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FORECASTING SOLID WASTE GENERATION IN NEGERI SEMBILAN AND MELAKA

(Peramalan Penjanaan Sisa Pepejal di Negeri Sembilan dan Melaka)

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ABSTRACT

Solid waste management is vital to ensure the cleanliness of the country and keeping the good health of the people. In Malaysia, the solid waste management system is highly dependent on landfills to manage waste. However, landfill sites in Malaysia are in dire state and constructing new landfills become impossible due to land scarcity. On top of that, the practice of recycling among the public are critically lacking which contributes to rapid increase in the volume of solid waste generated. Thus, forecasting solid waste generation is crucial to avoid overflow of waste. In this study, the solid waste produced in Negeri Sembilan and Melaka is forecasted to one year ahead and to see whether the landfills in both states are still able to accommodate the solid waste produced. Secondary data of the solid waste generated in Negeri Sembilan and Melaka from January 2017 to August 2020 is used in this study. The error measures of several univariate and ARIMA models are evaluated using the Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) to choose the best model in forecasting the solid waste generation in both states. The results revealed that ARMA (2,2) and ARMA (3,1) is the best model to forecast the solid waste generation in Negeri Sembilan and Melaka respectively. Besides, the estimated solid waste generation for both states also is approaching the maximum landfill capacity and this issue should be taken seriously so that environmental damage can be reduced.

Keywords: solid waste management; forecasting, landfill

ABSTRAK

Pengurusan sisa pepejal sangat penting untuk memastikan kebersihan negara serta menjaga kesihatan rakyat. Di Malaysia, sistem pengurusan sisa pepejal sangat bergantung pada tapak pelupusan sampah untuk menguruskan sampah. Namun begitu, tapak pelupusan sampah di Malaysia berada dalam keadaan yang menakutkan dan pembinaan tapak pelupusan sampah baharu menjadi mustahil kerana kekurangan tanah. Di samping itu, amalan kitar semula dalam kalangan masyarakat adalah sangat kurang sehingga menyumbang kepada peningkatan cepat dalam jumlah sisa pepejal. Oleh itu, peramalan penghasilan sisa pepejal sangat penting untuk mengelakkan limpahan sisa. Dalam kajian ini, sisa pepejal yang dihasilkan di Negeri Sembilan dan Melaka diramalkan untuk satu tahun ke depan dan untuk melihat sama ada tapak pelupusan sampah di kedua-dua negeri masih dapat menampung sisa pepejal yang dihasilkan. Data sekunder mengenai sisa pepejal yang dihasilkan di Negeri Sembilan dan Melaka dari Januari 2017 hingga Ogos 2020 digunakan dalam kajian ini. Langkah ralat beberapa model univariat dan ARIMA dinilai menggunakan Min Kuasa Dua Ralat (MKDR) dan Min Peratusan Mutlak Ralat (MPMR) untuk memilih model terbaik dalam meramalkan penjanaan sisa pepejal di kedua-dua negeri. Hasil kajian menunjukkan bahawa ARMA (2,2) dan ARMA (3,1) adalah model terbaik masing-masing untuk meramalkan penjanaan sisa pepejal di Negeri Sembilan dan Melaka. Selain itu, penghasilan sisa pepejal yang dianggarkan untuk kedua-dua negeri juga menghampiri kapasiti tempat pembuangan sampah maksimum dan masalah ini harus ditangani dengan serius agar kerosakan persekitaran dapat dikurangkan.

Kata kunci: pengurusan sisa pepejal; peramalan; tapak pelupusan

1. Introduction

An overload solid waste is a never-ending concern not only in Malaysia but all around the world. Solid waste comes from human activities and falls into several categories. Household, commercial, construction and demolition (CD), industry and institutions are part of them. The main waste component is composed of organic or food waste, paper, plastic, metal, glass and others. Apart from the rapid increase in the waste management system expenditure, the way people managed these wastes may also bring adverse effects to the environment and public health (Ferronato & Torretta 2019). The most common form of waste disposal is landfilling. It is acknowledged as a significant alternative either now or in the near future, especially in low-income and middle-income countries, as it is the easiest and cheapest available technology (Ismail & Latifah 2013). The solid waste management system in Malaysia is highly dependent on landfills. According to the National Solid Waste Management Department (2015), there are a total of 296 landfills in Malaysia where 165 are operational landfills while the other 131 are closed. However, many landfills are reaching their design capacity and constructing new landfills becomes more challenging as population growth has led to land scarcity. In short, it is not surprising that Malaysia's solid waste management system has become harder to handle. With major growth in population, land scarcity has become an obstacle in constructing new landfills for waste disposal. Low awareness and participation in recycling among Malaysian should be improved to minimize the further impact of uncontrolled solid waste generation on the environment, social and economy.

Malaysians produced about 38,000 tons of waste daily (CheAzmi 2018) and 47 percent of the solid waste was food waste. Solid waste separation begins in September 2012 due to recycling activity was not properly conducted and controlled regardless of household or industry. There are 165 landfills was operated in Malaysia that needed 95 percent to accommodate solid waste. Consequently, landfill space was exhausted earlier than scheduled and was no longer sustainable in terms of security of disposal. The amount of waste produced increases parallel with development and population growth. Before it becomes critical, it is a need to find a way to address this problem. Landfill played a bigger role in waste management and sanitary landfill is one of the popular waste disposal methods. Here, landfill needs to be poisoned and isolated from the environment until it is safe. Landfill could environmentally harmful if not controlled. Every state in Malaysia has its own landfill, however, it is limited due to environmental safety. Each landfill has a lifespan and maximum capacity that can handle the waste. As the number of wastes increased, few of the landfills had to be closed because they reached maximum capacity.

Therefore, this study was important to forecast solid waste generated in the next one year in Negeri Sembilan and Melaka since each state has limited space for landfills. The study aims to (1) forecast the solid waste generated by Negeri Sembilan and Melaka; (2) identify whether both states landfill capacity can accommodate the solid waste generated in the next one year ahead. The discovery of this study contributed greatly to the benefit of society as well as Malaysia that faced a major problem which was solid waste. Due to the rapid growth of population and economy, the solid waste landfill is in demand since the solid waste is increasing. Moreover, the study aims to create awareness and gives insight information among society upon the environmental problem and find ways to help in managing solid waste in the household. For the researchers, the study will help to uncover the area of the landfill and solid waste in Malaysia that many researchers were not able to explore.

