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TRAJECTORY OF THE POPULATION DEPENDENCY INDEX BY USING ARIMA MODELS

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Abstract. *Population dependency is an important indicator to detect social transformations in a growing and aging population. This study selected Taiwan as the target to conduct related population dependency indices to tackle the issue. The total dependency ratio, young dependency ratio and old dependency ratio were used to detect the issues of current population structure in Taiwan. This study employed a 3D surface plot to determine how a response variable (population dependency) relates to two predictors (young dependency and old dependency population). In this study, ARIMA model is carried out using the Minitab® statistical package to verify the trajectory of the different population dependency indices. The results reveal the young dependency index will decline, while the old dependency index will increase in the next decade. This study found that the increasing of over 65-year-old adults will become the main effect of total of dependency population in Taiwan. The findings provide useful information to remodel the related policy to deal with the population dependency issues.*
Keywords: ARIMA, Population dependency index, Total dependency population, Surface plot, Time series analysis

1. **Introduction.** Population dependency has various meanings applied in different settings. The notion of dependency refers the results were calculated as absolute numbers of dependent people, proportion of the total population who were dependent, and the ratio of the dependent population to the "working-age" population (total population aged 15-59). Many countries will be greatly affected by the increasing number of dependent people and will need to identify the human and financial resources to support them [1,2]. A modified "dependency ratio" could be used to a specific purpose in a society, an area or the worldwide environment. For example, Shumaker et al. examined the link between savings and dependency rates by exploring the stability of dependency effects over time, holding the sample of country constant [3,4]; Yoshikura and Takeuchi presented population dependency of measles, syphilis, and amebiasis in Japan and community evolution [5]; European Commission's the 2015 Ageing Report is another example [6]. Meanwhile, the aging population in Taiwan has shown increasing rapidly. Based on the notions of the previous studies, this study tries to explore the effect of population dependency issues in Taiwan.

Previous studies related trend analyses have shown the total dependency ratio significantly declined from 102.5% in 1990 to 41.4% in 2012. Most of this reduction is attributed to reduction in young dependency ratio. Old dependency ratio (population of 65 years and more) was significantly growing. Furthermore, number of rural health house, family planning coverage, total fertility rate and general fertility rate was significantly associated with total dependency ratio [7,8]. Pekarek examined the effects of population aging on

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economic dependency ratio found using broader definition of economic dependency allowing for variability in employment rates of age- and gender-specific groups. Dependency ratios are predicted to increase from 110% in 2016 to 161% in 2060 and from 120% to 181% for Czech and Slovak economy respectively. Decomposition of the indicator shows substantial old-age cohort contribution, which indicates increased pressure on fiscal stability due to population aging [9]. Previous studies focused on the dependency ratios with short term effect, whereas this study will conduct ARIMA (autoregressive integrated moving average) model to tackle the issue with long term trajectory.

This study selected Taiwan as the target to conduct related population dependency indices to detect the emerging issue. The purposes of this study are as follows: a) to realize the effect of dependency population on the workforce system in Taiwan; b) to project the future development of dependency population in the system. Given these purposes, the structure of this paper is as follows. Section 1 addresses the current issues of population dependency. Section 2 provides a brief description of the method related to data transform and forecasting. Section 3 examines the robustness of predictive method and its predicted results. Finally, the conclusions are presented in Section 4.

2. **Method.** This study is designed by using the concept of data mining to tackle issues reflected from the population dependency data set. This section addresses how the data have been collected and transformed in the target country. The population data from MOI cover from 1974 to 2016 [10]. Excel is a useful tool for transforming the data. This study follows the format of population dependency ratio to restructure the data. The 3D surface plot and ARIMA model in Minitab were used to transform the different dependency ratios as the indices to interpret the issue of the population. The research framework is shown in Figure 1.

