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Predicting Dengue Outbreak in Selangor using Holt-Winters Models

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Abstract
Dengue fever is an internationally recognised virus that is spread by mosquitoes and can result in death. Dengue fever is a mosquito-borne illness that affects people throughout the world. Dengue fever has been endemic in Malaysia since its breakout in the 1980's with the state of Selangor having the greatest number of cases. The corona disease (COVID-19), a new pandemic that has swept the globe, like Selangor, has prompted this report on the pattern of dengue cases during COVID-19 pandemic. Due to the new outbreak COVID-19, the Movement Control Order (MCO) has been extended from time to time, and with most health resources at the state and federal levels being used to combat COVID-19, dengue control activities have been limited to a non-contact activity in outbreaks and hotspot areas. The aim of this research is to forecast weekly dengue cases in Selangor for 10 weeks ahead. This study used Additive Holt-Winters and Multiplicative Holt-Winters Models to predict the dengue cases in Selangor. This study was carried out using Excel Solver. The best model was calculated by comparing the Sum Square Error (SSE) Mean Square Error (MSE) and Mean Absolute Percent Error (MAPE) measurement errors. Then, the predicted number of dengue cases was calculated using the best model generated. The model for which the values of criteria are the smallest is considered as the best model. The finding in this study indicates that the Multiplicative Holt-Winters Model has the smallest measurement errors compared to the Additive Holt-Winters Model. The forecasted values showed a decreasing number of dengue cases for 10 weeks ahead.
Keywords: Dengue, Prediction, Multiplicative Holt-winters, Additive Holt-Winters, Measurement Errors

Introduction

Dengue fever is a tropical illness that affects people and has become a serious public health issue on a global scale in recent decades. According to the World Health Organization (WHO), about 2.5 billion people are, now living in dengue-infested areas. Dengue is an acute febrile disease triggered by an infection from dengue virus (DENV). DENVs are single positive-stranded RNA flaviviruses, members of the Flaviviridae family. This virus has four major serotypes (DENV-1, DENV-2, DENV-3, and DENV-4). Humans acquire dengue fever after being

bitten by DENV-carrying female Aedes mosquitoes, such as Aedes albopictus and Aedes aegypti. Subsequent infection with distinctive serotype of DENVs has been associated with increased risk of severe complications. (Wang et al., 2020)
The COVID-19 pandemic is sweeping the globe and dengue fever transmission is not at the top of the priority list. Between March 18 and March 30, 2020, the Movement Control Order (MCO) I was implemented in the nation. Since the significant surge in reported cases due to multiple Islamic religious gatherings involving 12,000 people in Sri Petaling, Kuala Lumpur, between February 28 and March 2, 2020, this MCO was largely used for controlling and reducing the spread of COVID-19 in Malaysia (Rahim et al., 2021) . Ong et al (2021) found that, dengue fever occurrences decreased significantly at the start of the lockdown, but then recovered at a faster pace and earlier time than in prior years.
In Selangor, many factors have caused a high incidence of dengue infection. With the highest population in Malaysia, many communities in Selangor tend to do littering and dumping, which have caused an abundance of trash thus contributes to the mosquitoes breeding there. It is difficult to change humans' behaviour unless they are aware of the risk of dengue infection. By investigating this issue, some preventive measures may be taken to reduce the rate of dengue cases occurring in Selangor as dengue is an infectious disease that can be transmitted through direct contact and in the air. Mudin (2015) found that the Ministry of Health, the Department of Safety and Employment and the Construction Industry Board (CIDB) had been carrying out integrated implementation at district and state levels on a regular basis since 2014. As the Ministry of Health is limited in human resources, there are still a lot more construction sites that need to be examined. Since many of these sites are abandoned, they provide large breeding sites for Aedes. Dengue disease cases are of concern to the World Health Organisation (WHO) of Malaysia as one of the most serious causes of death in the communities. The WHO has tried to take legal action to reduce dengue cases, but the pattern of dengue cases remains the same. This study will therefore focus on the trend of the outbreak of dengue.
The Holt-Winters method can also be used for forecasting time-series data. Muhammad & Din (2017) have pointed out that Holt's method is also referred to as Holt-Winters double exponential smoothing technique. This approach was proposed by Charles C. Holt and Peter Winters. In another previous study, Dumi et al., (2015)said that Holt presented a method for conducting trend data, which was introduced as the Holt's linear method. However, in 1965, Winter introduced a method that is Holt-method Winter's of seasonality.

