

Forecasting of the Cases of Covid-19 Patients in Indonesia using Fuzzy Time Series

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Abstract

In this study, the aim is to forecast cases of COVID-19 patients in Indonesia using fuzzy time series. The data used in this research comes from February 1, 2022 to February 28, 2022. The method used in this research are Fuzzy Time Series (FTS) Chen and FTS Cheng, using first order and second order. FTS is a forecasting method that uses rules and logic on fuzzy sets. The level of prediction accuracy is then calculated based on the Mean Absolute Percentage Error (MAPE) value. The MAPE values of these two methods are then compared to know which method is more suitable in this case study. The results showed that First Order FTS Chen produced an accuracy of 4,21% and First Order FTS Cheng produced an accuracy of 4,22%. Second Order FTS Chen and Second Order FTS Cheng produced the same MAPE, 1,23%. The results of this study to predict cases of confirmed Covid-19 patients showed that Second Order FTS Chen and FTS Cheng produced good accuracy.

Keywords: *Chen; Cheng; covid; first order; fuzzy time series*

1. Introduction

Coronavirus Disease 2019 (COVID-19) is a new type of disease that has never been previously identified in humans [1], [2]. The virus that causes COVID-19 is called Sars-CoV-2. Corona virus is zoonotic (transmitted between animals and humans) [3]. Based on scientific evidence, the transmission of COVID-19 occurs from human to human through coughing/sneezing droplets [4]. In this case, the people most at risk of contracting this disease are people who have frequent close contact with COVID-19 patients, for example those who treat COVID-19 patients. [5].

Common symptoms of COVID-19 infection are acute respiratory disorders such as fever, cough, and shortness of breath [6]. The average incubation period is 5 - 6 days with an incubation period of fever, cough, and shortness of breath. In severe cases, COVID-19 can cause pneumonia, acute respiratory syndrome, kidney failure, and even death [7]-[10].

Indonesia is a developing country and also the fourth most populous country in the world [11], [12]. When the new coronavirus SARS-CoV2 hit China in December 2019 – February 2020. Initially, patients infected with COVID-19 in Indonesia began with an incident in Jakarta where the patient was in contact with a Japanese citizen living in Malaysia. Where, after meeting the patient with a stranger, he complained of fever, cough and shortness of breath [13], [14].

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This paper discusses the fuzzy time series developed by Chen and Cheng. Where forecasting using fuzzy time series can explore past data patterns to predict future events using various properties, principles and logic in fuzzy sets. Fuzzy time series is one of the forecasting methods in this study which was introduced by Song and Chisom. Determination of the number of fuzzy classes using the average based method. The difference between the Chen and Cheng methods lies in the defuzzification process. Where the difference is, the Chen method does not use weighting, while the Cheng method uses weighting. This paper will discuss the comparison of the use of the first and second order in the Chen and Cheng method.

The purpose of this article is to predict the number of confirmed cases of Covid-19 sufferers using the Fuzzy Time Series Chen and Cheng methods of first order and second order. The prediction accuracy of the four methods is then calculated using MAPE. This article is a manifestation of the application of mathematics and statistics in the world of health in Indonesia.

2. Methods

The method that will be used for data on the increase in confirmed cases of Covid-19 sufferers per day is seen from February 1, 2022 to February 28, 2022 as shown in Table 1

Table 1. Data on additional confirmed cases of Covid-19 patients in February 2022

No	Date	Historical Data	No	Date	Historical Data
1	Feb 1, 2022	16021	15	Feb 15, 2022	57049
2	Feb 2, 2022	17895	16	Feb 16, 2022	64718
3	Feb 3, 2022	27197	17	Feb 17, 2022	63956
4	Feb 4, 2022	32211	18	Feb 18, 2022	59635
5	Feb 5, 2022	33729	19	Feb 19, 2022	59384
6	Feb, 6 2022	36057	20	Feb 20, 2022	48484
7	Feb 7, 2022	26121	21	Feb 21, 2022	34418
8	Feb 8, 2022	37492	22	Feb 22, 2022	57491
9	Feb 9, 2022	46843	23	Feb 23, 2022	61488
10	Feb 10, 2022	40618	24	Feb 24, 2022	57426
11	Feb 11, 2022	40489	25	Feb 25, 2022	49447
12	Feb 12, 2022	55209	26	Feb 26, 2022	46643
13	Feb 13, 2022	44526	27	Feb 27, 2022	34976
14	Feb 14 2022	36501	28	Feb 28, 2022	25054