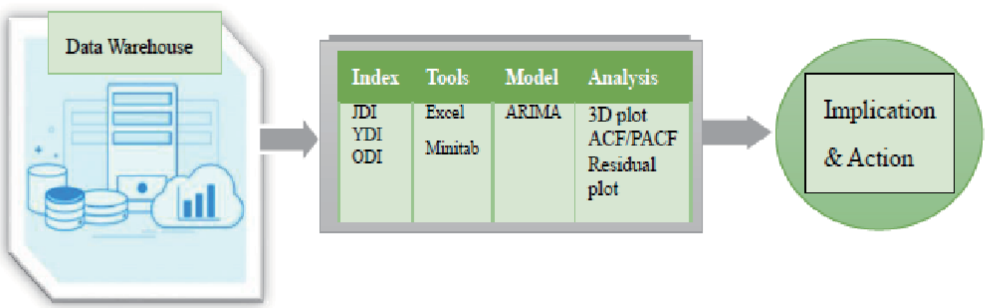

FIGURE 1. The research framework

2.1. **Definition of the dependency population.** Three population dependency ratios have been considered in this study, namely total dependency ratio, youth dependency ratio, and old dependency ratio. The total dependency ratio is the number of persons under age 15 plus persons aged 65 or older per one hundred persons 15 to 64. It is the sum of the youth dependency ratio and the old dependency ratio. The total dependency ratio was used to represent the total dependency index (TDI). The youth dependency ratio is the number of persons 0 to 14 years per one hundred persons 15 to 64 years which was used to represent young dependency index (YDI). The old dependency ratio is the number of persons 65 years and over per one hundred persons 15 to 64 years old that was used to represent the old dependency index (ODI). In this study, the three dependency ratios have been defined as specific dependency indices to realize the issues of the population structure.

2.2. **Checking with 3D surface plot.** A 3D surface plot is a three-dimensional graph that is useful for investigating desirable responsevalues and operating conditions. This study employed a 3D surface plot to display how a response variable relates to two predictor variables. A surface plot contains the following elements:

- Predictors on the x- and y-axes;
- A continuous surface that represents the response values on the z-axis.

The peaks and valleys correspond with combinations of x and y that produce local maxima or minima. Minitab was used to create the surface area between the data points.

2.3. **Projecting the trend of dependency index.** This study follows the ARIMA model building process, preparing data sets from Ministry of Interior, differencing the data sets to obtain stationary series, identify potential models, check ACF (autocorrelation function)/PACF (partial autocorrelation function) of residuals, and forecasting [11-15]. This study defined a non-seasonal ARIMA model is classified as an "ARIMA(p, d, q)" model, where:

p is the number of autoregressive terms (AR),
d is the number of non-seasonal differences needed for stationarity (I), and
q is the number of lagged forecast errors in the prediction equation (MA).

This study plots the ACF and PACF of the differenced series to look for the data more consistent with a stationary process. This study also considered the Box-Pierce Chi-square statistics to check the residual appears to be low and diminish as the number of lags increases [16,17]. In this study, the analyses are conducted by using the Minitab® statistical package.

3. Results.

3.1. **The key result for 3D surface plot.** The surface plot contains the following elements:

- Predictors on the x- (young dependency population) and y-axes (old dependency population);
- A continuous surface that represents the response values on the z-axis (total dependency population).

Figure 2 displays the surface plot for the total population dependency index vs. old dependency index and young dependency index.

z = total dependency population,
y = old dependency population,
x = young dependency population.

The peak on the plot corresponds with the highest total dependency population, and occurs at approximately young dependency population = 200,000 and old dependency population = 500,000.

3.2. **Trends of dependency indices.** Based on definition of 2.1, this study transforms the data to YDI and ODI. Figure 3 displays the trend of YDI and TDI from 1974 to 2016. These trends of indices indicate that population of young 0-14 group drops rapidly, while the aging population increases steadily in this society.

3.3. **Interpretation of the total dependency index by ARIMA.** Total dependency index is calculated by summing the youth dependency ratio and the old dependency ratio. Initially, inspection of the ACF of the series of total dependency index (TDI) is necessary to determine if the series is stationary or will require differencing. Because the data is not stationary, the series presents variance from one period to another need to one difference for station. Tests for ACF (autocorrelation) and PACF (partial autocorrelation) indicated that the model ARIMA$(1, 2, 1)$ could be used to predict the series, shown in Figure 4.

Evidence therefore exists to support that the residuals follow a white noise process and the ARIMA(1, 2, 1) is a robust representation of the observed time series, see Figure 5 and Table 1.