Abas & Halim (2018) also stated that the Holt-Winters method can be used to manage the time series when trends and seasonal variations are present. The Holt-Winters method consists of a multiplicative and an additive, where the application of either one can be used depending on the features of the exact time series. In order to predict dengue incidence, the researchers used additive Holt-Winters in their study and compared the performance of the models, Mean Absolute Percentage Error (MAPE), Mean Squared Deviation (MSD) and Mean Absolute Deviation (MAD) have been calculated. The lowest value for each numeric assessment indicates a good fit between the observed and the predicted values.

The advantage of this method was shown in some studies where it was found that Holt's method would give better performance or the lowest error occurred if compared to the other methods. However, there is also a drawback to the use of Holt's method in the forecasting of time series data as it is difficult to determine the best value for the smoothing parameter because two smoothing parameters are required and it can only deal with trend variation (Muhammad & Din, 2017).The value of the α , β , and γ parameters is between 0 and 1.The search for the values was made by a grid approach where the results using different values for α, β and γ were compared to find the combination that minimizes the Mean Square Error (MSE) or Mean Absolute Deviation (MAD) (Tamber & Oladejo, 2020).

Many applications used the exponential smoothing. For example, Dantas et al (2017) used the combination of Holt-Winters and Bootstrap aggregation (Bagging) to predict the demand for air transportation industry. In comparison to the other five time series approaches, including the original Holt-Winters, SARIMA, Seasonal Nave, and the Bagging Holt-Winters methods offered a more accurate forecast.

In forecasting revenue, Rahman et al (2016) also stated that trends and seasonal patterns (monthly crore revenue) were present in the time series. Holt Winter's approach is valid for predicting the future state. The methodology was designed to estimate the monthly income (in crore) of Bangabandhu Multipurpose Bridge Bangladesh. The equations took shape and the designed models are shown below with their approximate parameters. The result offered the coefficient of variance for monthly profit (in crore) and monthly expected sales (in crore) were 0.5283 and 0.06048151, respectively, for Additive Holt Winter's. The statistical approach, Holt Winter's additive form, is superior to that of Holt Winter's multiplicative approach.

Meanwhile, Rahman & Ahmar (2017) compared ARIMA Model and Holt-Winters Model based on the smallest values of MAE, RSS, MSE, and RMS criteria in predicting the Primary Energy Consumption Total data in the US. It was found that Additive Holt-Winters is the most accurate model compared to Multiplicative Holt-Winters and ARIMA Models. Ismail Djakaria (2019) concluded that the Multiplicative Holt-Winters Model was used to predict the data on passenger arrival and departure time in Djalaluddin Gorontalo Airport. This is evidenced by the plot data that is impacted not just by trend patterns but also by seasonal trends. Djakaria & Saleh (2021) showed that the best forecasting model in Covid-19 pandemic data area of Gorontalo, Indonesia, from April 10 to October 13, 2020 is Holt-Winters Exponential Smoothing with parameters alpha=0.1, beta=gamma=0.5 which give the smallest Mean Absolute Percentage Error (MAPE) value of 6.14.

Ahmad & Nor (2020) applied two different forecasting methods to forecast the electricity consumption at Universiti Tun Hussein Onn Malaysia (UTHM), which are Holt's Linear Trend method and Holt-Winters method, both in long-term forecasting. It was found that both methods performed well and Holt-Winters is with the lowest error compared to Holt's Linear Trend method based on the smallest values of the Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE).

