ICIC Express Letters
Part B: Applications
Volume **10**, Number **4**, April **2019**

ICIC International ©2019 ISSN 2185-2766
pp. **319–326**

TWO-STAGE APPROACH FOR DETECTING TEACHER'S SUPPLY AND DEMAND ISSUES IN ELEMENTARY EDUCATION

Dian-Fu Chang[1], Bih-Chyi Sheng[2,*] and Wen-Ching Chou[1]

[1]Graduate Institute of Educational Policy and Leadership
[2]Doctoral Program of Educational Leadership and Technology Management
Tamkang University
No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City 25137, Taiwan
140626@mail.tku.edu.tw; *Corresponding author: edu618@gmail.com; sauichou1226@gmail.com

Received September 2018; accepted December 2018

Abstract. *Teacher's supply and demand has become a crucial management issue in elementary education due to declining birth rate and teacher retirement issues. This study selects Taiwan as an example to tackle the teacher's supply and demand issues. The two-stage approach was used to detect the previous series data from Ministry of Education and predict their future trends. Based on the notion of balancing supply-demand, the strategy selection for future has been demonstrated in the model. The supply side includes enrollment of teacher training programs in terms of capacity of teacher preparations (CTP) in elementary schools. The demand side includes elementary school's capacity which has shown the teacher demand is decreasing in this system. ARIMA was used to build forecasting models for the capacity of elementary schools and the capacity of teacher preparation for elementary education. The findings reveal the supply side in teacher preparation programs will confront great pressure in future. This study suggests adjusting RST to 10 to provide more job opportunities in elementary schools for new comers. This strategy also can release the pressure of oversupply teachers in current system.*
Keywords: ARIMA, Education management, Supply and demand, Teacher preparation

1. **Introduction.** Balancing teacher's supply and demand is a hot topic in various education systems. For example, shortages of teachers in United States are particularly severe in special education, mathematics, science, and bilingual/English learner education, and in locations with lower wages and poorer working conditions [1]. United States' education system reflects teacher demand is growing, while the teacher supply is shrinking. In Australia, demand for teachers is largely a result of the number of children in the population. In most states, the primary school student population has been declining slowly since 2001: only Queensland and Western Australia saw any real growth from 2001-2010 [2]. Using a range of national databases, Green et al. indicated what extent state-led interventions are assisting to meet the foundation phase teacher supply and demand challenge. Their study attempts to move beyond simply basing an analysis of supply and demand on teacher attrition, and takes account of multiple variables that should be considered in supply and demand planning [3]. Typically, demand for teachers is largely a result of the number of children in the population. Different education systems may have confronted with dissimilar issues. However, the elementary school student population has been declining slowly in most countries. This study selects Taiwan as an example to tackle the teacher's supply and demand issue in elementary education level. In general, there are four types of certifications for different levels of teachers in Taiwan. The major reason to select the elementary education is to consider that it has become an important part of teachers' demand in the education system. Recently, teacher's supply and demand has become a crucial management issue in elementary education due to declining birth rate

DOI: 10.24507/icicelb.10.04.319

and teacher retirement issues. This study perceives the issue has been going to worsen in current setting. For example, the local, central government and teacher preparation centers are confused with the dramatically change patterns of supply and demand. Do they have any better strategy to solve the issue? This study aims to detect the issue by using the selected data from Ministry of Education (MOE) to build supply and demand model to fit current and future trend [4].

Because of the low birth rate, the newborn babies have dropped from 410,000 in 1981, to 270,000 in 1998 to 167,000 in 2010, which has achieved the lowest level in the last 50 years [5]. According to the data from Ministry of Interior, the newborn babies are decreasing from 1974 (328,461) to 2016 (196,973) which means 40% drop [6]. The current issues have shown birth rate declining with dramatically drop in the specific years we called "years of Tiger", see Figure 1. According to the Chinese zodiac, the years of Tiger are 1986, 1998 and 2010 in the last three decades.