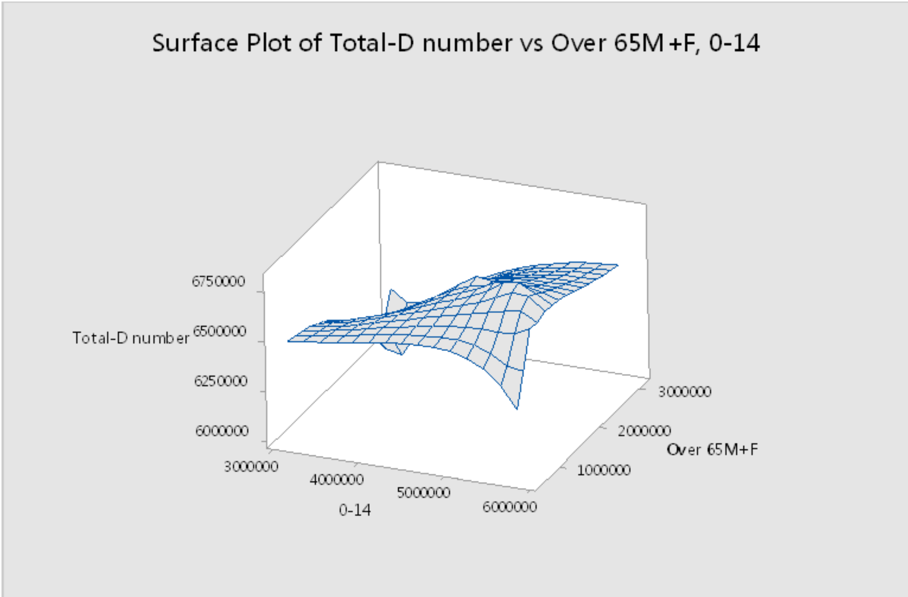

FIGURE 2. Surface plots of total dependency population vs. young dependency and old dependency population