2. Literature Review

2.1. *Solid waste and landfill*

Due to the rapid growth of population and economy, the solid waste landfill is in demand since the solid waste is increasing. Chief Statistician Department of Statistics Malaysia, Mahidin (2020) reported that there is an increasing number of current population estimation from year 2019 with 32.5 million to 2020 expected of 32.7 million population. From time to time, both the increasing population and economic expansion have increased, and these scenarios have significantly increased Municipal Solid Waste generation (MSW). Due to the growing global population, existing waste management is unable to manage disposal rates, and economic growth in Malaysia is on the rise based on study by Chua *et al.* (2019). Furthermore, study by Abd Hamid *et al.* (2015) shows that, Malaysia’s solid waste production has been modified by rapid urbanization and industrialization, which has increased dramatically from approximately 9.0 million tons in 2000 to approximately 10.9 million tons in 2010 and eventually to approximately 15.6 million tons in 2020. Additionally, approximately 0.5-1.9 kg/capita/day of Municipal Solid Waste is produced by Malaysia. The total of Municipal Solid Waste is in 2014 are producing about 25,000 tons per day and is expected to reach 30,000 tons per day by 2020 with 3% annual increase of population rate (Aja & Al-Kayiem 2014). Table 1 shows the estimated solid waste generated by two states. Negeri Sembilan state shows that the amount of solid waste generated from 2017 with estimate in 2020 is 1,385.8 tons which already exceed the maximum capacity where Negeri Sembilan landfill can hold only 1,190 tons per day. Meanwhile, Melaka state also estimated to generate 941.9 tons per day in 2020 which has also reached the maximum capacity of Melaka landfill that can hold only 760 tons per day.

Table 1: Waste generation in Melaka and Negeri Sembilan from 2014–2020

States	Estimated solid waste generation (tonnes/day)						
	2014	2015	2016	2017	2018	2019	2020
Melaka	815.9	836.9	857.9	878.9	899.9	920.9	941.9
Negeri Sembilan	1200.4	1231.3	1262.2	1293.1	1324	1354.9	1385.8

Source: Aja & Al-Kayiem (2014)

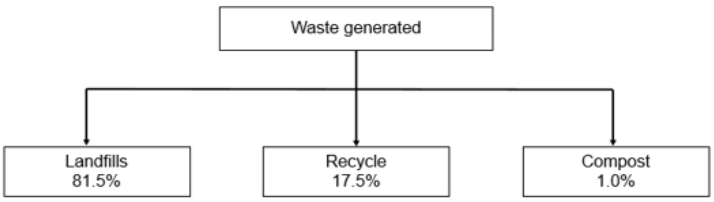


Figure 1: The overall flow of the municipal solid waste (Priatamby, 2017)

Moreover, based on a study by Pariatamby (2017), the overall flow of municipal solid waste is about 81.5 percent of waste generated go to landfills while less than 20 percent go to recycle and compost as shown in Figure 2.2 above. The study also stated that Malaysia is still very dependent on landfills as the primary waste disposal process. Out of 296 landfills in Malaysia, 165 are active, with only eight of them being sanitary landfills. Nearly 95 percent of national waste enters the landfills with recycling at 5 percent.

Landfills are the most common methods to manage waste not only in Malaysia but also in different countries (Younes *et al.* 2015). Hoque & Rahman (2020) stated that the demand for landfill would remain despite the fact that alternative disposal options being initiated as a part of the future sustainable solid waste management. However, the landfill has already reached its maximum capacity, due to rapid development and lack of space for new landfills. Undoubtedly, untreated solid waste often contains components that can cause infectious diseases. In Malaysia, poor solid waste management is one of the major contributors to environmental pollution and human health risks (Samsudin & Dona 2013). Although the Malaysian government has introduced recycling programs to reduce waste, its policy begins to appear to be less effective because there is a lack of clear guidance. Many Malaysian households have inadequate information about separating waste which leads to a relatively low percentage of recycling rate (Zulkipli *et al.* 2017). In addition to this, financing arrangements are also under consideration as it is unclear who will pay for waste management. Using tax money instead of waste management fees does not seem to create conditions for waste reduction (Omran *et al.* 2007). Thus, this study focused on the solid waste produced by Malaysian and the landfill's capacity since this problem could affect the future environment of Malaysia.

Negeri Sembilan lies on the west of Peninsular Malaysia with an area of approximately 6,686 km^2. Negeri Sembilan's population is estimated at 1.13 million as in 2019 (Department of Statistic Malaysia 2019a). Negeri Sembilan has been struggling to manage household waste and has opened what is believed to be the state's last landfill (Ismail & Latifah 2013, CheAzmi 2018) . Melaka is a historic city that is the most popular tourist destinations in Malaysia. It is located in the west of Peninsular Malaysia and bounded by Negeri Sembilan and Johor. The population in Melaka is estimated at 0.93 million in 2019 (Department of Statistic Malaysia 2019b). Since it holds enormous potential in the tourism industry, it is crucial to maintain its good image by preventing any solid waste issues from arising. This urged the need to forecast the Municipal Solid Waste (MSW) produced and the area of landfill in order to discover whether in the next one-year Malaysia landfill capable to accommodate the solid waste generated. With this forecast, Malaysia will be able to avoid from facing an overflowing amount of waste in the future.

2.2. *Forecasting*

Forecasting is used to make predictions of a future event based on past and present data and most commonly by analysis of trends. Forecasting plays a significant role in various fields. As in the case of this study, solid waste management should be aware of the solid waste generated in order to properly manage them and decide what should be done if any problem occurs in the future. It is important to understand the components of the waste that needs to be managed and predicting the future rates of generation to develop sustainable waste management (Al-Salem *et al.* 2018). It is similar to a study on solid waste in Bangkok, Thailand where the need to forecast the amount of municipal solid waste is crucial due to the increasing trend of waste throughout the decades (Sun & Chungpaibulpatana 2017). There are two categories of forecasting: qualitative and quantitative. Qualitative techniques are based on expert opinion or personal judgment while quantitative techniques are based on objective mathematical models. Time series or causal variables are used to establish quantitative forecasting. Historical data is used in time series forecasting to predict the desired future, while causal variable forecasting determines the relationship between the input and output variables and then applies the relationship to predict the future (Makridakis *et al.* 2008).