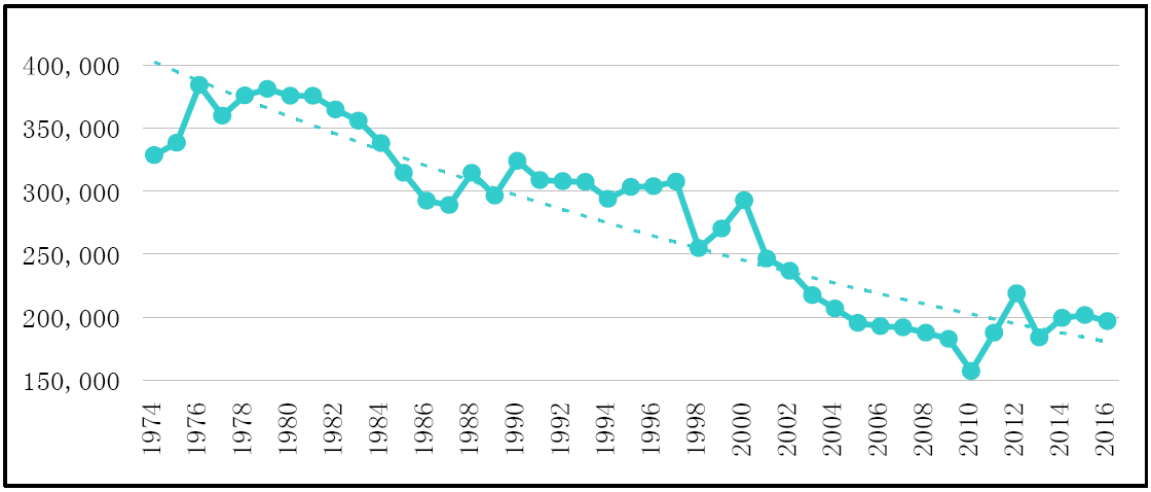

FIGURE 1. The trend of newborn babies from 1974 to 2016

Typically, young couples did not like bear babies in the year of Tiger. Therefore, enrollment in elementary education will be impacted by the dramatically drop after six years later. According to the trend of average students in elementary schools, the declining is not smooth. Both the increasing drop or dramatically drop have impacted the demand of elementary education teachers directly. How to balance teacher's supply and demand has become an emerging issue in this education system. This is why the study focuses on the elementary education level. Given these purposes, this study will answer the following questions:

a. How wide the gap between potential enrollment and school capacity?
b. What kind of trend exerts in previous teacher's supply and demand?
c. What kind of the strategy can be used to ameliorate the issues in future?

With regard to this issue, this paper begins with the definition of the terms and research design in the method section. Then, the results of the study are addressed. Finally, Section 4 concludes the work.

2. Method.

This study was designed for determining the teacher's supply and demand in the elementary schools. The related series data (1976-2017) have been cited from MOE which have been reviewed and taken into account in the supply-demand model. The two-stage approach was used to detect the previous series data and their future trends. Based on the notion of supply-demand, the strategy selection will work in the model.

2.1. **Definition of the terms.** There are four terms related to the supply and demand model in this study. Their definitions are listed as follows:

- Ratio of student-teacher (RST) refers to numbers of elementary school students over teachers in elementary schools. In this study, the RST is 12;
- Capacity of elementary schools (CES) refers to total number of elementary school students in the education system;
- Capacity of teacher preparations (CTP) refers to the numbers of students enrolled in the teacher preparation programs. In this study, the CTP focuses on preparation for the elementary school teachers.
- The gap between capacity of elementary school and capacity of teacher preparation (GAP) refers to the unbalance issue between supply and demand in the system.

2.2. **The two-stage approach.** The research design includes two stages in this study. Stage one focuses on the data transformation to fit the supply and demand model. The second stage focuses on the future trend. The result of prediction will provide useful information for the strategies selection, see Figure 2.