The forecasting method used in this research is the Fuzzy Time Series Chen and Cheng method using MAPE as a method to calculate the accuracy of the prediction results [15]-[18]. The calculation scheme for the Fuzzy Time Series Chen and Cheng can be seen in Figure 1.

Explanation of Chen and Cheng's Fuzzy Time Series calculation scheme:

1. Data on additional confirmed cases of Covid-19 sufferers is used as input for Chen and Cheng's Fuzzy Time Series method
2. Determine X_{min} , X_{max} , D_1 , D_2 , the middle value (midpoint)

X_{min} : Minimum data

X_{max} : Maximum data

Where D_1 , and D_2 are arbitrary positive numbers and are determined by the researcher. Meanwhile, D_1 , and D_2 are usually values or numbers that make it easier to calculate the universe set from historical data that is formed.

3. Determine U , namely the Universe of discourse or the set of historical data universes, namely.

$$U = \{X_{min} - D_1, X_{max} + D_2\} \quad (1)$$

4. The length of the interval is calculated using the average based length method [14]. Once the length of the interval is known, we will get the sum of the intervals.
5. After getting the number of intervals, we define the fuzzy set according to the number of classes. For example, is a fuzzy set that has a linguistic value, the definition of the set in the universe of speech U is as follows

$$\begin{aligned}
A_1 &= \frac{1}{u_1} + \frac{0.5}{u_2} + \frac{0}{u_3} + \dots + \frac{0}{u_p} \\
A_2 &= \frac{0.5}{u_1} + \frac{1}{u_2} + \frac{0.5}{u_3} + \dots + \frac{0}{u_p} \\
A_3 &= \frac{0}{u_1} + \frac{0.5}{u_2} + \frac{1}{u_3} + \frac{0.5}{u_4} + \dots + \frac{0}{u_p} \\
&\vdots \\
A_p &= \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \dots + \frac{0.5}{u_{p-1}} + \frac{1}{u_p}
\end{aligned}$$

Where $u_i (i = 1, 2, 3, \dots, p)$ is the element of the universal set u and the number marked with the symbol "/" represents the degree of membership $\mu_{A_i}(u_i)$ to $A_i (i = 1, 2, 3, \dots, p)$ which the value is 0, 0.5 or 1.

6. The historical data is classified according to the fuzzy set in step 5.
7. After getting the fuzzy set, we form the FLR. FLR is a fuzzy relation between data in year i and data in year j . $F(t-1) = A_i$ and $F(t) = A_j$, then the FLR formed is . FLR is a fuzzy relation between data in year i and data in year j . After all historical data is classified into FLR, FLRG is formed. FLRG is a group obtained from FLR which has the same left side. The difference between the Chen and Cheng methods is in the weighting of the FLRG. The Chen method does not use weighting and the Cheng method uses weighting.
8. After getting FLRG, defuzzification is carried out. in Chen and Cheng's Fuzzy Time Series there are several forecasting rules [15], [16], namely:

Rule 1.

If the result of fuzzification in year t is A_i and there is no fuzzy logic relation, for example if $A_i \rightarrow \emptyset$, then the forecasting result F_{t+1} is m_i , where m_i the middle value u_i

Rule 2.

If the fuzzification result in year t is A_i and A_j there is only one FLR in the FLRG, for example if $A_i \rightarrow A_j$, where A_i and A_j are fuzzy sets, then the forecasting result F_{t+1} is m_i .