The amount of solid waste produced in Tarkwa Municipality was calculated from a secondary data source on the basis of the (Akyen *et al.* 2016) report, over seven-year quarterly intervals. The data was analyzed using the modeling technique of the ARIMA time series to produce an effective model for the municipality to estimate and forecast solid waste. The result shows that ARIMA (2,1,2) has the lowest value of the Akaike's Information Criterion and was selected as the best model in Tarkwa Municipality suitable for predicting waste produced. The life span of the new Tarkwa Nsuaem Municipal Assembly landfill situated in Aboss was also determined, giving the municipality of solid waste management enough time to prepare ahead. The use of the ARIMA time series model in the prediction of solid waste in the municipality provides satisfactory results in terms of its prediction and forecasting of solid waste data recorded.

This study assessed and discussed the importance of time series analysis and forecast (Akyen *et al.* 2016). The ARIMA time series model is suggested to be used by the assembly to estimate solid waste in the municipality since the choice of an acceptable model affects the decision-making process. They also concentrate more on the seasonality pattern and trend in the before and after the forecast for the generation of solid waste for the next ten years and did not emphasizes more on the municipality's landfill potential. Moreover, this study did not mention from the forecast solid waste generated whether in the ten years, Tarkwa Nsuaem Municipal Assembly landfill will reach its maximum capacity or otherwise.

Owusu-Sekyere *et al.* (2013) stated that the key challenge faced by the Kumansi Metropolitan Area is the inability of the city authorities to manage solid waste due to lack of proper plan and the inability of the authorities to forecast and predict the amount of solid waste produced for the coming year based on the current pattern. The Autoregressive Integrated Moving Average (ARIMA) time series model was used in this predictive analysis study to explore the dynamics of solid waste generated and forecast monthly solid waste generated in the metropolitan area. This research used monthly data collected from the Kumansi Metropolitan Assembly Solid Waste department from 2005 to 2010. The result shows that in December 2008, the trend in solid waste generated is increasing. The best model to forecast solid waste generated is ARIMA (1,1,1). The forecast revealed that solid waste generated continue to increase in the next few years due to the high urbanization rate in metropolitan regions. Therefore, research assumed that an effective waste management system should be placed to save the current situation and prepare for expected solid waste resulted from the forecast data. However, the study only predicts and forecast the monthly quantity of solid waste generated and recommended effective management of solid waste. This study did not explain whether in the next three years, the metropolitan area landfill reaches its maximum capacity or otherwise.

For this reason, researchers have employed several methods such as artificial neural network, time series analysis and parametric techniques to estimate the amount of solid waste generated. Research by Owusu-Sekyere *et al.* (2013), Chung (2010) and Momani & Naill (2009) has mentioned that the ARIMA time series model is one of the feasible techniques that yield precise predicted solid waste generated. The Box-Jenkins method is one of the most used technique for solid waste time series data modelling (Akyen *et al.* 2016). ARIMA able to predicts the future values of a time series using a linear combination of past values and a series of errors (Zafra *et al.*, 2017). This method performs well when the data is stationary or non-stationary (Sriploy & Lertpocasombut 2020). ARIMA is reported suitable for all kinds of data such as level, trend, seasonality, cyclicality and many more (Ceylan *et al.* 2020).

In forecasting, measuring the accuracy is important because it is an excellent process to identify how well the model fits the data. The study should consider the model's performance on new data that were not used when estimating the model to determine forecasts' accuracy. The available data will be separated into two parts: training and testing. It is also known as the estimation and the evaluation data. Training data is used to estimate the parameters of a forecasting method while the testing data is used to evaluate data accuracy. Usually, the test set will use about 1/4 of the series. This value depends on the length of the sample and how far ahead the study wants to forecast. The important point that needs to be considered is the model that fits the training data well is not necessarily forecastable. In the training set, residuals are calculated while in the test set, forecast errors are calculated. Residuals are based on one-step forecasts while forecasting errors are involved in multi-step forecasts (Hyndman 2014).

3. Methodology

3.1 *Data description*

Historical data is required in predicting future events. Hence, this study used secondary data. A time-series data on estimates of solid waste generated under the solid waste management and Public Cleansing Corporation (SWCorp) from January 2017 to August 2020 is used to forecast the future solid waste generation in Negeri Sembilan and Melaka by using the Autoregressive Integrating Moving Average (ARIMA) model. The data is obtained from SWCorp. This data provides the total amount of solid waste generated in each state (tons). In total, there are 44 data in this study. In order to do the forecasting, the data has been divided into two parts which are the estimation part and evaluation part. There are 33 data used in the estimation part while one-quarter of the whole data that equivalent to 11 data was used in the evaluation part.

3.2 *Irregularities in trend estimation and identification*

Figure 2 shows the irregularities that might happen because of certain peculiarities on the trend line. The existence of irregularities may complicate the process of estimation and identification of a model. This is when there is occurrence of major turning points, incidence of an outlier or random shock. Major turning points is defined as the point in the series where the trend changes its direction, from upward to downward or vice versa over a significant amount of time. Incidence of an outlier happens when there are observations that have extremely large or small values. The outliers would significantly affect the trend. However, the removal of the outlier may result in loss of vital information pertaining to the series being investigated. The effect of the random shocks may be identified as either the short-term memory effect or the long-term memory effect. For the short-term memory effect, the level returns to normal within a short period of time. In the case of the long-term memory effect, the level may take a longer period of time before returning to its normal level (Hyndman 2014). The occurrence of random shock which affects the trend and later returns to the normal level is not permanent and cannot be eliminated (Vajpayee & Dubey 2018). The effect of the random shock identified in this study is the short-term memory effect since the level returns to normal within a short period of time.

