Forecasting the Number of Participants of Social Security Agency's (BPJS) Programs in Banyumas Regency for Contributory Beneficiaries (PBI) Category Using Fuzzy Time Series Cheng Method

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Abstract. The Social Security Agency (BPJS) is an agency responsible for organizing the social security program for the community. It is found that the number of JKN PBI participants keeps on increasing each month as the services at BPJS improve. This research aims at predicting the number of JKN participants for PBI category for October 2023 based on the data on the number of JKN PBI participants in October 2022-September 2023 using the fuzzy time series Cheng method. Using the fuzzy time series Cheng method, it was predicted that in October 2023 the number of JKN PBI participants would be 1,040,000. In terms of its accuracy level, the forecasting using this method had an MSE value of 3.34 and MAPE value of 0.04%. Therefore, it could be concluded that the forecasting of JKN participants for PBI category was highly accurate.

Keywords: *BPJS, number of participants, forecasting, fuzzy time series Cheng.*

1   Introduction

The Social Security Agency (BPJS) is an agency that covers health or employment insurance for Indonesian society. One of the programs that BPJS manages is the National health insurance (JKN). This is the national social security system (SJSN) implemented under a social health insurance mechanism for members of society registered with BPJS to pay premium at a certain amount. Participation in JKN is divided into three. They are (i) non-wage recipient workers (PBPU) where participants bear the premium fee personally, (ii) wage recipient workers (PPU) for workers in a company receiving wage with their monthly premium being like civil servants and non-civil servant government employees, and (iii) contributory beneficiaries (PBI) specifically for underprivileged community where their monthly fee will be paid and governed by the government.

As time passes by, the health services in BPJS gets better and better. The same goes to JKN participants for PBI category as well. Therefore, to allow companies to make effective decisions, a forecasting is needed to figure out the number of participants on the

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months to come. One of the forecasting methods is the fuzzy logic one, namely fuzzy time series.

Fuzzy time series (FTS) is a forecasting method introduced by Song and Chissom [1]. It is used to forecast problems with actual data formed in linguistic values. According to Prayogi [2], FTS has its own models such as Chen, Cheng, and Ruey Chyn Tsaur models, as well as several other models.

One study that used FTS Cheng model was conducted by Fathurokman [3] who evaluated Fuzzy Time Series Cheng and Ruey Chyn Tsaur methods and found that the MAPE values were 0.43% for Cheng method and 0.47% for Ruey Chyn Tsaur method. Furthermore, Rahmawati [4] applied the Sugeno Fuzzy Inference System (FIS) method to forecast the number of PBI participants in BPJS Kesehatan Pekanbaru City Branch, and the results showed that the Sugeno FIS model produced forecasts with an accuracy of 94.17%, which indicates the effectiveness of the model in predicting membership numbers with high precision. In another study [5], the researchers predicted the number of BPJS participants for the contributory beneficiaries (PBI) category using the Fuzzy Time Series Cheng method and found that the MAPE value was 0.97%, indicating that the prediction level was excellent.

Based on this, the author is interested in forecasting the number of JKN participants for contributory beneficiaries (PBI) category using FTS Cheng. This forecasting will transform the data into a binary form as per the definition of fuzzy through fuzzification stage. It is expected that the results of this research would be useful for consideration for BPJS Kesehatan to pass better policies.

2 Materials and Methods

2.1 Research Step

This research used literature review. The steps taken in this research were [6],[7], [8] and [9]:

1. Creating a data plot using Microsoft Excel software.
2. Defining the U universe using the following equation:

$$U = [D_{min} - D_1, D_{max} + D_2], \tag{1}$$

where, D_{min} : least data and D_{max}: biggest data.