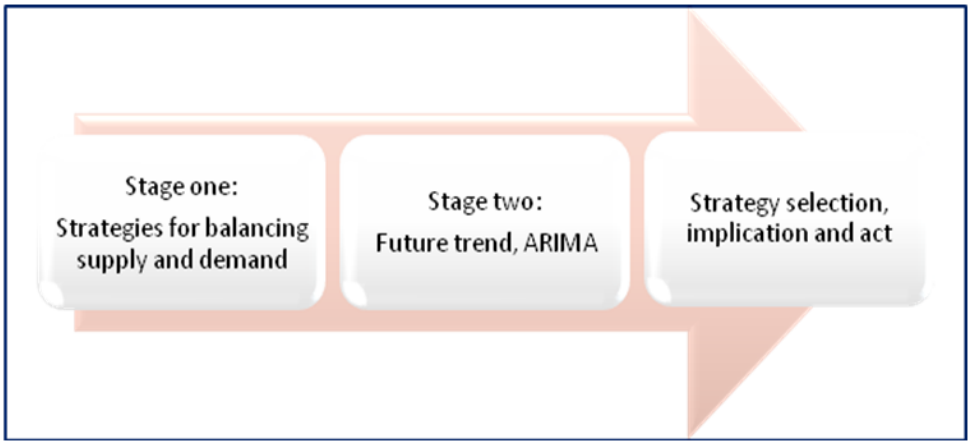

FIGURE 2. Research framework

Stage one: Detecting the supply and demand

Supply: The enrollment of teacher training programs in terms of capacity of teacher preparations (CTP) in elementary schools is considered as the gross of teacher supply in the supply-demand model. In this model, the license pass rate (LPR) has been considered as a policy intervention in the supply side. Recently, the government sets up about 50% as the pass rate for qualify students in teacher training programs to be new teachers. Therefore, the estimated model can be displayed as:

$$\text{Supply} = \text{CTP} * \text{LPR}$$

Demand: Elementary school's capacity declining implies the major demand in the elementary schools is decreasing. The gap between 0-year group and student enrollment in elementary schools can be as an indicator for calculating the teacher's demand. This factor can be taken into account in the demand side. RST is a policy factor for control of teacher's demand in elementary schools. Usually, the RST was designed by the government. Therefore, the formula of demand can be displayed as follows:

$$\text{Demand} = (\text{CES}/\text{RST})$$

In this supply-demand model, the logic of data selection and transformation is presented as Figure 3. How to balance the supply and demand has become a tacit issue in the process of strategy selection.

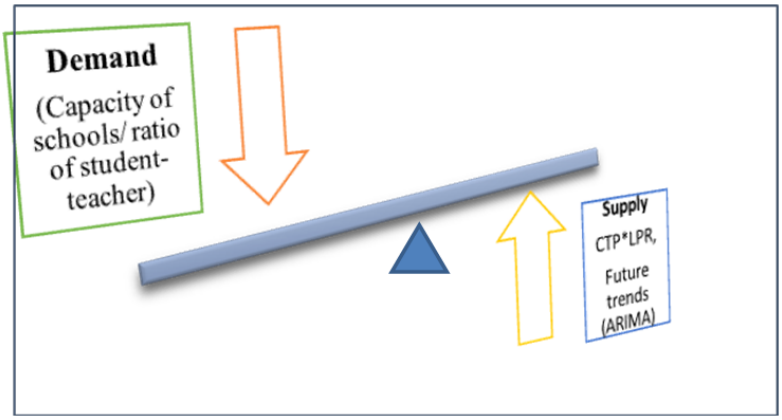

FIGURE 3. Logic of demand and supply

Stage two: Building future trends

This study follows the process of autoregressive integrated moving average (ARIMA) to build forecasting models for the capacity of elementary schools (CES) and the capacity of teacher preparation for elementary education (CTP). The ARIMA(p, d, q) model indicates p as the order of the autoregressive part, d as the amount of difference and q as the order of the moving average part [7-10]. The processes of model building are as follows. First, detect the series of CES and CTP are seasonal or non-seasonal. Second, select ARIMA(p, d, q) model by using differences and the visualization of ACF (autocorrelation function) and PACF (partial autocorrelation function) [11,12]. Third, verify the robustness of series with the fitted ARIMA model for next ten years.

2.3. **Strategy selection.** Can the ratio of student-teacher be adjusted? What kind of RST is acceptable? In this study, the RST has been considered as the policy intervention which could be impacted of the demand of teachers in future. Furthermore, the retired teachers could be as an impact factor in the model. Current retired teacher data, collected from 2006 to 2016, reveal that the average retired teachers (ART) are 2,308 in elementary schools. This study considers the RST equals 12 and the ART equals 2,308 as the policy intervention in the supply-demand model. Projecting the next decade, both the CES and forecast teachers (FT) are transformed by ARIMA. The GAP is used to detect the oversupply issues in the system. The logic of strategy selection will follow the proposed formula to control the GAP:

$$\text{GAP} = (\text{CES}/\text{RST}) - (\text{FT} - \text{ART}) = (\text{CES}/12) - (\text{FT} - 2{,}308)$$

When the GAP $= 0$, it implies the demand and supply of teachers is balanced. The study justifies the unbalance of demand and supply follows the rules:

If the GAP > 0, then the supply side of teachers is shortage;

If the GAP < 0, the system is oversupply of the teachers.

3. **Results.** The previous trend of population and enrollment in elementary schools provides useful information to detect the gap of both series. Figure 4 displays the gap between 0-year population and enrollment in elementary schools is negative which implies the elementary schools have faced the shortage of students. These phenomena have displayed significant changes in the years of Tiger in terms of 1986, 1998 and 2010, respectively.

