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TIME SERIES MODELING AND FORECASTING OF DENGUE DEATH OCCURRENCE IN MALAYSIA USING SEASONAL ARIMA TECHNIQUES

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ABSTRACT

The incidence of dengue cases and dengue death has grown-up dramatically around the world in recent decades. Recently, the number of reported cases, especially in Malaysia continued to increase. Over the year, many researchers try to estimate the number of deaths that cause by dengue. One of the methods in Biostatistics is ARIMA method which is involving time series analysis. Time series analysis commonly referred to any analysis which involved in a time series data. If the continuous observation is dependable, then the values that will come are able to be forecasted from the previous observation. The objective of this research paper is to forecast the number of dengue deaths, to describe the behavior of the time series data and afterwards made use of skilled statistical techniques for estimation, forecasting but also the controlling. In this paper the recognition of concerning the SARIMA (p,d,q) $(P,D,Q)_{15}$ was given attention through the approach to the Autocorrelation Function ACF and Partial Autocorrelation Function (PACF) theory plot. SARIMA (2,1,0) $(0,1,1)_{15}$ is being selected as the best model to represent the dengue death data. The gained model will be used as a tool for the prediction of the dengue death.

Keywords: Autoregressive Process model AR (p), Moving Average Process MA (q), SARIMA (p,d,q), time series, forecasting and dengue.

Introduction

Dengue fever is a mosquito-borne viral infection caused by an RNA virus of the family Flaviviridae. It is a major public health problem worldwide and particularly in Asian countries with tropical and subtropical climates. Malaysia is a tropical climate country which a suitable environment for the breeding of mosquitoes particularly of the genus Aedes. Dengue infection has become endemic in Malaysia endemic since the early 1990s and from there the outbreak seems to be never stopped a year by year[1]. The disease causes a spectrum of illness ranging from mild symptoms (such as fever, body ache, joint pain, headache and body rashes) and also severe hemorrhagic complications[2]. There is no specific treatment for dengue or severe dengue, but early detection and access to proper medical care lowers fatality rates below 1%[3]. The case fatality rate has been reduced from 0.6% in year 2000 to 0.2% in the year 2016[4]. Globally the dengue cases reported to increase, however the mortality trend seems to be plateauing for the past few decades. There is a reflective of the shift in the demographics of dengue cases in Malaysia where more adults are affected and underlying co-morbidities may be the contributing factors towards the rapid deterioration in severe dengue[5]. The dengue death in adults (aged 15 years old and above) showed a slight increment as compared to dengue death in children (aged less than 15) [6]. The strengthening of guidelines and protocols in managing dengue cases involving the all health care facilities either primary, secondary and tertiary hopefully would reduce the severity dengue infection and preventing dengue death.

The reported causes of death in Malaysia are almost similar to other countries in southeast Asia. For example in Malaysia dengue shock syndrome occurs more than 70% in all age group [7, 8]. It is followed by severe organ dysfunction such as liver and kidneys failure together with severe bleeding tendencies by acute gastrointestinal, pulmonary and intracranial bleeding [7, 8]. Dengue shock syndrome followed by dengue hemorrhagic fever are listed as main cause of death in a 5-years Singaporean retrospective study [9].In Indonesia, dengue hemorrhagic fever has been seen increasing in trend according to a 45-year analyses [10]. In Thailand, dengue shock syndrome and dengue hemorrhagic fever are identifiable causes of death [11]. Could the death due to dengue be prevented? Around 78.1% of death are preceded by several warning signs. For example patient may be presented with lethargy, persistent vomiting and abdominal pain [8]. Another important warning signs that would to be identified are bleeding of mucosa, pleural effusion or ascites as results of fluid accumulation [8]. In addition, treatment of underlying diabetes mellitus, hypertension and heart disease could potentially reduced mortality rate [8].

Furthermore, around 5-6 days of illness time taken from onset of the symptoms to the death of the patient, in which may give the potential golden time for the treatment [7, 8]. In brief, mortality rate of dengue patient could be prevented by identification of warning signs, treatment within the 5-6 days of illness and treat underlying disease.