Rule 3.

If the fuzzification result on day t is and has several FLRs on the FLRG, for example if $A_i \rightarrow A_{j1}, A_{j2}, \dots, A_{jk}$, where $A_i, A_{j1}, A_{j2}, \dots, A_{jk}$ is a fuzzy set and the maximum value of the membership function of is $A_i, A_{j1}, A_{j2}, \dots, A_{jk}$ in $u_{j1}, u_{j2}, \dots, u_{jk}$ the interval and the mean of is $u_{j1}, u_{j2}, \dots, u_{jk}$, then the forecasting result F_{t+1} is

$$F_{t+1} = \frac{m_{j1} + m_{j2} + \dots + m_{jk}}{k} \quad (2)$$

Where k is the number of midpoints. To find the mean value in the fuzzy m_i set interval, the following equation can be used:

$$m_i = \frac{\text{upper limit} + \text{lower limit}}{2} \quad (3)$$

9. The determination of FLR for the second order involves 2 (two) or more historical data symbolized by $F(t-n), \dots, F(t-2), F(t-1)$. For example, for the second order, it is necessary to involve 2 historical data in determining the FLR, namely $F(t-2)$. and $F(t-1)$ so that FLRG is formed into groups based on observational data. For example, if $F(t-2) = A_i, F(t-1) = A_j, F(t) = A_k$, then the FLR formed is $A_i, A_j \rightarrow A_k$ which is the second order FLR writing.

10. The error rate of the prediction or MAPE can be calculated by the formula

$$MAPE = \sum_{i=1}^n \left| \frac{x_i - p_i}{x_i} \right| \times 100\% \tag{4}$$

Where

- x_i : actual data in year i
- p_i : forecast value in year i
- n : number of data