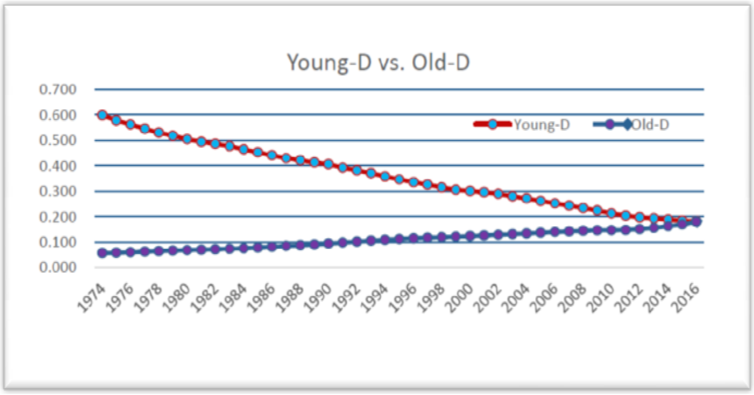

FIGURE 3. The trends of dependency indices for young and old groups

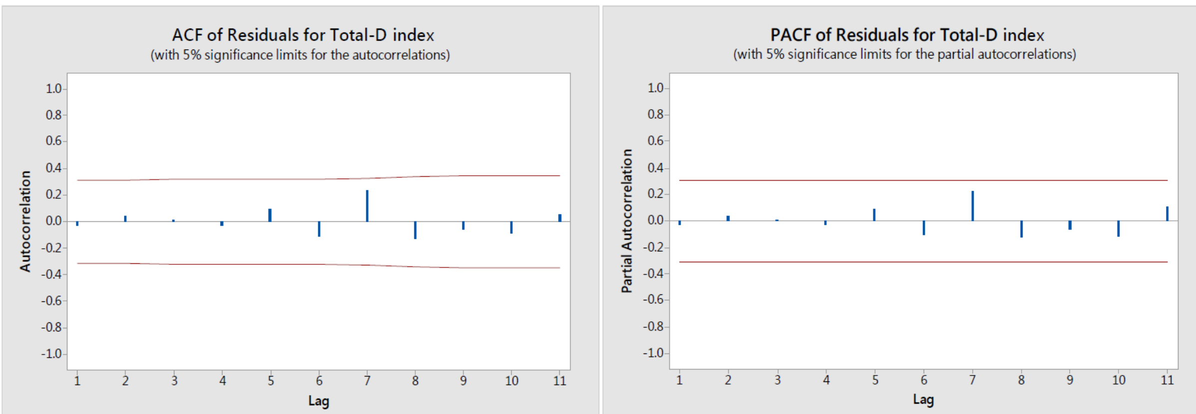

FIGURE 4. Checking TDI with ACF and PACF

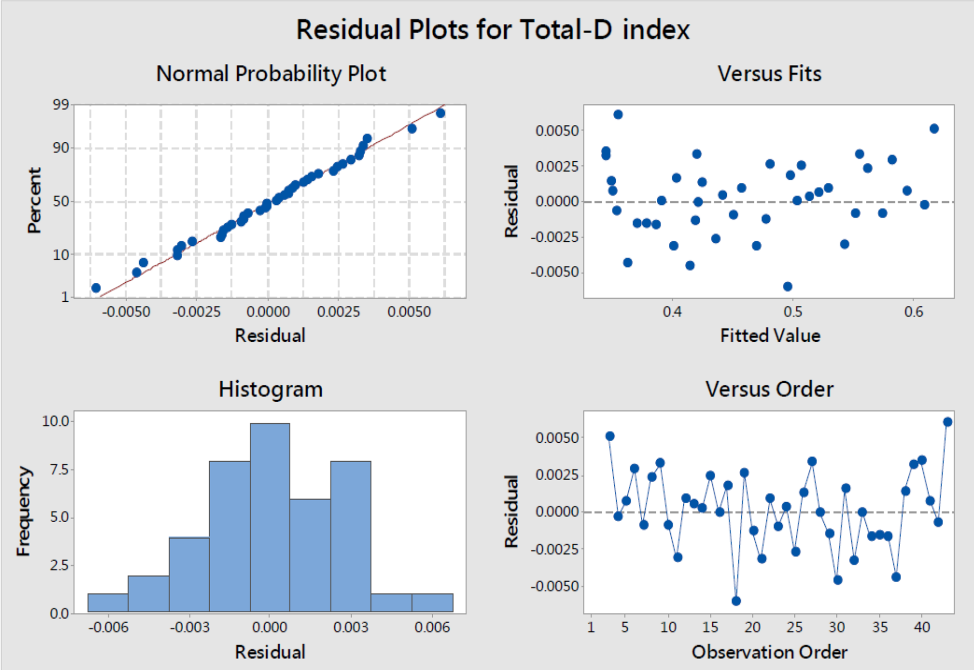

FIGURE 5. Residual plot for TDI in ARIMA(1, 2, 1)

TABLE 1. Final estimates of parameters for TDI

Type	Coef.	SE Coef.	t-value	p-value
AR(1)	0.851	0.228	3.73	0.001
MA(1)	0.956	0.170	5.62	0.000
Constant	0.000080	0.000056	1.42	0.164

Note. Differencing: 2 regular differences;
Original series 43, after differencing 41

TABLE 2. Modified Box-Pierce Chi-square statistics

Lag	12	24	36	48
Chi-square	10.74	28.24	37.69	*
DF	9	21	33	*
p-value	0.294	0.134	0.263	*

Under the assumption of no correlation left in the residuals the Ljung-Box statistic is Chi-square distributed with K-n_C degrees of freedom, where n_C is the number of estimated parameters in model except for the constant δ [16,17]. In this study, Ljung-Box Chi-square statistics demonstrate the model meets the assumptions that the residuals are independent, see Table 2. Basically, a significant level of .05 (denoted as α) works well. In this study, most of the p-values for the Ljung-Box Chi-square statistics are all greater than .05.

The consistency of the forecast total population dependency index implies that the modelling process is robust. It indicates the reliability of the TDI to generate future trend of TDI is workable in this ARIMA model. The forecasting 10 years ahead of TDI (2017-2026) are demonstrated in Figure 6 and Table 3. The result reveals the TDI implies that the increasing of over 65-year-old adults and declining of young dependency population will impact total dependency population in Taiwan.