1.0 Materials and Methods

The method of seasonal ARIMA is commonly applied to time series analysis. The term of ARIMA is in short stands for the three components which is Autoregressive, Integrated and Moving Average models. The fundamental concept to undertake when our developing models is to understand the characteristics of the series data sets and how it behaves over times [7, 8]. There are some advantages of undertaking this strategy is to give the freedom to the researcher to select the most appropriate model from all potential models according to time plot. In our case, we arranged the dataset according to the state which is repeated from 2000 till 2016. The series with seasonal, need the additional differencing to eliminate the seasonal effect. Let z_t be seasonal differences series, $z_t = y_t - y_{t-15}$ for state data series. If z_t remained non-stationary, then the next step is to perform non-seasonal differencing which is denoted by $w_t = z_t - z_{t-1}$. The specific name of the seasonal model is SARIMA (p, d, q)(P, D, Q)s [7]. Below are the steps of model identification.

1.1 Initial data Investigation

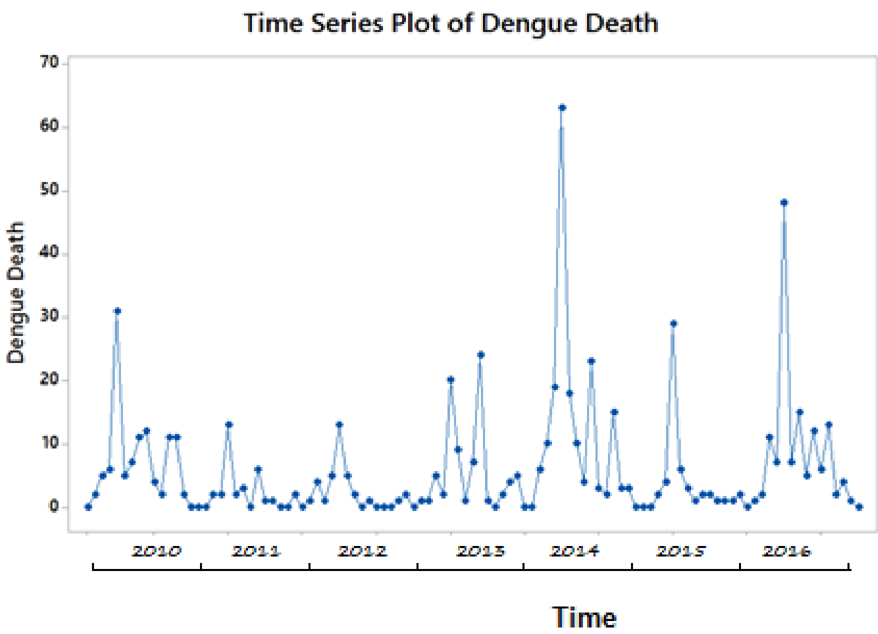

Figure 1: Time Plot of Dengue Death

At first, a simple data investigation was conducted to understand the basic pattern of the series. From the series plot, it is indicated that the series is not stationary with the existence of the seasonal component. Figure 2 and Figure 3 shows at the lag of 15, the spike is significant. These character (from Figure 2 and Figure 3.) show that the seasonal effect is present.