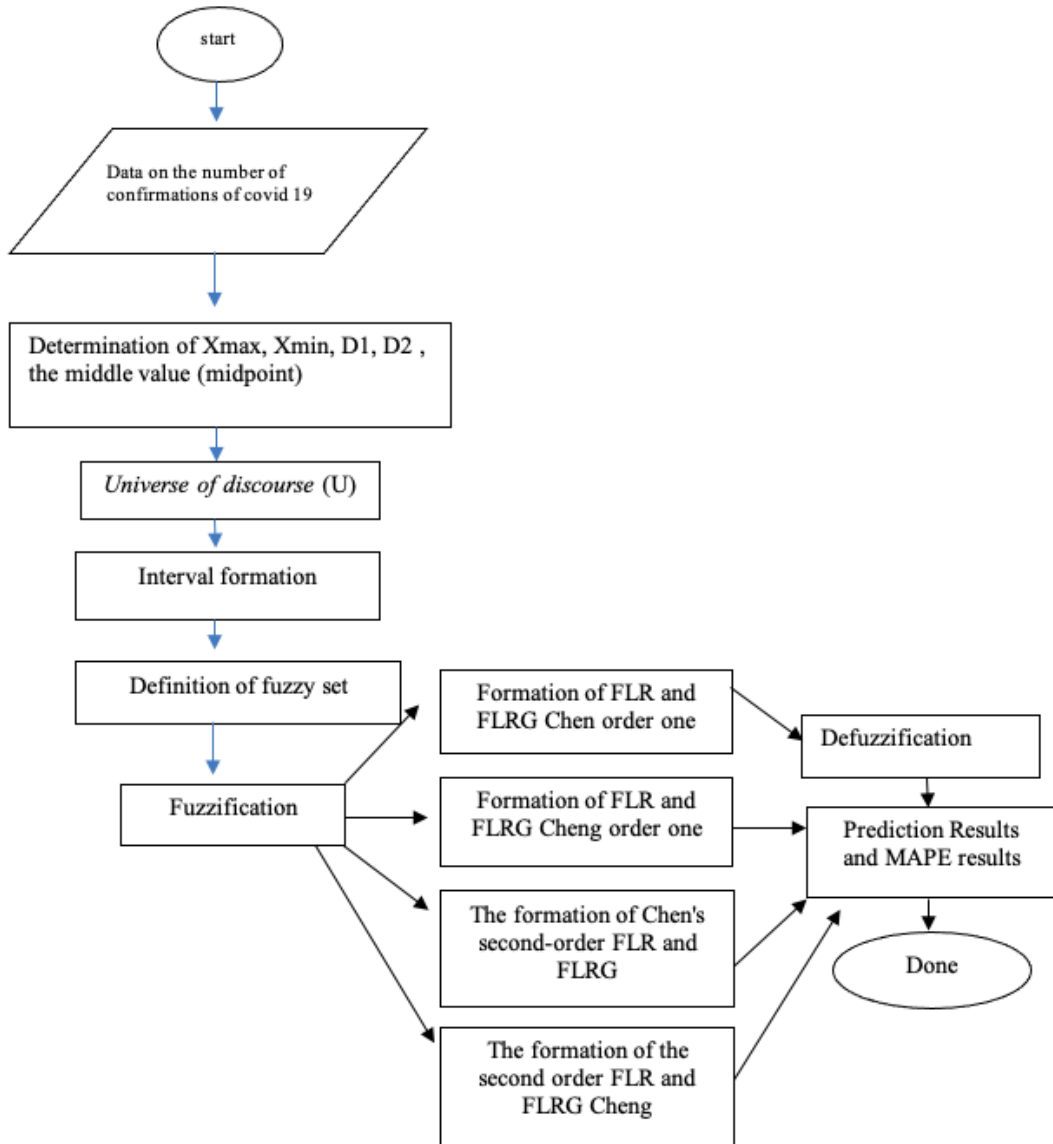


Figure 1. Chen and Cheng Fuzzy Time Series Calculation Scheme.

3. Result and Discussion

Based on these data, we get $X_{min} = 16021$ and $X_{max} = 64718$. The selected $D1$ and $D2$ are $D1 = 21$ and $D2 = 3282$, so the value obtained is $U = [16000,68000]$. By using the average based method, we get the length of the interval = 3935.13 and rounded to 4000. With the interval length of 4000, we get the number of intervals (fuzzy numbers) as many as 13 intervals. , i.e. $[16000,20000]$, $[20000,24000]$, $[24000,28000]$, ..., $[60000,64000]$, $[64000,68000]$.

The fuzzification stage is carried out according to the number of intervals formed. Fuzzification results can be seen in the Table 2.

Table 2. Fuzzifikasi

No	Date	Historical Data	Fuzzifikasi	No	Date	Historical Data	Fuzzifikasi
1	Feb 1, 2022	16021	A1	15	Feb 15, 2022	57049	A11
2	Feb 2, 2022	17895	A1	16	Feb 16, 2022	64718	A13
3	Feb 3, 2022	27197	A3	17	Feb 17, 2022	63956	A12
4	Feb 4, 2022	32211	A5	18	Feb 18, 2022	59635	A11
5	Feb 5, 2022	33729	A5	19	Feb 19, 2022	59384	A11
6	Feb 6, 2022	36057	A6	20	Feb 20, 2022	48484	A9
7	Feb 7, 2022	26121	A3	21	Feb 21, 2022	34418	A5
8	Feb 8, 2022	37492	A6	22	Feb 22, 2022	57491	A11
9	Feb 9, 2022	46843	A8	23	Feb 23, 2022	61488	A12
10	Feb 10, 2022	40618	A7	24	Feb 24, 2022	57426	A11
11	Feb 11, 2022	40489	A7	25	Feb 25, 2022	49447	A9
12	Feb 12, 2022	55209	A10	26	Feb 26, 2022	46643	A8
13	Feb 13, 2022	44526	A8	27	Feb 27, 2022	34976	A5
14	Feb 14, 2022	36501	A6	28	Feb 28, 2022	25054	A4

1. Process the first FLR order

The FLR that is formed pays attention to the fuzzy relationship from day to day which can be seen in Table 3.