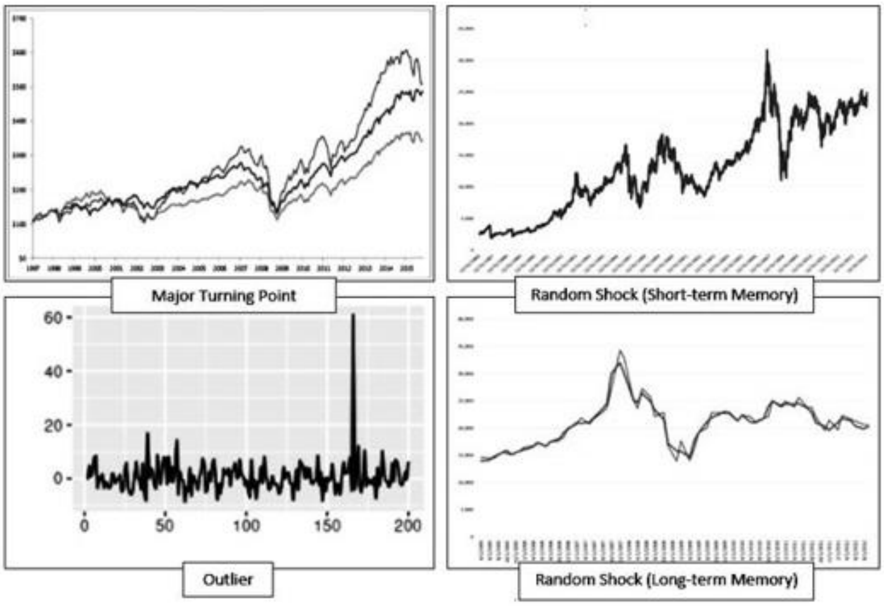


Figure 2: Irregularities pattern

3.3 *Forecasting method*

3.3.1 *Box-Jenkins method*

Box Jenkins method is a systematic method of identifying, fitting, checking and using autoregressive integrated moving average (ARIMA) time series models. ARIMA model is a model that can represent stationary and non-stationary time series and to produce an accurate forecast based on a description of historical data of a single variable. There are four steps in ARIMA models (Kumar & Anand 2014). The steps of procedure are as in Figure 3.

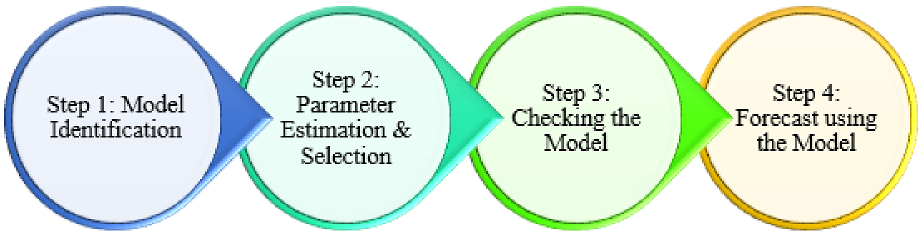


Figure 3: The ARIMA procedures

3.3.2 *Unit root test*

To determine the trend of the data in time series, a unit root test is used. It can also determine whether the data need the differencing for stationary of data. Unit root test is often the first step in the procedure of forecasting. Testing the stationary of data is important in time series analysis. Stationarity is statistical properties that generate time series and do not change over time. Many statistical tests, analytical tools and models rely on the stationary data. The basic method to determine the stationary properties is by plotting and visualize the data. In this study, stationary is determined by plotting the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). The plot of ACF and PACF is called correlogram. The data is stationary if the pattern of correlogram is decreasing to zero quickly while for non-stationary data the decreasing is slowly (Palachy 2019).

3.3.3. *Validation of forecasting model*

Specific models can generate good forecast values in a particular situation because each model type has its unique characteristics which define its suitability to be fitted to the given data series. Evaluating the model is a part of the significant process in most forecasting activities. Forecasters are able to know how well the performance of the selected model forecasts. The large forecast errors by the wrong selection of forecasting method would give the effect of substantial financial loss to the organization. Models can be evaluated to determine the one that may generate the best forecast values. Error measure is to differentiate between a poor forecast model and a good forecast model. The standard measurement to determine a good forecast is when the error measure has the smallest value. The error can be computed from Mean Square Error (MSE) in Eq. (1) and Mean Absolute Percentage Error (MAPE) in Eq. (2). In addition, the residual can be obtained by assuming to have the property of white noise in a well fitted model.

$$MSE = \frac{\sum {e_t}^2}{n} \tag{1}$$

where $e_t = y_t - \hat{y}_t$ where y_t is the actual observed value at time t and $\hat{y}_t$ is the fitted value at time t.

$$MAPE = \sum \frac{\left|\left(\frac{e_t}{y_t}\right)\right| \times 100}{n} \tag{2}$$

where n is denotes as effective data points while $|(e_t / y_t)| \times 100$ is defined as the absolute percentage error calculated on the fitted values for particular forecasting method.

Validation of the model and diagnostic testing included evaluating the residuals for white noise resemblance. If the residuals are white noise, then no significant coefficients of autocorrelation and no significant partial coefficients of autocorrelation are assumed to occur. The Portmanteau Test is used to determine the significant of the white noise. The hypotheses are:

H_0: The errors are random (white noise).
H_1: The errors are nonrandom (not white noise).

The rejection rule is H_0 will be rejected if the p-value is less than $\alpha = 0.05$. In conclusion, the H_0 must be accepted in order for the residuals to be random, therefore white noise exists.

4. Results and Discussions

4.1 *Trend analysis on solid waste generation in Negeri Sembilan and Melaka*

The data of the solid waste generated in Negeri Sembilan and Melaka from January 2017 to August 2020 is analyzed to find out whether the forecast value of solid waste in both states exceeded the maximum capacity of solid waste that can be accommodated by the landfills in each state as in Figure 4.

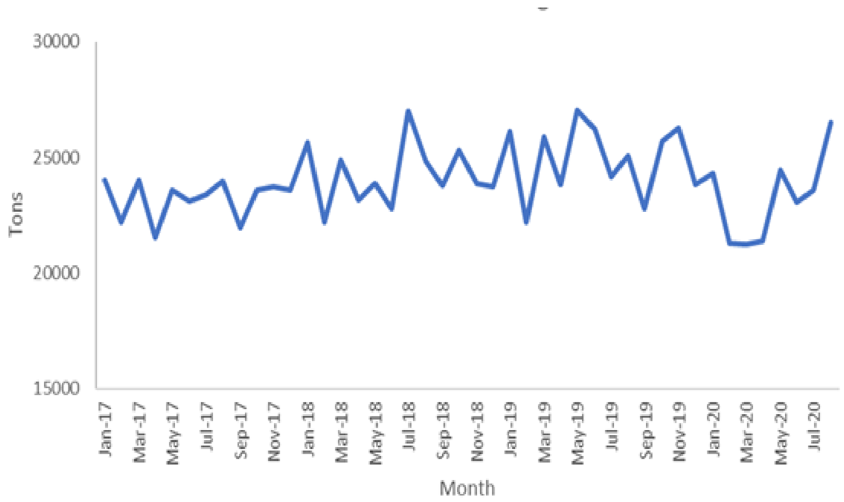


Figure 4(a): Trend analysis on solid waste generation in Negeri Sembilan

Figure 4(a) shows that on July 2018 to July 2019, the volume of the solid waste generated can be seen increasing compared to previous month then reduces in early 2020. The decrements may due to people stay at home during the Restricted Movement Control Order (RMCO). However, the solid waste generated increased tremendously starting April2020 onward. This is because the RMCO was lifted during that period of time and implementation of Conditional Movement Control Order (CMCO) begins where people are allowed to go out as long as they follow the Standard Operating Procedure (SOP).