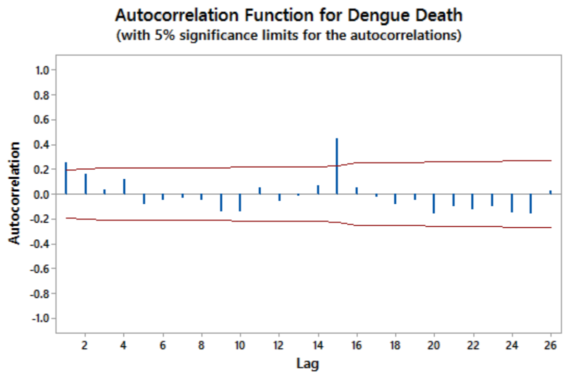

Figure 2: ACF Plot Original Series

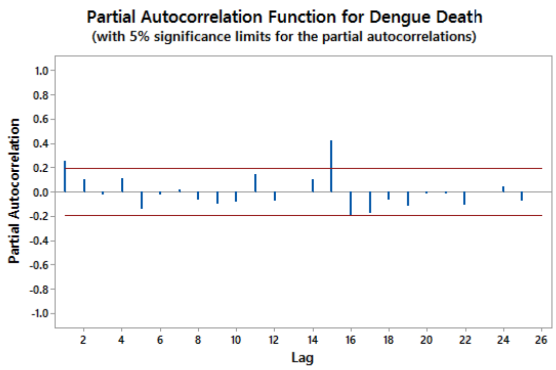

Figure 3: PACF Plot Original Series

1.2 Performing Seasonal Differencing

The seasonal difference is given as $z_t = y_t - y_{t-15}$. By observing Figure 4, one can conclude that the series is not yet stationary. Beside that, Figure 5 and Figure 6 depicts the decaying and undulating characteristics.

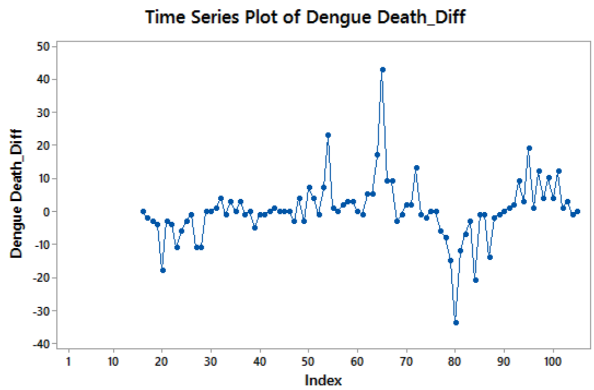

Figure 4: Time plot of Series in Seasonal Difference $z_t = y_t - y_{t-15}$

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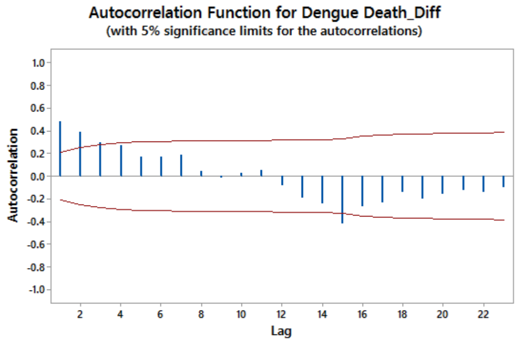

Figure 5: The ACF of z_t

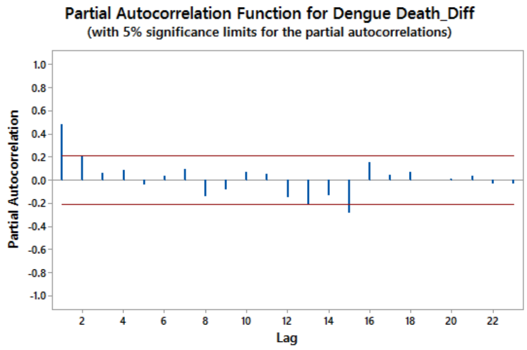

Figure 6: The PACF of z_t

1.3 Performing Non-Seasonal Differencing

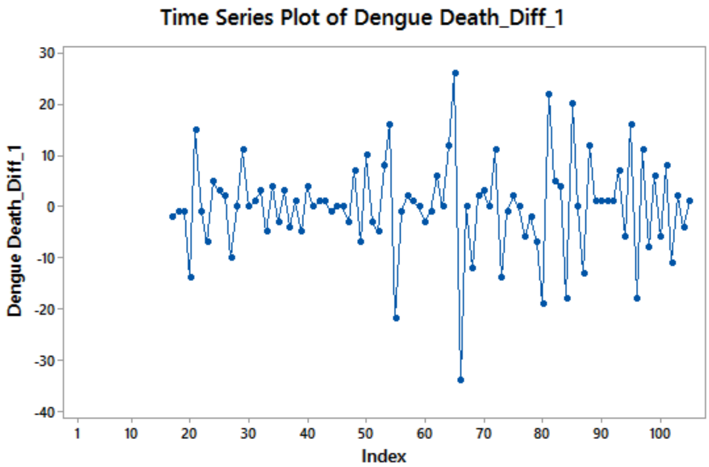

Figure 7: Time plot of Series in Non-Seasonal Differencing $w_t = z_t - z_{t-1}$

In this step of analysis, non-seasonal differencing $w_t = z_t - z_{t-1}$ was performed and the time plot was obtained as shown in Figure 7. Figure 8 and Figure 9 does not show the presence of trend and the series is now stationary.