Table 3. FLR

No	Date	FLR	No	Date	FLR
1	1 → Feb 2, 2022	A1→ A2	15	15 → Feb 16, 2022	A11→ A13
2	2 → Feb 3, 2022	A1→ A3	16	16 → Feb 17, 2022	A13→ A12
3	3 → Feb 4, 2022	A3→ A5	17	17 → Feb 18, 2022	A12→ A11
4	4 → Feb 5, 2022	A5→ A5	18	18 → Feb 19, 2022	A12→ A11
5	5 → Feb 6, 2022	A5→ A6	19	19 → Feb 20, 2022	A11→ A9
6	6 → Feb 7, 2022	A6→ A3	20	20 → Feb 21, 2022	A9→ A5
7	7 → Feb 8, 2022	A3→ A6	21	21 → Feb 22, 2022	A5→ A11
8	8 → Feb 9, 2022	A6→ A8	22	22 → Feb 23, 2022	A11→ A12
9	9 → Feb 10, 2022	A8→ A7	23	23 → Feb 24, 2022	A12→ A11
10	10 → Feb 11, 2022	A7→ A7	24	24 → Feb 25, 2022	A11→ A9
11	11 → Feb 12, 2022	A7→ A10	25	25 → Feb 26, 2022	A9→ A8
12	12 → Feb 13, 2022	A10→ A8	26	26 → Feb 27, 2022	A8→ A5
13	13 → Feb 14, 2022	A1→ A2	27	27 → Feb 28, 2022	A6→ A11
14	14 → Feb 15, 2022	A1→ A2			

2. Forming the first order FLRG

FLRG is done by grouping fuzzy sets that have the same current state and then grouping them into one group in the next state based on the FLR table. The Chen method FLRG is listed in Table 4 and the Cheng method FLRG is listed in Table 5.

Table 4. FLRG Chen method first order

No	FLRG
1	A1 → A1, A3
2	A3 → A5, A6
3	A5 → A4, A5, A6, A11
4	A6 → A3, A8, A11
5	A7 → A7, A10
6	A8 → A5, A6, A7
7	A9 → A5, A8
8	A10 → A8
9	A11 → A9, A11, A12, A13
10	A12 → A11
11	A13 → A12

Table 5. FLRG Chen method first order

No	FLRG
1	A1 → A1, A3
2	A3 → A5, A6
3	A5 → A4, A5, A6, A11
4	A6 → A3, A8, A11
5	A7 → A7, A10
6	A8 → A5, A6, A7
7	A9 → A5, A8
8	A10 → A8
9	A11 → 2A9, A11, A12, A13
10	A12 → 2A11
11	A13 → A12

3. Forming a second order FLR

By paying attention to the fuzzification results, we get the second order FLR as follows:

Table 6. FLR Chen method second order

No	Date	FLR	No	Date	FLR
1	1,2 → Feb 3, 2022	A1, A1 → A3	14	14,15 → Feb 16, 2022	A6, A11 → A13
2	2,3 → Feb 4, 2022	A1, A3 → A5	15	15,16 → Feb 17, 2022	A11, A13 → A12
3	3,4 → Feb 5, 2022	A3, A5 → A5	16	16,17 → Feb 18, 2022	A5, A5 → A6
4	4,5 → Feb 6, 2022	A1, A3 → A6	17	17,18 → Feb 19, 2022	A12, A11 → A11
5	5,6 → Feb 7, 2022	A5, A6 → A3	18	18,19 → Feb 20, 2022	A11, A11 → A9
6	6,7 → Feb 8, 2022	A6, A3 → A6	19	19,20 → Feb 21, 2022	A11, A9 → A5
7	7,8 → Feb 9, 2022	A3, A6 → A8	20	20,21 → Feb 22, 2022	A9, A5 → A11
8	8,9 → Feb 10, 2022	A6, A8 → A7	21	21,22 → Feb 23, 2022	A5, A11 → A12
9	9,10 → Feb 11, 2022	A8, A7 → A7	22	22,23 → Feb 24, 2022	A11, A12 → A11
10	10,11 → Feb 12, 2022	A7, A7 → A10	23	23,24 → Feb 25, 2022	A11, A12 → A11
11	11,12 → Feb 13, 2022	A7, A10 → A8	24	24,25 → Feb 26, 2022	A11, A9 → A8
12	12,13 → Feb 14, 2022	A10, A8 → A6	25	25,26 → Feb 27, 2022	A9, A8 → A5
13	13,14 → Feb 15, 2022	A8, A6 → A11	26	26,27 → Feb 28, 2022	A8, A5 → A4

