for mark middle (m) *fuzzy* with equality.
   $$m_i = \frac{(Batas\ Bawah\ U_i + Batas\ atas\ U_i)}{l}$$
3. Defining set fuzzy for all U set
4. Do historical data fuzzification.
   All magnitude mark firms will be changed into the magnitude fuzzy at this stage.
5. Forming Fuzzy Logical Relationship (FRL) and Fuzzy Logical Relationship Group (FLRG).
   FLR is denoted with $A_i \rightarrow A_j$. A_i is *the current state* and A_j is *the next stage*. Based on the FRL table that is formed then determine the *Fuzzy Logical Relationship Group* (FLRG)
6. Count results forecasting early.
   According to [17] in count results mark forecasting beginning use rule as follows:

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Rule 1: if FRLG A_i is empty ($A_i \to \phi$), then mark forecast.

$$F(t) = m_i$$

With m_i is the middle value of u_i

Rule 2: if FRLG (A_i) is one-to-one, $(A_i \to A_k)$ then the forecasting result is:

$$F(t) = m_k\, p_{ik} = m_k$$

With p_{ik} mark matrix transition

Rule 3: if the FRLG (A_i) is one too many $(A_i \to A_1, A_2, \ldots A_n)$ then the forecasting result is:

$$F(t) = m_1 p_{j1} + m_2 p_{j2} + \ldots + m_{j-1} p_{j(j-1)} + Y(t-1) p_j + m_{j+1} p_{j(j+1)} + \ldots + m_n p_{jn}$$

7. Determine mark adjustment (*Dt)*

There are several rules, according to [18], in determining trend forecasting, namely:

Rule 1: if the state A_i is related to A_i at the time *t-1* was implemented $F(t-1) = A_i$ and there is an upward transition toward the state A_i at the time, $t(i < j)$. Then the adjustment value is determined by:

$$D_{t1} = \left(\frac{1}{2}\right) l$$

Rule 2: if the state A_i related to A_i at time *t-1* implemented as $F(t-1) = A_i$ and a downward transition occurs in the state A_j at the time $t(i < j)$. Then the forecasting adjustment value is determined by

$$D_{t1} = -\left(\frac{1}{2}\right) l$$

Rule 3: If the *state* A_i. At time *t-1* and a forward-to-state transition occurs A_{i+s}. Then the forecast adjustment value is determined with

$$D_2 = -\left(\frac{1}{2}\right) s$$

Rule 4: If the *state* A_i. At time *t-1* as $F(t-1) = A_i$ and a backward transition to the state A_{i+s}. Then the forecasting adjustment value is determined by

$$D_2 = -\left(\frac{l}{2}\right) s$$

8. Determine mark forecasting end.

If FRLG A_i is one too many, and the state A_{i+1} can be obtained from the state A_i where the state communicates , then the forecasting result adjustment is obtained $F'(t) = F(t) + D_{t1} + D_{t2} = F(t) + \frac{l}{2} + \frac{l}{2}$. If FRLG from A_i is one too many, and the *state* A_{i+1} can be obtained from the *state* A_i but A_i does not communicate with it A_i, then the forecasting result adjustment is obtained as $F'(t) = F(t) + \frac{1}{2}$. If FRLG A_i is one too many, and the *state* A_{i-2} can be obtained from the *state* A_i but A_i does not communicate with it A_i, then the adjustment of forecast results is obtained, and the general form of forecasting is obtained $F'(t) = F(t) \pm D_{t1} \pm D_{t2} = F(t) \pm \frac{1}{2} \pm \left(\frac{1}{2}\right) 2$

.

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b. Fuzzy Time Series Lee

The development of the fuzzy time series model from the Cheng, Chen, Song, and Chisson model is Lee's fuzzy time series in foresee period.