This study aims to investigate the trends of dengue cases, fit the Additive and Multiplicative Holt-Winters Models, check the accuracy and forecast dengue cases in Selangor using the best Holt-Winters Model. The study used the data sets from the Ministry of Health Selangor. To check the accuracy model, their goodness of fit had been compared using the Sum of Square Error (SSE), Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute

Deviation (MAD) and Mean Absolute Percent Error (MAPE) measurement errors by looking at their smallest error values.

Methodology

The data obtained in this study was collected from the Ministry of Health Selangor. The collected data are the total number of dengue cases per week in Selangor from January 2018 to June 2021. Every year in 2018, 2019, there are 52 weeks and 53 weeks in 2020. However, data for the year 2021 were collected for 22 weeks. Therefore, the data collected consists of 179 data on dengue cases which were used to predict dengue cases for the next twenty weeks.

Additive Holt-Winters Model

The Additive Holt-Winters Model is presented in the following equations:

Level: $L_t = \alpha\left(Y_t - S_{t-s}\right) + \left(1-\alpha\right)\left(L_{t-1} + b_{t-1}\right)$ (1)

Trend: $b_t = \beta\left(L_t - L_{t-1}\right) + \left(1-\beta\right)b_{t-1}$ (2)

Seasonal: $S_t = \gamma\left(Y_t - L_t\right) + \left(1-\gamma\right)S_{t-s}$ (3)

Forecast: $F_{t+m} = L_t + b_t m + S_{t-s+m}$ (4)

The initial for Holt-Winters Additive Model are:

$$L_s = \frac{1}{s}\left(Y_1 + Y_2 + \ldots.. + Y_s\right) \quad (5)$$

$$b_s = \frac{\sum\left(Y_{s+1} - Y_t\right)}{s^2} \quad (6)$$

$$S_s = Y_i - L_s \quad (7)$$

$$F_{t+1} = L_t + b_t + S_{t+1-s} \quad (8)$$

Multiplicative Holt-Winters Model

The Multiplicative Holt-Winters Model is presented in the following equations:

Level: $L_t = \alpha\left(\frac{Y_t}{S_{t-s}}\right) + \left(1-\alpha\right)\left(L_{t-1} + b_{t-1}\right)$ (9)

Trend: $b_t = \beta\left(L_t - L_{t-1}\right) + \left(1-\beta\right)b_{t-1}$ (10)

Seasonal: $S_t = \gamma\left(\frac{Y_t}{L_t}\right) + \left(1-\gamma\right)S_{t-s}$ (11)

Forecast: $F_{t+m} = \left(L_t + b_t m\right)S_{t-s+m}$ (12)

The initial for Holt-Winters Multiplicative Model are:

$$L_s = \frac{1}{s}\left(Y_1 + Y_2 + \ldots.. + Y_s\right) \quad (13)$$

$$b_s = \frac{\sum(Y_{s+1} - Y_t)}{s^2} \tag{14}$$

$$S_s = \frac{Y_i}{L_s} \tag{15}$$

$$F_{t+1} = (L_t + b_t) S_{t+1-s} \tag{16}$$

Where L_t denotes an estimate of the level of the series at time t, b_t denotes an estimate of the trend of the series at time t, S_t is an estimate of the seasonality at time t, s is the seasonality length which is the number of week in a year (s=52), F_{t+m} is the forecast for m time ahead and F_{t+1} is the forecast within the data set.

Model Performance

Goodness of fit is the measure of accuracy of the forecasted model to the actual value. The model forecast accuracy was measured by the following criteria:

Sum of Square Error (SSE): $\sum e_t^2$ (17)

Mean Square Error (MSE): $\frac{\sum e_t^2}{n}$ (18)

Root Mean Square Error (RMSE): $\sqrt{\frac{\sum e_t^2}{n}}$ (19)

Mean Absolute Error (MAE): $\frac{\sum |e_t|}{n}$ (20)