The calculation results of the second order Cheng method FLR are the same as the second order Cheng method FLR

Table 7. FLRG Chen Second order

No	FLRG	No	FLRG
1	A1, A1 → A3	13	A8, A5 → A4
2	A1, A3 → A5	14	A8, A6 → A11
3	A3, A5 → A5	15	A8, A7 → A7
4	A3, A6 → A8	16	A9, A5 → A11
5	A5, A5 → A6	17	A9, A8 → A5
6	A5, A6 → A3	18	A10, A8 → A6
7	A5, A11 → A12	19	A11, A9 → A5
8	A6, A3 → A6	20	A11, A11 → A9
9	A6, A8 → A3	21	A11, A12 → A11
10	A6, A11 → A13	22	A11, A13 → A12
11	A7, A7 → A8	23	A12, A11 → A9, A11
12	A7, A10 → A8	24	A13, A12 → A11

Table 8. Second Order FLRG Cheng

No	FLRG	No	FLRG
1	A1, A1 → A3	13	A8, A5 → A4
2	A1, A3 → A5	14	A8, A6 → A11
3	A3, A5 → A5	15	A8, A7 → A7
4	A3, A6 → A8	16	A9, A5 → A11
5	A5, A5 → A6	17	A9, A8 → A5
6	A5, A6 → A3	18	A10, A8 → A6
7	A5, A11 → A12	19	A11, A9 → 2A5
8	A6, A3 → A6	20	A11, A11 → A9
9	A6, A8 → A3	21	A11, A12 → A11
10	A6, A11 → A13	22	A11, A13 → A12
11	A7, A7 → A8	23	A12, A11 → A9, A11
12	A7, A10 → A8	24	A13, A12 → A11

4. The process of defuzzification of forecasting values, namely by finding the middle value of each interval based on equation (4), and calculating the forecast value according to the defuzzification rules that have been discussed.

The results of the defuzzification for the first-order Chen method, the first-order Cheng, are shown in Table 9.

Table 9. Defuzzification results of the first order Chen method and the first order Cheng method

No	Group	Prediction Chen first order	Prediction Cheng first order
1	A1	22000	22000
2	A3	36000	36000
3	A5	40000	40000
4	A6	43434	43434
5	A7	48000	48000
6	A8	38000	38000
7	A9	40000	40000
8	A10	46000	46000
9	A11	59000	57200
10	A12	58000	58000
11	A13	62000	62000

Table 10. Defuzzification results of the second order Chen method and the second order Cheng method

No	Group	Chen/Cheng second order	No	Group	Chen/Cheng second order
1	A1,A1	26000	13	A8,A5	30000
2	A1,A3	34000	14	A8,A6	58000
3	A3,A5	34000	15	A8,A7	42000
4	A3,A6	46000	16	A9,A5	58000
5	A5,A11	62000	17	A9,A8	34000
6	A5,A5	38000	18	A10,A8	38000
7	A5,A6	26000	19	A11,A11	50000
8	A6,A11	66000	20	A11,A12	58000
9	A6,A3	38000	21	A11,A13	62000
10	A6,A8	42000	22	A11,A9	40000
11	A7,A10	46000	23	A12,A11	54000
12	A7,A7	54000	24	A13,A12	58000

FLRG on the Chen and Cheng methods for the second order gave the same results, so that the results of the defusification for both methods are the same and are shown in the table above. The results of forecasting positive confirmed cases of Covid-19 can be seen in Table 11. The forecasting plot using the first order Chen method, first order Cheng and second order Chen/Cheng can be seen in Figure 2.