According to Pajriati et al. (2021), The following are the steps in forecasting using the fuzzy time series Lee method. Steps 1-5 forecasting *fuzzy time series Markov chain* is also step forecasting in *fuzzy time series Lee.*

6. did *defuzzzification*

There are several rules in *Lee defuzzzification,* namely as follows:

- If the results are *fuzzzification* at the moment, *t* is A_j , and there is no fuzzification relation logic *fuzzy* ($A_j \rightarrow \emptyset$), where the maximum value of the membership $A_j$is in the interval u_i, and the middle value $u_i$is m_i, then the forecasting equation is

$$\hat{y}' = m_i$$

- If the results *fuzzzification* when t is A_j and only there is one FRL on FRLG ($A_i \rightarrow A_j$) where $A_i$and A_j is *fuzzzification* and value maximum from $A_i$is in the interval u_j and the mean $u_j$is m_j. Then the forecasting equation is

$$\hat{y}'_t = m_j$$

- If the results *fuzzzification* moment *t* is $A_j, A_k, \ldots A_l$having multiple FRLs in FRLG ($A_i \rightarrow A_j, A_k, \ldots A_l$) where$A_j, A_k, \ldots A_l$ are fuzzification and value maximum and minimum of mark membership $A_j, A_k, \ldots A_l$is on the interval $u_j, u_k, \ldots u_l$and the mean value $m_j, m_k, \ldots m_l$. So results forecast is

$$\hat{y}'_t = \frac{2}{p} m_j + \frac{2}{p} m_k + \ldots + \frac{1}{p} m_l \qquad [21]$$

7. Data forecasting

c. Dccuracy Forecasting

Method forecasting aims to earn the best forecast with tiny errors. The more small error in forecasting results will be better. Here are the levels of criteria forecast used:

a. Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{\sum_{t=2}^{n} \frac{|X_t - F_t|}{X_t} * 100}{n}$$

with,

n = lots of data

X_t = value actual for the period time t.

F_t = value forecast for a while

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Table 2. MAPE Criteria

MAPE	Information
< 10%	Forecasting ability is excellent
10% - 20%	Good forecasting ability
20% - 50%	Forecasting ability is sufficient.
> 50%	Poor forecasting ability

[23]

b. Mean Square Error (MSE)

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(X_t - F_t)^2$$

with:

n = Lots of data
Xt = Actual value in period time t
Ft = Forecast value for a while

RESULTS AND DISCUSSION

1. Data Description

This research uses value data imported from North Sumatra from January 2014 to September 2021. The data is from the official website of the Central Statistics Agency (BPS) of North Sumatra. The import Value of North Sumatra from January 2014 – September 2021 always experienced every data fluctuation the month. Data from January 2014 – September 2021 value The lowest North Sumatra import occurred in July 2015, which amounted to 253,349; meanwhile, North Sumatra's highest import occurred in May 2018, reaching 805,693.

2. Forecasting With Fuzzy Time Series Markov Chain and Fuzzy Time Series Lee methods

Step 1. Determine the set universe U talk.

North Sumatra Import Value Data from January 2014 – September 2021 has the Lowest D_{min} in July 2015, namely D_{min} = 235. 349. Whereas mark North Sumatra's highest import D_{max} occurred in May 2018, namely D_{max} = 805. 693. The researcher set marks Z_1 = 1 and Z_2 =1.

U =[235. 349-1;805. 693+1]= [253. 348; 805. 694]

Step 2: Determine The amount of set *Fuzzy*

For counting many set *fuzzy* built on value North Sumatra imports begin from January 2014 – September 2021 got done with method following:

1. Universe interval length discussion (U) obtained R=805,693+1-253,349-1 = 552,346
2. Average value Absolute difference is obtained.
   Means = 66314.39
3. Set interval basis *fuzzy* got based on results than the average difference absolute shared with 2, namely K = 33157.2. As a result, mark K the enter into 10,000 based intervals basis interval table 2.1.
4. The amount set *fuzzy* got from the K value is divided with R that is n = 56.

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As for the 56 intervals formed in the set universe talks U with each mark center (m) of the universe talks U is as follows:

Table 3Interval and Mid Value (m)

No	intervals	Middle Value (m)
1	$u_1 = [253.348;263.348]$	$m_1 = [258348]$
2	$u_2 = [263.348;273.348]$	$m_2 = [268348]$
3	$u_3 = [273.348;283.348]$	$m_3 = [278348]$
\	\	\
56	$u_7 = [803.348;813.348]$	$m_{56} = [808348]$

Step 3 Do *fuzzification* of any observational data.