Figure 4(b) shows that the solid waste generated in Melaka increased majorly in May 2018. The increment may due to the start of Ramadan for Muslims in Malaysia. The streets would be buzzing with bazaars few hours before iftar. Even non-Muslims enjoy going to the bazaars since there will be smorgasbord of local delicacies. Consequently, people tend to waste food during this month. Towards the end of Ramadan, people will start making preparation for Raya where the shopping mall and the night market will be swamped with people. More waste are generated during this phase since the restaurants or eatery are packed with people either to break their fast or to have supper. On the other hand, there exist irregularities pattern in the data series. The occurrence of random shock (short-term memory) which affects the trend and later returns to the normal level can be seen from March 2020 to May 2020. For the short-term memory effect, the level returns to normal within a short period of time. Based on graph, the sudden decrease in solid waste generated during that period of time may due to the Restricted Movement Control Order (RMCO) implemented to curb the global virus outbreak, Covid-19. During that phase, people are obligated to stay at home. All outdoor activities including shopping, going on vacation and eating at the eatery were not allowed. These contribute to less solid waste generated during that period of time.

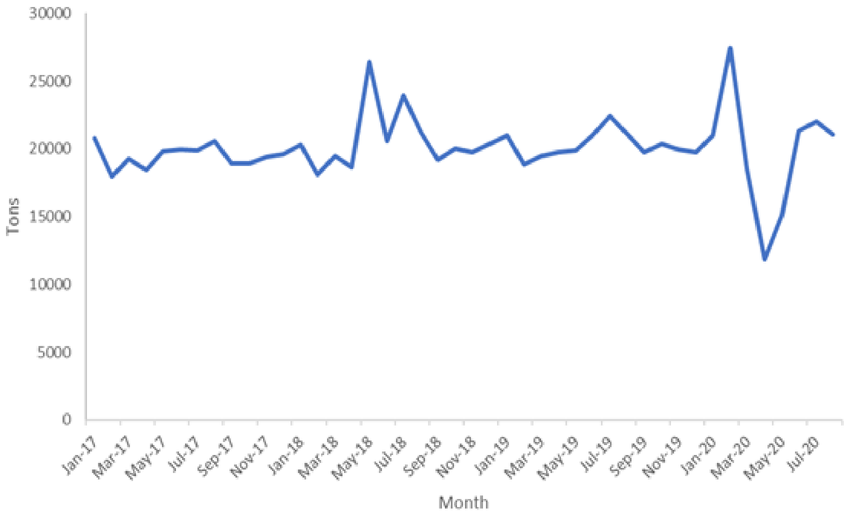
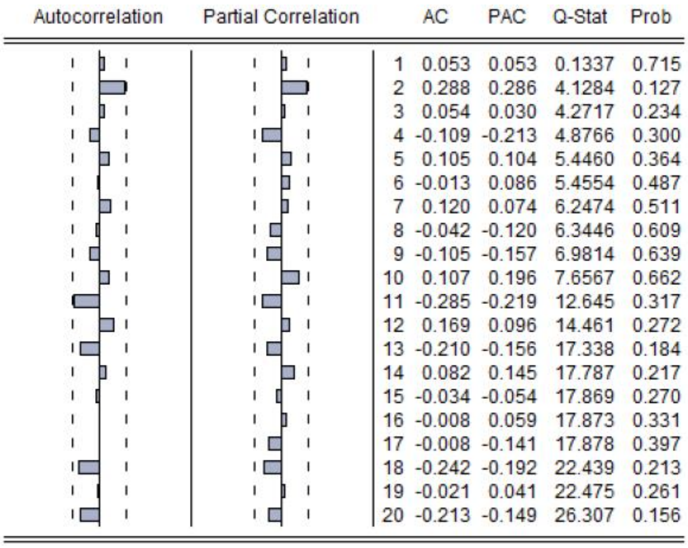


Figure 4(b): Trend analysis on solid waste generation in Melaka

4.2 *Stationary*

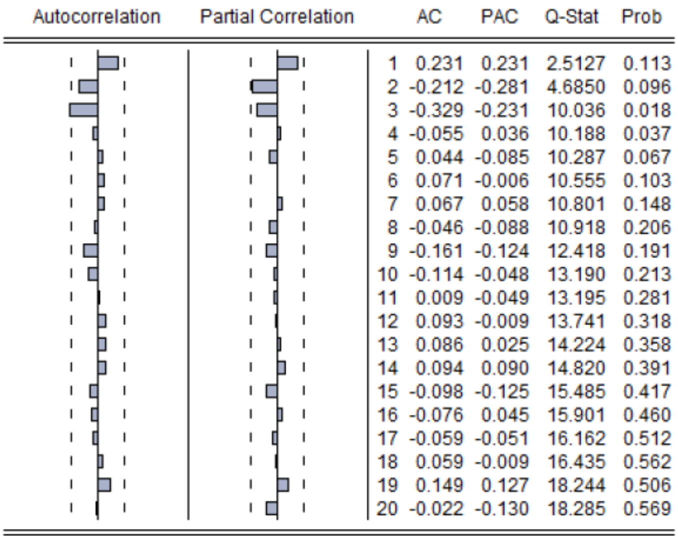
This study starts by plotting the autocorrelation function (ACF) and partial autocorrelation function (PACF) in the collection to ensure more reliable stationary condition of the data. Based on the Figure 5(a) Negeri Sembilan state reveals that there is no decaying trend for both ACF and PACF plots and no values surpass the maximum significance. It is concluded that the series is stationary and no differentiation from the initial data is needed. A statistical test that is a unit root test is one of other way to determine whether the data is stationary. In addition, the *t*-statistic of -5.852 with a probability value of 0.000 based on Augmented Dickey-Fuller (ADF) performance, which is significantly lower than all three critical values given. It can be inferred that Negeri Sembilan sequence is stationary.