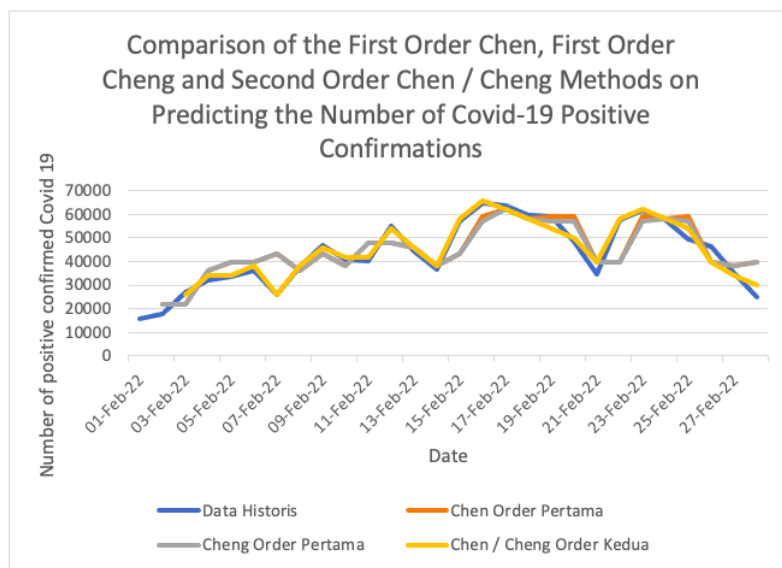


Figure 2. Forecasting plot using the first order Chen method, first order Cheng and second order Chen/Cheng.

Table 11. Forecasting Results of Chen and Cheng Method

Date	Data Historis	Chen first order	Cheng first order	Chen/Cheng second order
1-Feb-22	16021			
2-Feb-22	17895	22000	22000	
3-Feb-22	27197	22000	22000	26000
4-Feb-22	32211	36000	36000	34000
5-Feb-22	33729	40000	40000	34000
6-Feb-22	36057	40000	40000	38000
7-Feb-22	26121	43334	43334	26000
8-Feb-22	37492	36000	36000	38000
9-Feb-22	46843	43334	43334	46000
10-Feb-22	40618	38000	38000	42000
11-Feb-22	40489	48000	48000	42000
12-Feb-22	55209	48000	48000	54000
13-Feb-22	44526	46000	46000	46000
14-Feb-22	36501	38000	38000	38000
15-Feb-22	57049	43334	43334	58000
16-Feb-22	64718	59000	57200	66000
17-Feb-22	63956	62000	62000	62000
18-Feb-22	59635	58000	58000	58000
19-Feb-22	59384	59000	57200	54000
20-Feb-22	48484	59000	57200	50000
21-Feb-22	34418	40000	40000	40000
22-Feb-22	57491	40000	40000	58000
23-Feb-22	61488	59000	57200	62000
24-Feb-22	57426	58000	58000	58000
25-Feb-22	49447	59000	57200	54000
26-Feb-22	46643	40000	40000	40000
27-Feb-22	34976	38000	38000	34000
28-Feb-22	25054	40000	40000	30000

4. Conclusion

Chen and Cheng's Fuzzy Time Series can be used to predict the number of confirmed cases of Covid-19 sufferers. The first order MAPE for the Chen method is 4.21% and the first order MAPE for the Cheng method is 4.22%. MAPE method Chen/Cheng second order is 1.23%. It can be seen that the Fuzzy Time Series, especially the use of the second order produces a small MAPE and this method can be used to predict the number of confirmed cases of Covid-19 sufferers. The second order produces a smaller MAPE compared to the first order.

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