Set *the fuzzy* formed is 56 based amount mark *n* that can be. So that set formed *fuzzy* is:

$$A_1 = \{1/u_1 + 0{,}5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + \Lambda + 0/u_{55} + 0/u_{56}\}$$
$$A_2 = \{0{,}5/u_1 + 1/u_2 + 0{,}5/u_3 + 0/u_4 + 0/u_5 + \Lambda + 0/u_{55} + 0/u_{56}\}$$
$$A_3 = \{0/u_1 + 0{,}5/u_2 + 1/u_3 + 0{,}5/u_4 + 0/u_5 + \Lambda + 0/u_{55} + 0/u_{56}\}$$
$$M \qquad\qquad M$$
$$A_{56} = \{01/u_1 + 0{,}5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + \Lambda\ 0{,}5/u_{55} + 1/u_{56}\}$$

Step 4 Do *fuzzification* of any observational data.

For example, monthly data for January 2014 ($t = 1$), namely 437,660, are in the interval. $u_{19} = [433.348:443.348]$ So, the data for January 2014 are in the set $A_{19}$and *fuzzified* in A_{19}.

Table 4. Data Fuzzification

Period	Data actual	Fuzzification
Jan-14	437,660	A_{19}
Feb-14	363,193	A_{11}
Mar-14	398,774	A_{15}
\	\	\
Sep-21	401459	A_{15}

Step 5. Forming table *Fuzzy Logical Relationships* (FLR) and *Fuzzy Logical Relationship Groups* (FLRG).

Table 5. Fuzzy Logic Relationships

Order	FL R
1-2	$A_{19} \rightarrow A_{11}$
2-3	$A_{11} \rightarrow A_{15}$
3-4	$A_{15} \rightarrow A_{22}$
\	\
92-93	$A_{22} \rightarrow A_{15}$

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Furthermore, based on obtained FRL table, it will form FLRG (Fuzzy Logic Relations Group), which means grouping the same current stage and Then grouping in form next state.

Table 6 Fuzzy Logic Relationship Groups

Current State	Next State
A_1	$\rightarrow A_7, A_{19}$
A_2	$\rightarrow A_6, A_{10}(2), A_{14}$
A_3	$\rightarrow A_4$
⋮	
A_{56}	$\rightarrow A_{20}$

4.2.1 Modeling *Fuzzy Time Series Markov Chain*

Step 6. Counting mark forecasting beginning

Calculation forecasting is determined based on historical data results, then form matrix probability transition chain Markov based on the FRLG table that has been formed. Here is the matrix probability transition with an order 56×56 with the element $P_{ij} = \frac{M_{ij}}{M}$

$$\begin{matrix} 0 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 1 & \cdots & 0 \\ 0 & 0 & \frac{1}{3} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{matrix}$$

For example, on February 2014, is at ($t = 2$). So, forecasting using the previous data, namely of January 2014 ($t = 1$) where $t = 1$ is at A_{19} transition with $t = 2$ at A_{11}. So that calculation forecast is as follows:

$$\begin{aligned} F_2 &= m_9 p_{19\ 9} + m_{11} p_{19\ 11} + m_{15} p_{19\ 15} + m_{20} p_{19\ 20} \\ &= 338348\left(\frac{1}{4}\right) + 358348\left(\frac{1}{4}\right) + 398348\left(\frac{1}{4}\right) + 448348\left(\frac{1}{4}\right) \\ &= 385848 \end{aligned}$$

So the data on forecasting furthermore can be done in the same way.

Table 7. Preliminary Forecasting of FTS Markov Chain

Period	Data actual	Early Forecasting
Jan-14	437,660	-
Feb-14	363,193	385,848
Mar-14	398,774	355,848
Apr-14	465,156	411,681.33
⋮	⋮	⋮
Sep-21	401459	491681.33

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Step 7. Counting trend forecasting

Calculation trend This forecast is based on each relation *Fuzzy Logic Relations* (FRL), from the *current state* to the *next state*. For example, in Table 7, January 2014, where the *current state* is A $_{19}$ and the next state is A $_{11,}$ the calculations use the 2nd rule.

$$d_2 = -\left(\frac{l}{2}\right)s$$
$$= -\left(\frac{10000}{2}\right)8$$
$$= -40000$$

Table 8 Value Adjustment

Current State	Next State	Adjustment Value
A $_{19}$	A $_{11}$	-40000
A $_{11}$	A $_{15}$	20000
A $_{15}$	A $_{22}$	35000
\	\	\
A $_{22}$	A $_{15}$	-35000

Step 8. Determine results forecasting end.