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3. Determining the interval length, namely

a. Determining the number of classes with equation

$$n = 1 + 3.322\, log(N) \qquad (2)$$

b. Determining the range with equation

$$R = (D_{max} - D_2) - (D_{min} - D_1) \qquad (3)$$

c. Determining the interval width with equation

$$I = \frac{range(R)}{class\ interval\ number\ (n)} \qquad (4)$$

d. Finding the median value with equation

$$m_i = \frac{upper\ limit\ + lower\ limit}{2} \qquad (5)$$

4. Defining fuzzification, namely

$$A = \frac{\mu Ai(u1)}{u1} + \frac{\mu Ai(u2)}{u2} + \cdots + \frac{\mu Ai(un)}{un} \qquad (6)$$

5. Determining the fuzzy logic relationship (FLR) and FLR group (FLRG).

6. Determining the weighting matrix in FLRG, namely

$$W_{ij} \mathrel{*}= \frac{W_{ij}}{\sum_{j=1}^{n} W_{ij}} \qquad (7)$$

7. Determining the defuzzification of forecasted value, namely

$$F_i = w_{i1} * (m_1) + w_{i2} * (m_2) + \cdots + w_{in} * (m_n) \qquad (8)$$

8. Testing the forecasting method accuracy using Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) [10].

2.2 Data

The data used in this research were the ones on the number of BPJS Kesehatan participants in Banyumas for contributory beneficiaries (PBI) category from October 2022 to September 2023. These data were obtained from BPJS Kesehatan of Purwokerto. The data used can be seen in Table 1.

Table 1. Data of number of BPJS Kesehatan participants for contributory beneficiaries' category

Year	Number of BPJS Kesehatan Participants	Year	Number of BPJS Kesehatan Participants
October 2022	973,211	December 2022	987,679
November 2022	985,340	January 2023	986,806

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Table 2. (Continue) Data of number of BPJS Kesehatan participants for contributory beneficiaries' category

Year	Number of BPJS Kesehatan Participants	Year	Number of BPJS Kesehatan Participants
February 2023	985,679	June 2023	1,015,132
March 2023	990,873	July 2023	1,022,858
April 2023	1,003,482	August 2023	1,027,729
May 2023	1,009,196	September 2023	1,037,111

3 Results and Discussion

3.1 Data Plot

Below is the time series data plot on the number of BPJS Kesehatan participants in Banyumas for PBI category in October 2022 to September 2023 using Microsoft Excel. Based on Figure 1, the time series plot of number of BPJS Kesehatan participants for PBI category in October 2022 to September 2023 constituted an increasing trend since the data plot showed a movement that tended to increase in a long run.
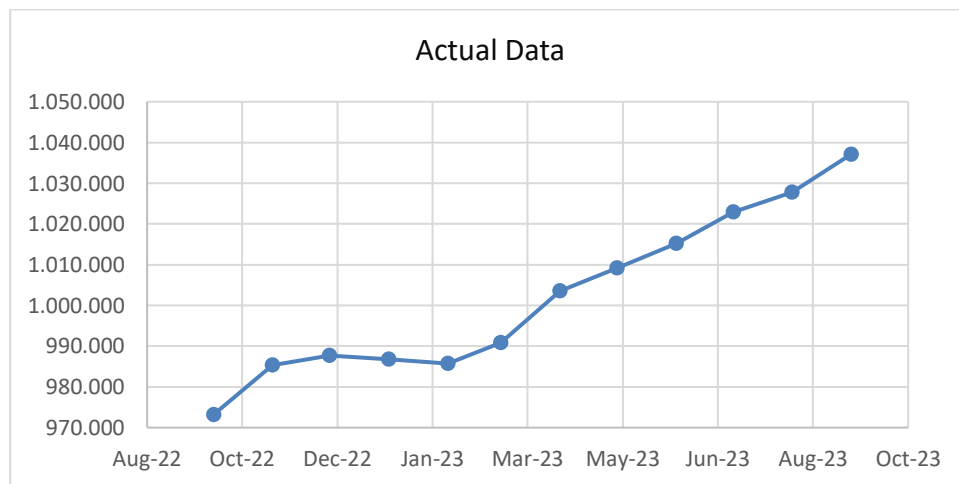