The capacities of elementary schools shrink because of birth rate declining in the system. In this study, the CES with ARIMA$(2, 1, 1)$ indicates the future trend of student number is declining. Similarly, the capacity of teacher training programs is diminishing in future. The CTP with ARIMA$(1, 2, 1)$ shows the number of students in teacher training programs will decrease in next decade. It implies the supply of teacher will decrease in future. The details have been presented in Figure 5 and Table 1.

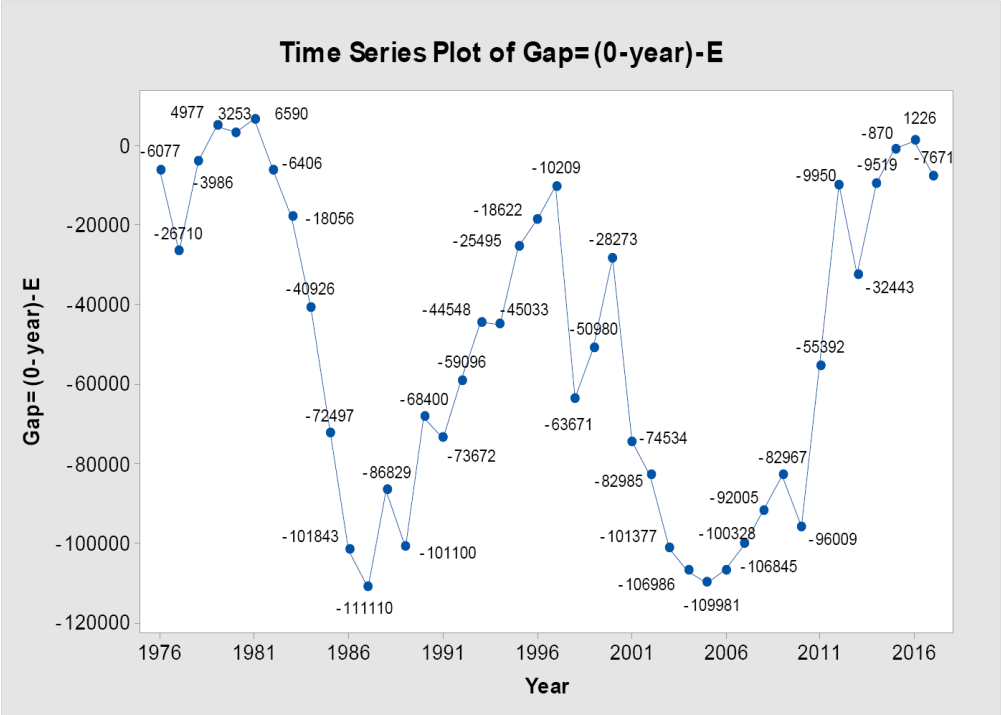

FIGURE 4. The gap between 0-year population and enrollment in elementary schools

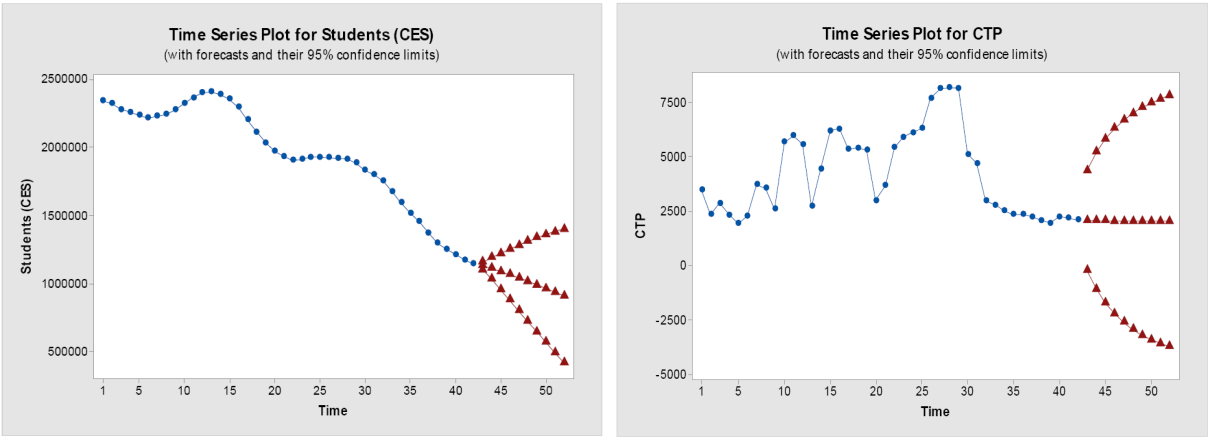

FIGURE 5. ARIMA models for CES and CTP

TABLE 1. Forecasts of CES and CTP from 2018-2027

	CES	95% Limits		CTP	95% Limits	
Year	Forecast	Lower	Upper	Forecast	Lower	Upper
2018	1131659	1103514	1159804	2081	−192.43	4356.35
2019	1111031	1032044	1190018	2067	−1083.82	5218.08
2020	1089384	957959	1220808	2055	−1715.79	5825.81
2021	1066142	880462	1251822	2045	−2205.03	6296.21
2022	1041803	801991	1281615	2038	−2597.81	6675.57
2023	1016549	723586	1309511	2034	−2918.55	6988.29
2024	990571	645968	1335174	2033	−3182.20	7249.32
2025	964015	569546	1358483	2034	−3398.84	7468.75
2026	936996	494552	1379440	2039	−3575.78	7653.90
2027	909608	421097	1398119	2045	−3718.60	7810.31

3.1. **Estimating the supply of teachers for next decade.** Following the following supply's formula, LPR is a policy intervention and the pass rate sets at 50%. The estimated supplies of the future teachers are listed as 1040, 1033, 1027, 1022, 1019, 1017, 1016, 1017, 1019 and 1022.