To get mark results forecasting, end with sum up results mark forecasting beginning with mark trend forecasting.

Table 9. FTS Markov Chain Final Forecasting

Period	Forecasting beginning	Mark Adjustment	Forecasting End
Jan-14	-	-	-
Feb-14	385848	-40000	345848
Mar-14	355848	20000	375848
\	\	\	\
Sept-21	472818.94	-35000	-35000

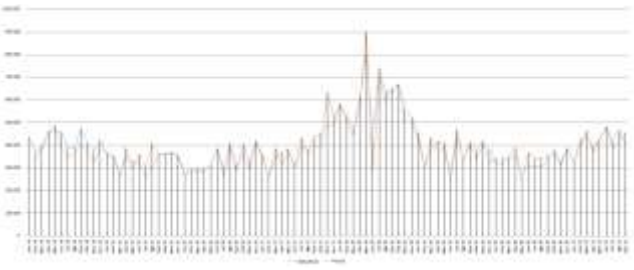

Figure 1. FTS Markov Chain Final Forecasting

2.2. Fuzzy Time Series Lee

Forecasting using the Fuzzy time series Lee has some equality steps with the fuzzy time series Markov Chain. The steps are the same, namely step 1 to step 5. Forecasting fuzzy time series Lee is as follows:

Step 6. Do Defuzzification.

Defuzzification in forecasting using fuzzy time series Lee is changing the fuzzy output to the in-value firm to calculate results in forecasting.

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Table 10. Defuzzification

No	Forecasting beginning	Defuzzification
1	$A_1 \rightarrow A_7, A_{19}$	$A_1 = 12\ (318348) + 12\ (438348) = 378348$
2	$A_2 \rightarrow A_6, A_{10}(2), A_{14}$	$A_2 = 14\ (308348) + 24\ (348348) + 14\ (388348) = 348348$
3	$A_3 \rightarrow A_4$	$A_3 = 278348$
⋮	⋮	⋮
56	$A56 \rightarrow A20$ _ _	$A56 = {}_{448348}$

Step 7. Do Data forecasting.

Forecasting on Lee's fuzzy time series based on results mark defuzzification FLRG that has got. For example, data forecasting to 2 (*t = 2),* then View data at the moment t = 1, which is in fuzzification A_{19}, then data forecasting for *t = 2* is the result defuzzification FRLG *A19*.

Table 11. Forecasting FTS Lee

Period	Data actual	Forecasting
Jan-14	-	-
Feb-14	385848	385848
Mar-14	355848	355848
⋮	⋮	⋮
Sept-21	401459	491681.33

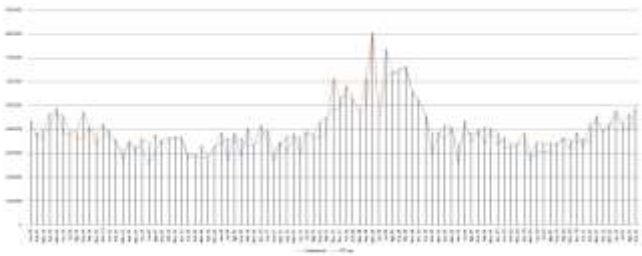

Figure 2. Forecasting FTS Lee

1. Count accuracy Forecasting

1. *Mean Absolute Percentage Error* (MAPE)

a. Calculation of MAPE on forecasting method *fuzzy time series Markov chain*

$$MAPE = \frac{\sum_{t=2}^{n} \frac{|X_t - F_t|}{X_t} * 100}{n}$$

$$= \frac{\left(\frac{|363.193 - 345848|}{363.193} + \frac{|398774 - 375848|}{398774} + \Lambda + \frac{|401459 - 446681{,}33|}{401459} \right) \times 100}{92}$$

$$= 7{,}7467\%$$

From the calculation above got that MAPE value of 7.7467%. If the table MAPE criteria, the MAPE value of 7.7467% entered in MAPE < 10%, meaning ability forecasting is perfect.