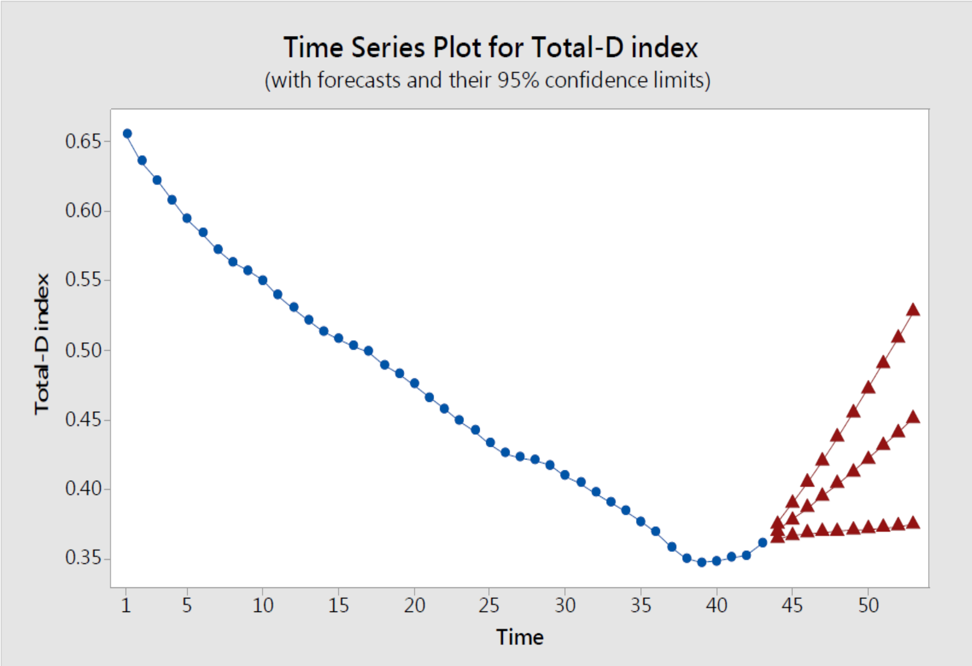

FIGURE 6. Time series plot for TDI from 1974 to 2026

TABLE 3. Forecasts from period 43 (2017-2026) with TDI

Period	Year	Forecast	95% limits	
			Lower	Upper
44	2017	0.369712	0.364408	0.375016
45	2018	0.378047	0.366686	0.389408
46	2019	0.386417	0.368143	0.404691
47	2020	0.394897	0.369125	0.420668
48	2021	0.403550	0.369867	0.437232
49	2022	0.412429	0.370538	0.454320
50	2023	0.421582	0.371262	0.471901
51	2024	0.431045	0.372133	0.489958
52	2025	0.440854	0.373224	0.508484
53	2026	0.451035	0.374590	0.527480

3.4. **Trajectory of young and old population dependency ratios.** The results of ARIMA models reveal the YDI with ARIMA$(1,1,1)$, and ODI with ARIMA$(1,2,1)$ are acceptable based on ACF, PACF, and residual plots. This study plots the trends of YDI and ODI, the ARIMA results present in Figure 7.

The results reveal most of the p-values for the Ljung-Box Chi-square statistics are all greater than .05 in both predicted series. Based on the ARIMA models, the 1-43 period data for 10 years ahead of the series are displayed in Table 4. Even though the young dependency population is declining, the old dependency population will become a new burden of the society. Based on the long term development of the series, the trend of YDI and ODI will cross at 2016-2017, see Figure 8.

4. **Conclusions.** Population dependency has become a crucial issue in a growing and aging population society. Taiwan has confronted with declining young dependency population and growing old dependency population. Totally, the dependency population is