$$\text{Supply} = \text{CTP}_i * \text{LPR} = \text{CTP}_i * 50\%$$

Based on the previous numbers of teachers in elementary schools (from 1976 to 2017), this study applied ARIMA$(1, 2, 1)$ to predicting the number of teachers in next decade (from 2018 to 2027). The results reveal the teachers will decrease in next decade (from 43 to 52 period), see Figure 6 and Table 2.

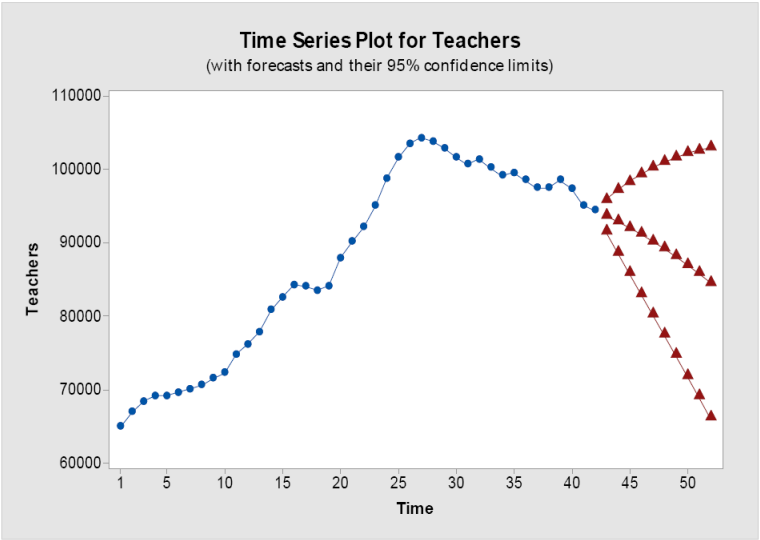

FIGURE 6. Forecasts of number of teachers with ARIMA$(1, 2, 1)$ model

TABLE 2. Forecasts of elementary school teachers from 2018 to 2027

	Time	ARIMA$(1, 2, 1)$	95% Limits	
Year	Period	Forecast (Teachers)	Lower	Upper
2018	43	93687	91486	95888
2019	44	92915	88684	97146
2020	45	92086	85863	98309
2021	46	91199	83061	99337
2022	47	90252	80279	100225
2023	48	89244	77503	100985
2024	49	88175	74721	101630
2025	50	87045	71918	102171
2026	51	85852	69083	102622
2027	52	84599	66207	102991

3.2. **Estimating the demand of teachers for next decade.** Based on the forecasts of future capacity of elementary schools, this study estimates the future teacher's demand in elementary schools. This study found RST equal to 12 is a policy intervention and the number of retired teachers is various in different years. The calculation has considered their average, then the ART equals 2,308 in the elementary system. Based on the following formula, the teacher demand (TD) in next decade has shown decreasing, see Table 3. The estimated formulae are demonstrated as follows:

$$\text{GAP} = (\text{CES}/\text{RST}) - (\text{FT} - \text{ART}) = (\text{CES}/12) - \text{FT} - 2{,}308$$