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b. Calculation of MAPE on forecasting method *fuzzy time series Lee.*

$$MAPE = \frac{\sum_{t=2}^{n} \frac{|X_t - F_t|}{X_t} * 100}{n}$$
$$= \frac{\left(\frac{|363.193 - 385848|}{363.193} + \frac{|398774 - 355848|}{398774} + \Lambda + \frac{|401459 - 491681,33|}{401459} \right) \times 100}{92}$$
$$= 10,014\%$$

From the calculation above, that MAPE value of 10.014%. The table MAPE criteria then MAPE value of 10.014 % entered in MAPE 10% − 20%, which means ability forecasting ok.

2. Mean Square Error (MSE)

a. Calculation of MSE on forecasting method *fuzzy time series Markov Chain*

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(X_t - F_t)^2$$
$$= \frac{1}{92}((363.193 - 345.848)^2 + ... + (401459 - 456681,33)^2)$$
$$= 176.748.587$$

b. Calculation of MSE on forecasting method *fuzzy time series Lee.*

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(X_t - F_t)^2$$
$$= \frac{1}{92}((363.193 - 345.848)^2 + ... + (401.459 - 491.681,33)^2)$$
$$= 2.387.874.804$$

4.2.4 Forecasting Results with Method Best

Based on the results, calculation, and mark *absolute mean percentage error* (MAPE) and mean square error, fuzzy the *fuzzy Markov chain* gets results MAPE and MSE values are better small from the *fuzzy time series Lee*. So, the *fuzzy time series Markov chain is* the best method for forecasting mark import in North Sumatra if comp to the fuzzy time series Lee method. So that method *fuzzy time series Markov chain* is the method that will be used in the forecast for the coming period come. Due to fortune-telling only obtained One period forward with the use method of *fuzzy time series Markov ch, the resulting forecast will make every output result* as input data. For example, results forecasting at t = 93, namely the result data forecasting on the moon September 2021 of 456681.33. so results are forecasted and then used as input data (actual data) in October 2021. Because the value 456681.33 is in the interval $u_{21,}$ the data on October 2021 *fuzzified on* $A_{21.}$

Table 12. Forecast 6 Periods Later

Period	Data actual	Mark Adjustment	Forecasting
Oct-21	411681.33	30000	441681.33
Nov-21	381125,77	-10000	371125,77
Dec-21	385848	-35000	350848
Jan-22	365940.59	-10000	355940.59
Feb-22	302348	5000	307348
Mar-22	355848	-25000	330848

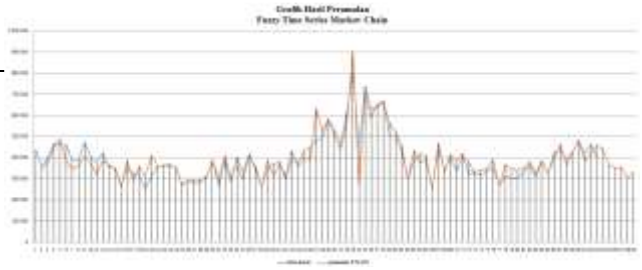

Figure 3. Forecast 6 Periods Later

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CONCLUSION

Application forecasting mark imports in North Sumatra use the method fuzzy time series Markov Chain obtained results forecasting data patterns follow or approach pattern from the actual data. For data patterns obtained, use the method fuzzy time series Lee tends to be different from actual data. Different data patterns are obtained from the second method because different calculation forecasting exists between the fuzzy time series Markov Chain and Lee's fuzzy time series. Absolute mean percentage error (MAPE) and mean square error (MSE) obtained using fuzzy time series Markov Chain on forecasting mark imports in North Sumatra were 7.7467% and 176,748,587, respectively. MAPE and MSE values using fuzzy time series Lee were 10.014% and 2,387,874,804, respectively.

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