Figure 1. Time Series Plot of Number of BPJS Kesehatan Participants for PBI category

3.2 Formation of Universe Set

$$U = [[D_{min} - D_1]; [D_{max} + D_2]]$$
$$= [[973,211 - 3,211]]; [1,037,111 - 12,889]$$
$$= [970,000; 1,050,000]$$

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3.3 Formation of Interval Length

a. Calculating the interval class

$$n = 1 + 3{,}322 \, log \, (12) \, = 4{,}58504 \approx 4$$

b. Determining the range value
$$R = 1{,}050{,}000 - 970{,}000 = 80{,}000$$

c. Determining the interval size and width

$$I = \frac{80{,}000}{4} = 20{,}000$$

Table 3. Hasil Partisi Himpunan Universal

Number of Class	Lower Limit	Upper Limit	Median
u_1	970,000	990,000	980,000
u_2	990,000	1,010,000	1,000,000
u_3	1,010,000	1,030,000	1,020,000
u_4	1,030,000	1,050,000	1,040,000

3.4 Fuzzification Process

The fuzzification process is a process to change numeric data into linguistic ones [7],[8],[9],[10] and [11]. Assume $A_1, A_2, \dots A_n$ is the fuzzy set of linguistic values of a linguistic variable. The number of A_n is as many as the obtained number of interval classes, namely 5 interval classes. Then, each class will be defined as fuzzy set A_i where $1 \leq i \leq 5$. Hence, the following linguistic variable will be formed as:

$$A_1 = \left\{ \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} \right\};$$

$$A_2 = \left\{ \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \frac{0}{u_4} \right\};$$

$$A_3 = \left\{ \frac{0}{u_1} + \frac{0{,}5}{u_2} + \frac{1}{u_3} + \frac{0{,}5}{u_4} \right\};$$

$$A_4 = \left\{ \frac{0}{u_1} + \frac{0}{u_2} + \frac{0{,}5}{u_3} + \frac{1}{u_4} \right\}.$$

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Table 4. Fuzzification

Year	Number of BPJS Kesehatan Participants	*Fuzzification*	Year	Number of BPJS Kesehatan Participants	*Fuzzification*
October 2022	973,211	A_1	April 2023	1,003,482	A_2
November 2022	985,340	A_1	May 2023	1,009,196	A_2
December 2022	987,679	A_1	June 2023	1,015,132	A_3
January 2023	986,806	A_1	July 2023	1,022,858	A_3
February 2023	985,679	A_1	August 2023	1,027,729	A_3
March 2023	990,879	A_2	September 2023	1,037,111	A_4

3.5 Formation of Fuzzy Logic Relationship and FLR Group

Based on the definition of Cheng Logic, if $F(t-1) = A_i$ and $F(t) = A_j$ the fuzzy logic relationship or FLR could be written as $A_i \rightarrow A_j$ [8] and [9]. Meanwhile, FLRG could be formed by combining the same fuzzy set values.

Table 5. Fuzzy Logic Relationship Results

Year	Number of BPJS Kesehatan Participants	Fuzzification	FLR
October 2022	973,211	A_1	-
November 2022	985,340	A_1	$A_1 \rightarrow A_1$
December 2022	987,679	A_1	$A_1 \rightarrow A_1$
January 2023	986,806	A_1	$A_1 \rightarrow A_1$
February 2023	985,679	A_1	$A_1 \rightarrow A_1$
March 2023	990,873	A_2	$A_1 \rightarrow A_2$
April 2023	1,003,482	A_2	$A_2 \rightarrow A_2$
May 2023	1,009,196	A_2	$A_2 \rightarrow A_2$
June 2023	1,015,132	A_3	$A_2 \rightarrow A_3$
July 2023	1,022,858	A_3	$A_3 \rightarrow A_3$
August 2023	1,027,729	A_3	$A_3 \rightarrow A_3$
September 2023	1,037,111	A_4	$A_3 \rightarrow A_4$