TABLE 3. The GAP between teacher demand and teacher supply

Year	CES Forecast	RST	Teachers Demand (TD = CES/12)	Forecast Teachers (FT)	ART	FT – ART	GAP = TD – (FT – ART)
2018	1131659	12	94305	93687	2308	91379	618
2019	1111031	12	92586	92915	2308	90607	−329
2020	1089384	12	90782	92086	2308	89778	−1304
2021	1066142	12	88845	91199	2308	88891	−2354
2022	1041803	12	86817	90252	2308	87944	−3435
2023	1016549	12	84712	89244	2308	86936	−4532
2024	990571	12	82548	88175	2308	85867	−5627
2025	964015	12	80335	87045	2308	84737	−6710
2026	936996	12	78083	85852	2308	83544	−7769
2027	909608	12	75801	84599	2308	82291	−8798

Because the estimated GAPs are negative in the next decade, the issue of teacher oversupply is emerging, see Table 3. The teacher preparation programs will suffer the pressure of oversupply in future. This study suggests adjusting RST to 10, and it may provide more job opportunities in elementary schools for new comers. This strategy also can release the pressure of oversupply teachers in the system.

4. **Conclusions.** This study found the gap between potential enrollment and school capacity in elementary education exists in the system. The result reveals the year of Tiger exerts more significant effect on the elementary enrollment and will directly impact teacher's demand. Based on the previous teacher's supply and demand data, this study demonstrates the result of ARIMA model. The finding demonstrates the number of teachers in next decade will decrease steadily. The result displays the capacities of elementary schools are shrinking because of birth rate declining. The capacity of teacher training programs is diminishing.

What kind of strategy can be used to ameliorate the issue in future? The design of two-stage approach is a logic process to detect the supply-demand issues. This study selects the elementary school education as an example and the result has shown workable. This study suggests adjusting the ratio of student-teacher to 10 to provide more job opportunities in elementary schools for new teachers. The related strategies for releasing the pressure of oversupply teachers in the system are welcomed. The proposal supply-demand model can be extended to wide environments to solve the similar issues. For further study, this model can be modified and applied to the follow-up issue in specific education system or other similar settings.

REFERENCES

[1] L. Sutcher, L. Darling-Hammond and D. Carver-Thomas, *A Coming Crisis in Teaching? Teacher Supply, Demand, and Shortages in the U.S.*, Learning Policy Institute, 2016.

[2] P. R. Weldon, The teacher workforce in Australia: Supply, demand and data issues, *Australian Council for Educational Research*, 2015.

[3] W. Green, M. Adendorff and B. Mathebula, Minding the gap? A national foundation phase teacher supply and demand analysis: 2012-2020, *South African Journal of Childhood Education*, vol.4, no.3, 2014.

[4] Ministry of Education, *Educational Statistics 2017, the Republic of China*, https://stats.moe.gov.tw/files/ebook/Education_Statistics/106/106edu_EXCEL.htm, Taipei, 2018.

[5] D.-S. Chen, *Higher Education in Taiwan: The Crisis of Rapid Expansion*, http://www.isa-sociology.org/universities-in-crisis/?p=417, 2010.

[6] Department of Statistics, Ministry of Interior, *The Main Directory of Dynamic Query Statistics*, http://statis.moi.gov.tw/micst/stmain.jsp?sys=100, 2018.
[7] S. Bisgard and M. Kulachi, *Time Series Analysis and Forecasting by Example*, Wiley & Sons, New York, 2011.
[8] R. J. Hyndman and G. Athanasopoulos, *Forecasting: Principles and Practice*, OTexts, Melbourne, Australia, 2013.
[9] P. J. Brockwell and R. A. Davis, *Time Series: Theory and Methods*, Springer-Verlag, 1991.
[10] P. J. Brockwell and R. A. Davis, *Introduction to Time Series and Forecasting*, Springer, Netherlands, 2016.
[11] R. Davis, T. Coole and D. Osipyw, The application of time series modelling and Monte Carlo simulation: Forecasting volatile inventory requirements, *Applied Mathematics*, no.5, pp.1152-1168, 2014.
[12] P. Rotela Junior, F. L. R. Salomon and E. de Oliveira Pamplona, ARIMA: An applied time series forecasting model for the Bovespa stock index, *Applied Mathematics*, no.5, pp.3383-3391, 2014.