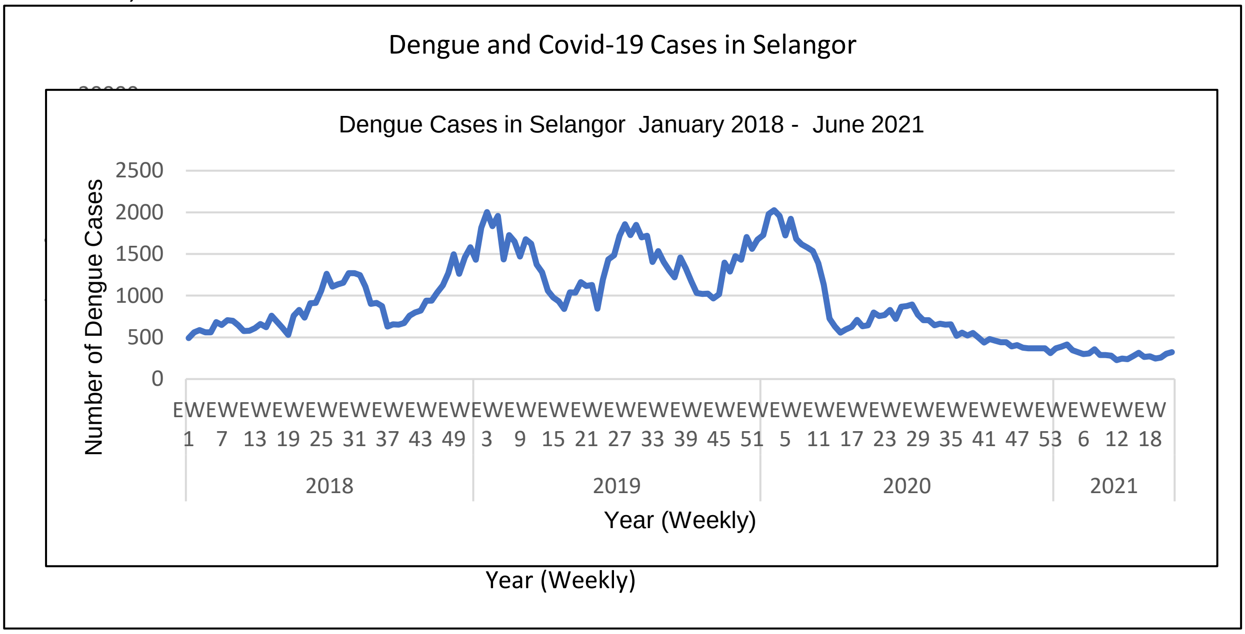
Mean Absolute Percentage Error (MAPE): $\left(\frac{1}{n}\sum\left|\frac{e_t}{Y_t}\right|\right)(100)$ (21)

Where the forecast error is e_t, and it is calculated by subtracting the forecast value from the series' actual value, Y_t. Here n is the number of effective observations used to match the model. Minimum values of these accuracy measures provide the best fitting models.

Findings and Discussions

Trend of Dengue Cases

Figure 1 below shows the time series of dengue cases in Selangor from Epidemic Week 1, January 2018 to Epidemic Week 22, 2021. Dengue cases have shown a trend where there was an increase in the number of cases from 2018 to 2019. Then, the number of dengue cases started to drop dramatically from Epidemic Week 3 to Epidemic Week 16, 2020 as the new pandemic, COVID-19 occurred in early 2020 (Figure 2). From the actual data, the highest number of dengue cases recorded in Epidemic Week 3, January 2020 was 2026 while the lowest number of reported dengue cases from the collected data was 227 cases in Epidemic Week 21, June 2021.



Data Analysis and Results Presentation

In this study, the data were divided into two parts which were estimation (70%) and evaluation (30%) parts. The data selected for the estimation part were from Epidemic Week 1, January 2018 (n=1) to Epidemic Week 21, May 2020 (n=125). The data for the evaluation part started from Epidemic Week 22, May 2020 (n=126) to Epidemic Week 22, June 2021 (n=179). The data on the estimation part were used to identify the level component, the trend component and the seasonality component. The forecast values were calculated on the evaluation part. To find the best combination of α, β and γ, Solver in Excel was used that minimized the Mean Square Error (MSE) and the Mean Absolute Error (MAE).