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3.6   FLRG Weighting

The process of FLRG weighting was done by seeing the number of the same relations in FLRG as in the following table:

Table 5. FLRG and Weighing

Current state		Next Stage
A_1	$\rightarrow$	$(4)A_1, (1)A_2$
A_2	$\rightarrow$	$(2)A_2, (1)A_3$
A_3	$\rightarrow$	$(2)A_3, (1)A_4$
A_4	$\rightarrow$	$\emptyset$

For the fuzzy set $A_1 \rightarrow (4)A_1, (1)A_2$, it was found that there were four fuzzy relationships $A_1 \rightarrow A_1$, and there was only one fuzzy relationship $A_1 \rightarrow A_2$. Based on this FRLG, the weighting $w_{11} = 4$ from (A_1) and $w_{12} = 1$ from (A_2) were found. This formed the weighting matrix Wt = $[\ w_{11}\ w_{12}] = [\ 4\ 1\ ]$.

Table 6. Weighing Matrix

FLRG	A_1	A_2	A_3	A_4
A_1	4	1	0	0
A_2	0	2	1	0
A_3	0	0	2	1
A_4	0	0	0	0

Furthermore, the FLRG weight was transferred into a standardized weighting matrix form (W*). For the fuzzy set $A_1 \rightarrow (4)A_1, (1)A_2$ that had the weighting $w_{11} = 4$ and $w_{12} = 1$ with matrix Wt = [1 2], then, based on the weighting of the weighting matrix formula was standardized into

$$W_{ij} \ast= \frac{W_{ij}}{\sum_{j=1}^{n} W_{ij}}$$

$$W_{11} \ast= 4\ /\ 5 = 0.8$$

$$W_{12} \ast= 1/5 = 0.2$$

Based on this calculation, a standardized weighting matrix $W_{ij} \ast = [w_{11} \ast\ \ w_{12} \ast] = [\ 0,8\ 0,2\ ]$ was obtained. These steps were applicable henceforth for other fuzzy sets. Below is the result of the standardized weighting matrix.

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Table 7. Standardized Weighing Matrix

FLRG	A_1	A_2	A_3	A_4
A_1	0.8	0.2	0	0
A_2	0	0.66	0.33	0
A_3	0	0	0.66	0.33
A_4	0	0	0	0

3.7   Defuzzification Process

In Cheng method, the process of calculating defuzzification would use a standardized weighting matrix (W*) and a median value at interval or midpoint (m_i) for ever relations in fuzzy $A_i = A_1, A_2, ..., A_n$. For the result of defuzzification of forecasting value in fuzzy A_1, i.e., calculating the defuzzification, the forecasting F_1 value was as follows:

$$F_1 = w_{11} * (m_1) + w_{12} * (m_2)$$
$$= 0.8 * (980{,}000) + 0.2 * (1{,}000{,}000)$$
$$= 984{,}000$$

The steps above were applicable for every relation of other fuzzy sets. Below is the result of defuzzification process.

Table 8. Defuzzification Results

Current state		Next Stage	Forecasting
A_1	→	$(4)A_1, (1)A_2$	984,000
A_2	→	$(2)A_2, (1)A_3$	1,000,000
A_3	→	$(2)A_3, (1)A_4$	1,020,000
A_4	→	Ø	1,040,000

Tabel 9. Cheng Method Forecasting Results

Year	Number of BPJS Kesehatan participants	Fuzzification	Forecasting
October 2022	973,211	A_1	984,000
November 2022	985,340	A_1	984,000
December 2022	987,679	A_1	984,000
January 2023	986,806	A_1	984,000
February 2023	985,679	A_1	984,000

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Tabel 9. (Continue) Cheng Method Forecasting Results