Meanwhile, Figure 5(b) shows the Melaka sequence is stationary based. The value of ACF and PACF plot has no decaying pattern and no values surpass the significance limit. The ADF performance *t*-statistic value is -5.052 and probability value of 0.0001 are substantially lower than all three critical values from the unit root test, which concluded that the Melaka sequence being stationary.



Lag	AC	PAC	Q-Stat	Prob
1	0.053	0.053	0.1337	0.715
2	0.288	0.286	4.1284	0.127
3	0.054	0.030	4.2717	0.234
4	-0.109	-0.213	4.8766	0.300
5	0.105	0.104	5.4460	0.364
6	-0.013	0.086	5.4554	0.487
7	0.120	0.074	6.2474	0.511
8	-0.042	-0.120	6.3446	0.609
9	-0.105	-0.157	6.9814	0.639
10	0.107	0.196	7.6567	0.662
11	-0.285	-0.219	12.645	0.317
12	0.169	0.096	14.461	0.272
13	-0.210	-0.156	17.338	0.184
14	0.082	0.145	17.787	0.217
15	-0.034	-0.054	17.869	0.270
16	-0.008	0.059	17.873	0.331
17	-0.008	-0.141	17.878	0.397
18	-0.242	-0.192	22.439	0.213
19	-0.021	0.041	22.475	0.261
20	-0.213	-0.149	26.307	0.156

Figure 5a: Correlogam and Augmented Dickey-Fuller for Negeri Sembilan



Lag	AC	PAC	Q-Stat	Prob
1	0.231	0.231	2.5127	0.113
2	-0.212	-0.281	4.6850	0.096
3	-0.329	-0.231	10.036	0.018
4	-0.055	0.036	10.188	0.037
5	0.044	-0.085	10.287	0.067
6	0.071	-0.006	10.555	0.103
7	0.067	0.058	10.801	0.148
8	-0.046	-0.088	10.918	0.206
9	-0.161	-0.124	12.418	0.191
10	-0.114	-0.048	13.190	0.213
11	0.009	-0.049	13.195	0.281
12	0.093	-0.009	13.741	0.318
13	0.086	0.025	14.224	0.358
14	0.094	0.090	14.820	0.391
15	-0.098	-0.125	15.485	0.417
16	-0.076	0.045	15.901	0.460
17	-0.059	-0.051	16.162	0.512
18	0.059	-0.009	16.435	0.562
19	0.149	0.127	18.244	0.506
20	-0.022	-0.130	18.285	0.569

Figure 5b: Correlogam and Augmented Dickey-Fuller for Melaka

4.3 *Model identification*

This study conducted the model identification through the ACF and PACF pattern from the stationary series. ACF and PACF are included process of determining the appropriate models to be fitted to the data series. However, the model based on the number of spikes in ACF and PACF is not simple to determine precisely. To determine the number of lags needed, a careful judgment of the position and size of spikes is necessary. The ACF graph will represent the Moving Average (MA) while the PACF graph will represent the Autoregressive Model (AR). Both AR and MA will be denoted as p and q respectively.

Since the data is stationary, the value of d is detonated as 0. From the Correlogram for Negeri Sembilan in Figure 4.3, the most noticeable spike in ACF and PACF can be seen at lag

2. Therefore, the model that can be estimate for Negeri Sembilan is ARMA (2,2). While for the Melaka state, the most noticeable for ACF at lag 3 and PACF seen at lag 2. Thus, the model that can be predicted are ARMA (2,3).

4.4 *Performance evaluation*

From the model identification, it has been found that the most appropriate model form to forecast the solid waste generation in Negeri Sembilan and Melaka is ARMA (2,2) and ARMA (2,3) respectively. However, to obtain a more conclusive evidence of the best model form, five models are assumed and examined. The models are ARMA (2,2), ARMA (2,3), ARMA (3,1), ARMA (3,2) and ARMA (3,3). In this stage, all of the ARMA models are being evaluated using the value of Mean Square Error (MSE), Mean Absolute Percentage Error (MAPE) and several criteria which includes the R-squared, Ljung-Box Q statistic, p-value of Ljung Box, the Normalized Bayesian Information Criterion (BIC) and Durbin Watson are being calculated in this stage to determine which of the ARIMA model fits the best. The value obtained from the evaluation are as follows in Table 2 and Table 3.

Table 2: Statistics value for Negeri Sembilan

Statistics	Model				
	ARMA(2,2)	ARMA(2,3)	ARMA(3,1)	ARMA(3,2)	ARMA(3,3)
MSE	2,124,189.65	2,176,816.96	2,370,981.99	2,176,489.44	2,228,147.32
MAPE	4.657	4.628	4.791	4.629	4.582
R-Squared	0.187	0.188	0.093	0.188	0.191
Ljung-Box Q Statistics	11.233	11.761	16.589	11.788	11.120
p-value of Ljung-Box	0.668	0.547	0.264	0.545	0.519
Normalized BIC	14.999	15.109	15.109	15.109	15.219
Durbin Watson	1.896	1.864	1.921	1.893	1.853

It can be concluded that both Negeri Sembilan and Melaka does not contain the presence of a seasonal pattern. ARIMA approach consists of three main stages. Firstly, in model identification using ACF and PACF. Next, Augmented Dickey-Fuller (ADF) helps in evaluating the stationary of the data and from the result, both shows that Negeri Sembilan and Melaka are stationary and does not need differencing. Next, in model identification through measurement of Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE), five ARMA models for both Negeri Sembilan and Melaka state is assumed and examined to perform validation and diagnostic test. In model validation, the best fit model is determined by the lowest MSE, MAPE, Ljung-Box Q Statistics, Normalized BIC, highest R-squared and Durbin Watson value of near 2. Lastly, for model application, this study shows that ARMA (2,2) and ARMA (3,1) models are the best to analyze the solid waste generation in Negeri Sembilan and Melaka respectively. At the same time, model parsimony is also considered in determining the best model.