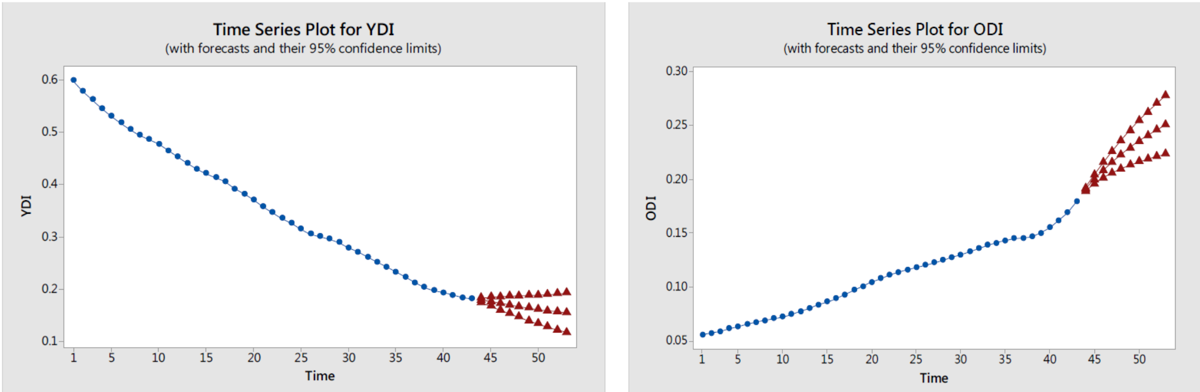

FIGURE 7. Time series plots for YDI and ODI

TABLE 4. Projecting 10 years ahead with YDI and ODI

YDI with ARIMA(1, 1, 1)				ODI with ARIMA(1, 2, 1)			
Period	Forecast	95% limits		Period	Forecast	95% limits	
		Lower	Upper			Lower	Upper
44	0.178980	0.174556	0.183405	44	0.190545	0.188904	0.192186
45	0.175879	0.167348	0.184410	45	0.200154	0.195972	0.204336
46	0.172665	0.160082	0.185247	46	0.208693	0.201661	0.215725
47	0.169499	0.153005	0.185993	47	0.216355	0.206338	0.226371
48	0.166476	0.146216	0.186736	48	0.223298	0.210261	0.236336
49	0.163650	0.139751	0.187550	49	0.229653	0.213616	0.245690
50	0.161056	0.133616	0.188495	50	0.235526	0.216546	0.254506
51	0.158710	0.127805	0.189615	51	0.241005	0.219158	0.262851
52	0.156626	0.122308	0.190945	52	0.246160	0.221535	0.270785
53	0.154810	0.117113	0.192507	53	0.251050	0.223739	0.278361

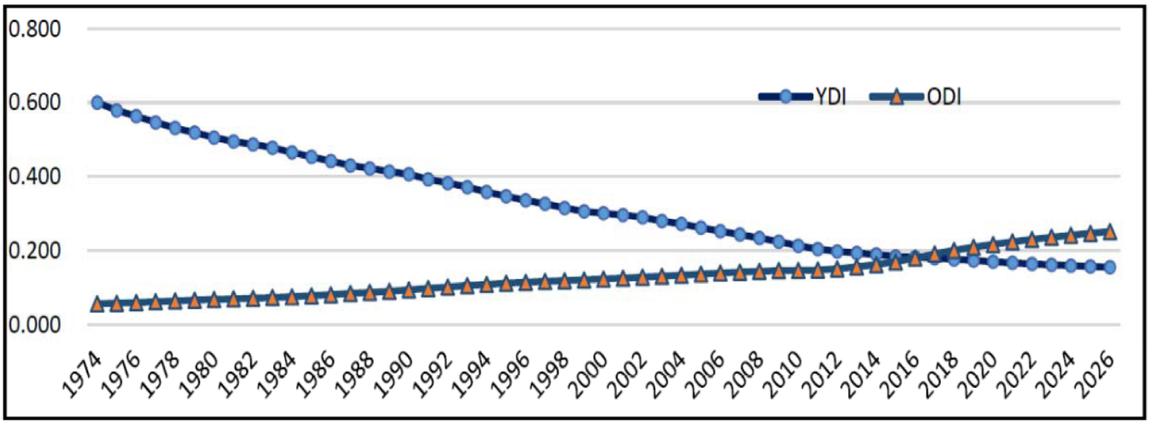

FIGURE 8. The trends of YDI and ODI from 1974 to 2026

growing in this society. This study has conducted with the idea of data mining and projecting their future trends of population dependency. The 3D surface plot was used to see how a response variable (population dependency) relates to two predictors (young dependency and old dependency population). In this study, dependency population and their related indices have been considered in the ARIMA models. The ARIMA analyses were employed by using the Minitab® statistical package to verify the trajectory of the different population dependency indices. The results reveal the young dependency index will decline, while the old dependency index will increase in the next decade. The increasing of over 65-year-old adults will become the main effect of total of dependency population in Taiwan. The findings can be used to remodel the related policy for the policy makers.

Furthermore, this study provides an example to tackle the similar issues in different settings. ARIMA models with rigidly verification process can be used to predict the related time series data set. This study also provides an example of the visualization of the data set which makes the data readable for readers.

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