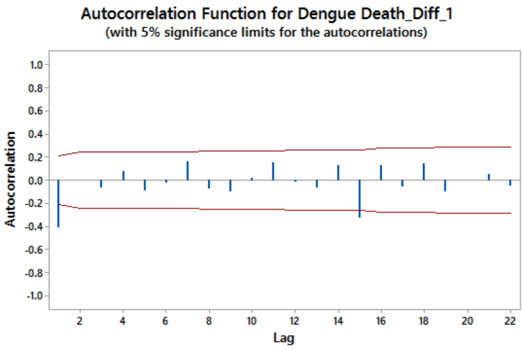

Figure 8: The ACF of w_t

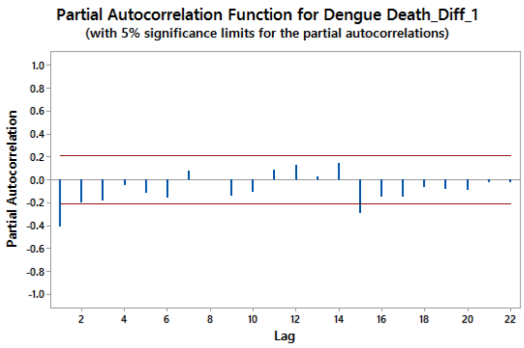

Figure 9: The PACF of w_t

1.4 Models Identified

In order to determine the best model formulations to be fitted to the data series one needs to observe for a significant spike in Figure 8 and Figure 9. At the ear list analysis Figure 1, contains the seasonal component and the general formulation is written as SARIMA (p, d, q)(P, D, Q)$_{15}$.To identify the non-seasonal and seasonal part, one needs to observe the spikes at ACF and PACF of w_t. Spike for MA can be identified by looking ACF plot of w_t and AR by looking at PACF of w_t. While spike for the seasonal MA and seasonal AR can be obtained by looking at the spike for uncommon for most series[7, 8, 9]. A significant spike is observed at the lag 15 to suggest the seasonal SMA (from ACF) and SAR (from PACF). All possible models will be correctly checked for their representative, this to ensure that a well specified model is not missed out. The potential model is summarized in Table 1.

Table 1: Summaries of Portmanteau Test For Each Model

	Model			
	SARIMA (1,1,2)(0,1,1)$_{15}$	SARIMA (1,1,2)(0,1,0)$_{15}$	SARIMA (2,1,0)(0,1,1)$_{15}$	SARIMA (1,1,0)(0,1,1)$_{15}$
Calculated Chi-Square (Df)	5.3 (8)	7.1(9)	11.6(9)	17.5(10)
P value	0.075	0.623	0.240	0.064
Decision (1% sig. Level)	Do not reject H_0	Do not reject H_0	Do not reject H_0	Do not reject H_0
Conclusion	The errors are white noise	The errors are white noise	The errors are white noise	The errors are white noise
MSE	40.07	63.28	42.43	57.43

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All four proposed models are well specified since the errors are white noise. After considering the concept of parsimony and the size of their respective MSE. Model SARIMA $(2,1,0)(0,1,1)_{15}$ therefore is being selected as the best model to represent the data. After selection of model, the next step is to forecast the future value of the gained model.