Table 3: Statistics value for Melaka

Statistics	Model				
	ARMA(2,2)	ARMA(2,3)	ARMA(3,1)	ARMA(3,2)	ARMA(3,3)
MSE	5,157,454.63	4,980,413.48	5,108,061.05	5,237,369.56	5,077,221.19
MAPE	6.846	7.373	6.880	6.923	7.261
R-Squared	0.172	0.221	0.180	0.181	0.227
Ljung-Box Q Statistics	4.251	4.921	4.086	4.200	4.168
p-value of Ljung-Box	0.994	0.977	0.995	0.989	0.980
Normalized BIC	15.886	15.937	15.876	15.987	16.042
Durbin Watson	1.584	1.550	2.073	1.546	1639.000

4.5 *Forecasting using ARMA*

As all models are stationary and no differentiation is needed, thus the best model to forecast the solid waste generation in Negeri Sembilan and Melaka become ARMA (2,2) and ARMA (3,1) respectively.

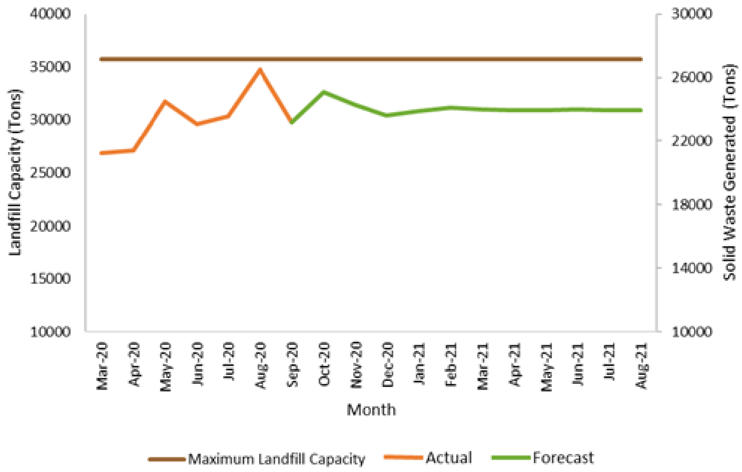


Figure 6: Estimated solid waste generation in Negeri Sembilan

Figure 6 shows the estimated solid waste generation in Negeri Sembilan from September 2020 to August 2021. The values are obtained by forecasting using ARMA (2,2) model. The maximum capacity of the landfill in Negeri Sembilan is 1,190 tons per day. This is equivalent to about 35,700 tons per month. Comparing the estimated solid waste generation in Negeri Sembilan and the landfill maximum capacity, the landfill might not be able to accommodate the solid waste generation in Negeri Sembilan in the future. Looking at the forecast value, the average of solid waste generated from September 2020 to August 2021 is equal to 23,989.58 tons. This already comprised two-thirds of the maximum landfill capacity every month.

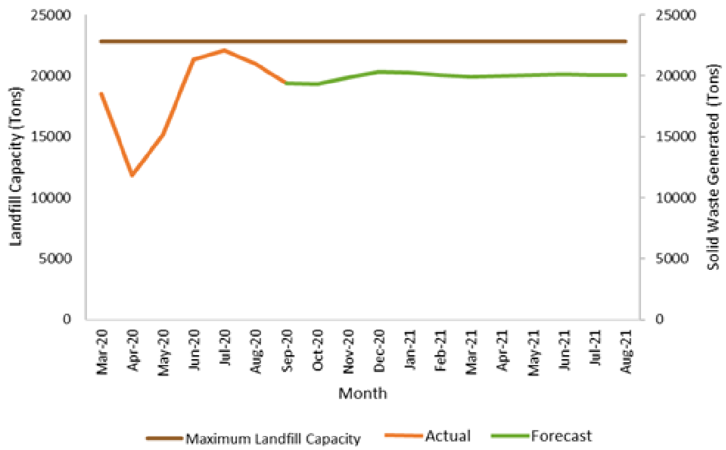
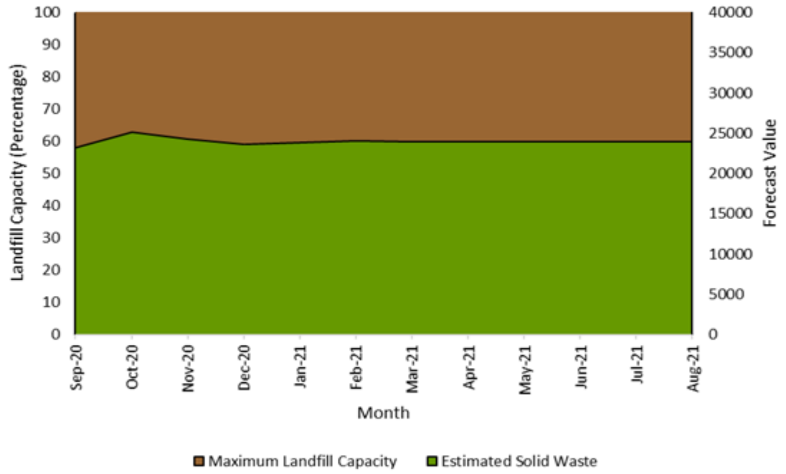


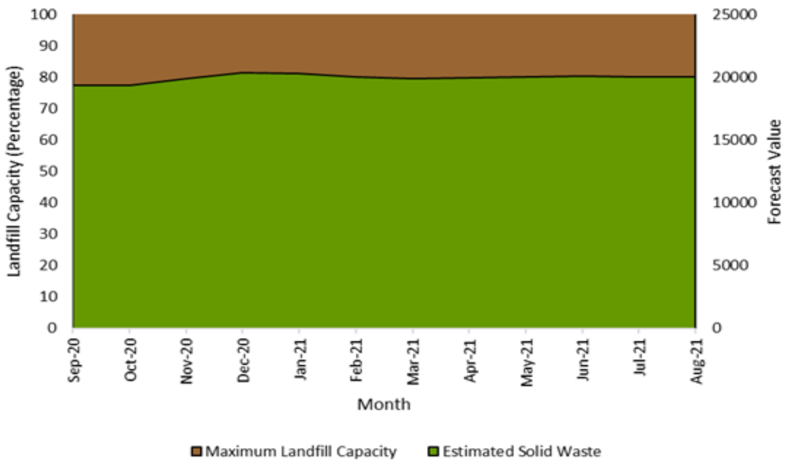
Figure 7: Estimated solid waste generation in Melaka

Figure 7 shows the estimated solid waste generation in Melaka from September 2020 to August 2021. The values are obtained by forecasting using ARMA (3,1) model. The maximum capacity of the landfill in Melaka is 760 tons per day. This is equivalent to about 22,800 tons per month. Every month, the estimated solid waste generation in Melaka is approaching the maximum capacity of waste that can be accommodated by Melaka's landfill. Looking at the forecast value, the average of solid waste generated from September 2020 to August 2021 is equal to 19,967.37 tons. This already comprised about 88 percent of the maximum landfill capacity every month.