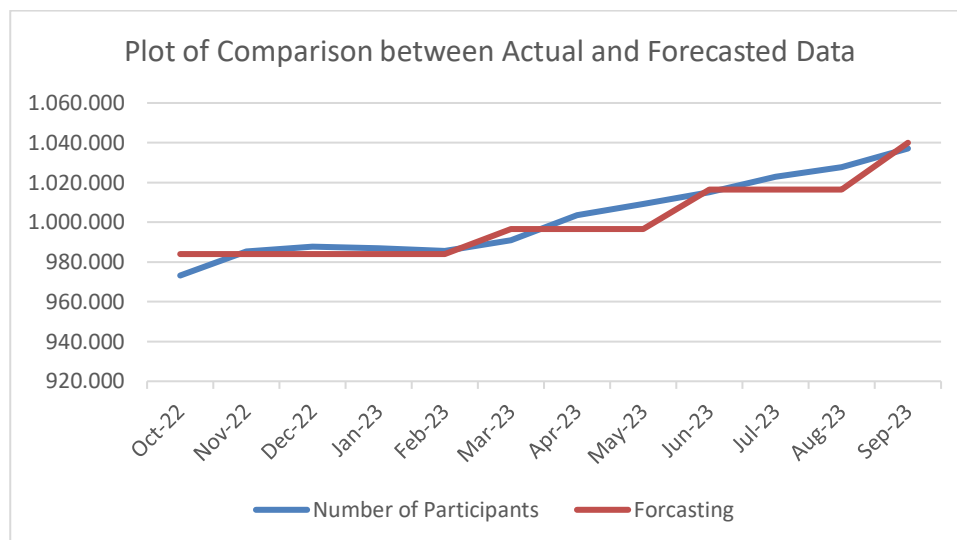| Year	Number of BPJS Kesehatan participants	Fuzzification	Forecasting
March 2023	990,873	A_2	996,600
April 2023	1,003,482	A_2	996,600
May 2023	1,009,196	A_2	996,600
June 2023	1,015,132	A_3	1,016,400
July 2023	1,022,858	A_3	1,016,400
August 2023	1,027,729	A_3	1,016,400
September 2023	1,037,111	A_4	1,040,000

Figure 2. Plot of Comparison between Actual and Forecasted Data

3.8 Fuzzy Time Series Cheng Forecasting

The forecasting of the next period was determined by seeing the formed relations in the previous period, in this case in September 2023 at a forecasting value of 1,040,000. Based on the table, the formed FLR was $A_3 \rightarrow A_4$ hence for the October 2023 period, the forecasting value was used in group A_4. Based on table 5, A_4 had no FLR, or $A_4 \rightarrow \emptyset$, hence the predicted F_4 value was the median value of u_4 at 1,040,000.

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3.9 Testing the Methods Accuracy

The final forecasted data would be tested for its precision and accuracy levels by calculating the Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) values [5].

1. Mean Square Error (MSE)

$$MSE = \frac{1}{n} \sum_{t=1}^{n} \left(Xt - \widehat{Xt}\right)^2$$

$$= \frac{40,113,541}{12} = 3,342$$

2. Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{Xt - \widehat{Xt}}{xt} \right| x \ 100 \ \%$$

$$= \frac{0.5057}{12} \ x \ 100 \ \% = 0.04 \ \%$$

This research found that the MSE value was 3.342 and the MAPE value was under 10% at 0.04 %. This means that this forecasting had a high accuracy.

4 Conclusion

Based on the result and discussion, it could be concluded that, the time series plot in the number of JKN participants for PBI category in Banyumas had an increasing trend data pattern, since the chart showed a data movement that tended to increase in a long run. The forecasting result obtained using the fuzzy time series method for October 2023 was 1,040,000 participants. In terms of accuracy level, the MSE value was obtained at 3.342 and the MAPE value under 10 % at 0.04%. Therefore, it could be concluded that the forecasting of number of JKN participants for PBI category in October 2023 had a high accuracy.

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