Table 1: Measurement errors of the Holt-Winters Models Parameters

Model	α	β	γ	MSE	MAE
Multiplicative Holt-Winters	0.78	0.02	0	36623.78	133.49
Additive Holt-Winters	0.56	0.02	0.12	91977.2	198.43

Table 1 reveals that Multiplicative Holt-Winters had lower MSE and MAE values than the additive model, implying that Multiplicative Holt-Winters is better suited for forecasting dengue outbreaks. The accuracy error measures as a diagnostic check were used as a final conclusion on which model fits better. To test for the model accuracy error measures, this study used SSE, RMSE and MAPE.

Table 2: Measurement errors of the Holt-Winters Models

Model	SSE	RMSE	MAPE
Multiplicative Holt-Winters	2998399	223.55	61.28
Additive Holt-Winters	4966769	303.28	45.46

Table 2 shows the result for these accuracy error measures which show that the Multiplicative Holt-Winters model has smaller SSE, RMSE and MAPE. Hence, Multiplicative Holt-Winters model has been selected as the more suitable model for forecasting the number of dengue cases in Selangor. The predicted number of dengue cases was computed using the best model selected as shown in Table 3.

Table3: Predicted number of dengue cases in Selangor

Epidemic Week	**Predicted Dengue Cases**
23	226
24	249
25	281
26	232
27	223
28	212
29	218
30	202
31	182
32	148
33	109
34	98
35	83
36	52
37	45
38	37
39	29
40	24
41	15
42	5

From Table 3, the number of dengue cases predicted in Selangor in Epidemic Week 23 to Epidemic Week 25 increased and the number of dengue cases predicted in Selangor in Epidemic Week 26 to Epidemic Week 42, October 2021 kept on decreasing from 281 cases to 5 cases.

Conclusion and Recommendations

To predict the dengue case values in Selangor for Epidemic Week 23 until Epidemic Week 32 in 2021, the Holt-Winters Multiplicative Method and Holt-Winters Additive method were used in this study. As a result, the best model was evaluated by the least measurement errors of the models used in the analysis. This study was therefore analysed using Multiplicative Holt-Winters Model, since the model was chosen as the best method for assessing the actual dengue case data in Selangor from Epidemic Week 1, January 2018 to Epidemic Week 22, June 2021. The analysis shows the number of dengue cases during the new pandemic with COVID-19 still occurring among the community in Selangor from the year 2020 until June 2021. In order to accurately predict the future dengue case values that may occur in Selangor for the weeks to come, Multiplicative Holt-Winters Model was assessed as the best model to be used. This study shows a pattern of prediction values in which dengue cases decreased during COVID-19, similar to the actual dengue case data collected. Previous research,(Martin et al., 2019) revealed a change in the *Ae. albopictus* habitat to an interior setting, where the species generally inhabits the forest or is largely vegetative and causes interspecies conflict with other existing mosquito species, such as *Ae. aegypti*. Therefore, when the COVID-19 lockdown was implemented, where the number of dengue cases got lower as a majority of people stayed at home and most of the time people were contained in their own housing areas which further decreased the human movement, so the cases of infection were reduced.

This research provides the estimated number of dengue cases ten weeks ahead of the actual data. By predicting the future outbreak of dengue, the Ministry of Health will gain some benefits and will be able to take a number of steps, such as a dengue-hazard campaign, if people get infected in Selangor. Other than that, some actions may be taken by the Ministry of Environment and Water to prevent the outbreak of dengue. They can organise an event where people gather to clean and clear their residential areas from any stagnant water. There will therefore be little chance of mosquito breeding if the environment is kept clean. Last but not least, from the data forecast, the community can also take action to ensure that their families are safe from dengue infection. The community will begin to have some self-awareness and fully cooperate with the government forces. The researcher recommends future study to be conducted using more time series methods to evaluate the accurate predicted dengue case values. The model generated is the best model to provide high accuracy of the predicted dengue cases with the smallest measurement errors computed by each method.

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