1.5 Forecasting Values From The Obtained Model

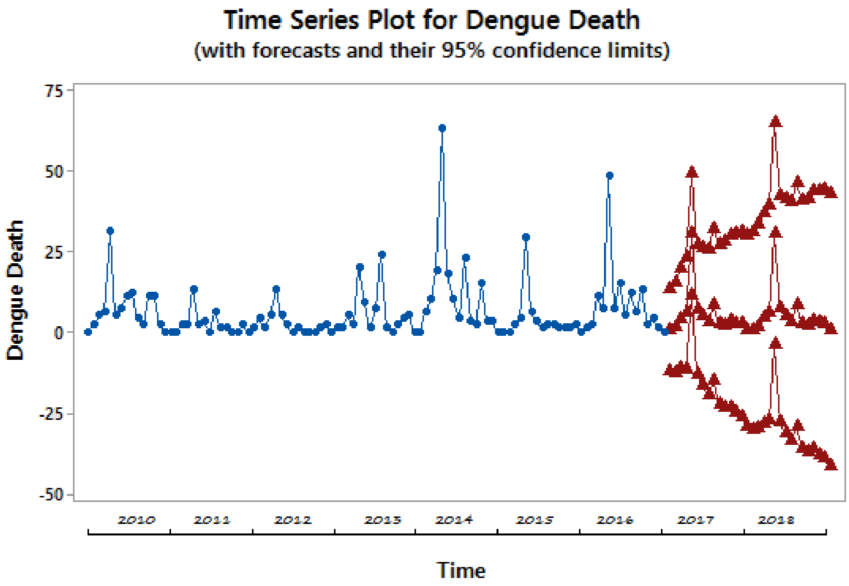

Figure 10: Time Series Plot With Forecasting Values

2.0 Result

Table 2: Estimation of Dengue Death for 2017 and 2018

	Year 2017		Year 2018
PERLIS	0.2352 ≈ 0	PERLIS	0.2312 ≈ 0
KEDAH	1.1130 ≈ 1	KEDAH	1.3553 ≈ 1
PULAU PINANG	3.8178 ≈ 4	PULAU PINANG	3.9335 ≈ 4
PERAK	5.4458 ≈ 5	PERAK	5.5766 ≈ 6
SELANGOR	29.9850 ≈ 30	SELANGOR	30.1357 ≈ 30
WPKL/PUTRAJAYA	6.8117 ≈ 7	WPKL/PUTRAJAYA	6.9480 ≈ 7
N.SEMBILAN	4.5400 ≈ 4	N.SEMBILAN	4.6799 ≈ 5
MELAKA	2.7416 ≈ 3	MELAKA	2.8827 ≈ 3
JOHOR	8.0254 ≈ 8	JOHOR	8.1650 ≈ 8
PAHANG	2.0313 ≈ 2	PAHANG	2.1715 ≈ 2
TERENGGANU	1.7515 ≈ 2	TERENGGANU	1.8917 ≈ 2
KELANTAN	3.1363 ≈ 3	KELANTAN	3.2764 ≈ 3
SARAWAK	2.3610 ≈ 2	SARAWAK	2.5012 ≈ 3
SABAH	2.0402 ≈ 2	SABAH	2.1803 ≈ 2
LABUAN	0.0386 ≈ 0	LABUAN	0.1787 ≈ 0

3.0 Conclusion

Dengue fever is considered one of the important fever in Malaysia since of its frequency of ending with death. The treatment of dengue is considered urgency while death is regarded as intolerable especially in Malaysia. The death of a dengue patient will be investigated promptly in all level of health care. The area of patient house will be cleared of the infection by fogging and frequent checking by the public health care workers. Despite the steps taken to ensure the safety of the patient, mortality rate is still ongoing. The first six days is crucial time for the medical personnel and the patient to work together to prevent the death. However, these timeline where the disease progression to the point of irreversible condition is still unexplained.

The presence of symptoms and signs such as lethargy, persistent vomiting and abdominal pain in addition to bleeding tendencies should be educated among the citizen since the delay in seeking the treatment would result in fatality. Presence of underlying disease should be optimized in treatment to avoid resistant to the dengue management. Fortunately, the dengue is considered important in almost all countries of South East Asia. The data of the death due to dengue is readily collected in detail for further analysis in predicting the death rate. The availability of the data will help the health ministry to target the important state/area. Forecasting technique is one of the most important analyses of a time series. The best selection model giving us the best results of the prediction. For the forecasting techniques, it involves a combination of science and art for the model determination. One need to be very careful to recognize the model identification based on the previous pattern.

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Declaration

Authors declare that the article has not been published or submitted for publication in any other journal.

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Author 4: Nor Azlida Aleng
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