ARMA (2,2) and ARMA (3,1) is used to forecast the solid waste generation in Negeri Sembilan and Melaka respectively. Result indicates that the estimated solid waste generation in each state is nearly consuming the whole landfill capacity. Figure 8 shows the consumption of estimated solid waste generation on landfills in Negeri Sembilan and Melaka. The estimated solid waste generation in each state is reaching the maximum capacity of the landfills in both states respectively. From the graph, the estimated solid waste generation in Negeri Sembilan consumed more than 50 percent of its landfill capacity while in Melaka, it is more than 70 percent. It can be concluded that the landfill in each state is nearly full and that is only for one year. Imagine what will happen in several years ahead. In short, appropriate measures should be applied to avoid overflow of solid waste in both states.



(a)



(b)

Figure 8. Consumption of solid waste in Negeri Sembilan (a) and Melaka (b)

5. Conclusion and Recommendation

This study shows the application of ARIMA model in forecasting the solid waste generation in Negeri Sembilan and Melaka for the next one year. The data used for this study is from January 2017 until August 2020. ARMA (2,2) and ARMA (3,1) models are selected respectively for Negeri Sembilan and Melaka as the model to forecast the future amount of solid waste generation. Through this study, the solid waste generation for the next one year is expected to reach the maximum capacity of the landfill area. Since the estimated solid waste generation for both states is approaching the maximum landfill capacity, it is worrisome that no more landfills will be able to accommodate the solid waste generation in the future. Moreover, it will pose environmental pollution due to the overload of waste and affect economic growth. Considering that solid waste can become an intractable challenge to developing countries, everyone should take action together in order to reduce solid waste generation in the future and maintain environmental sanitation. Everyone needs to start practicing recycling in daily life to reduce solid waste generation as well as preventing the country from overloaded with waste.

Every party should take several actions to reduce the amount of solid waste generation in the future. In this study, several actions have been recommended. The first action recommended is the restrictions on the use of plastic bags and food containers need to be tightened. In most supermarkets and shopping malls, there are restrictions on the usage of plastics, but only on Saturday. However, the government should give an order to restrict the usage of plastic bags and food containers every day. By doing this, the production of solid waste from plastics can be reduced. The second recommendation is that the government must enforce instructions on the use of grocery bags. Everyone needs to use the groceries bag that they brought from home. Groceries bag is usually easily accessible, washable and organizable. Groceries bag also simplify shopping experiences and eco-friendly than disposable plastics. The government can also ban the use of disposable plastics by increasing the amount of fine. Anyone who throw their rubbish everywhere and not using the grocery bag while shopping should be fined. The policies of law related to solid waste should be improved to discipline the people for better management and production of solid waste. The third recommended action is the awareness of 3Rs in society needs to be increased to save the earth from solid waste. Everyone seems to forget about this important practice. The 3Rs are meant to reduce, reuse and recycle. Reduce is by limiting the items they buy, reuse is by keeping the things that can be used again and the last 'R' is recycling items such as papers, glass bottles and plastics. Recycling bins are differentiating by three colors. The blue recycle bin is for papers only, the brown recycle bin is for glass only and the orange recycle bin is for cans and plastics. Solid waste segregation should be practiced from the beginning at home. Finally, this study is recommended to use a large amount of data in order to improve the forecast period in the future and to get the best forecast values.

References

Abd Hamid K.B., Ishak M.Y. & Abu Samah M.A. 2015. Analysis of municipal solid waste generation and composition at administrative building cafe in Universiti Putra Malaysia: A case study. *Polish Journal of Environmental Studies* **24**(5): 1969-1982.

Aja O.C. & Al-Kayiem H.H. 2014. Review of municipal solid waste management options in Malaysia, with an emphasis on sustainable waste-to-energy options. *Journal of Material Cycles and Waste Management* **16**(4): 693–710.

Akyen T., Boye C. & Ziggah Y. 2016. Municipal solid waste estimation and landfill lifespan prediction-A case study. *4th UMaT Biennial International Mining and Mineral Conference*, pp. GG127-133.

Al-Salem S., Al-Nasser A. & Al-Dhafeeri A. 2018. Multi-variable regression analysis for the solid waste generation in the state of Kuwait. *Process Safety and Environmental Protection* **119**: 172–180.

Ceylan Z., Bulkan S. & Elevli, S. 2020. Prediction of medical waste generation using SVR, GM (1, 1) and ARIMA models: A case study for megacity Istanbul. *Journal of Environmental Health Science and Engineering* **18**(2): 687-697.

CheAzmi N.A. 2018. Our attitude can save the environment. *New Straits Times*. https://www.nst.com.my/opinion/letters/2018/12/437694/our-attitude-can-save-environment (20 November 2020).

Chua H., Bashir M., Tan K. & Chua, H.S. 2019. A sustainable pyrolysis technology for the treatment of municipal solid waste in Malaysia. *AIP Conference Proceedings* **2124**: 020016.

Chung S.S. 2010. Projecting municipal solid waste: The case of Hong Kong SAR. *Resources, Conservation and Recycling* **54**(11): 759–768.

Department of Statistic Malaysia 2019a. Retrieved for Negeri Sembilan. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=dE1BS2RzYnZFclA3SVhTTS84WDl2UT09 (22 October 2020).

Department of Statistic Malaysia 2019b. Retrieved for Melaka. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=TmlOYTJZTEJJZXg5QUZQMUxrRVFKUT09 (22 October 2020).

Ferronato N. & Torretta V. 2019. Waste mismanagement in developing countries: A review of global issues. International *Journal of Environmental Research and Public Health* **16**(6):1060.

Hoque M.M. & Rahman M.T.U. 2020. Landfill area estimation based on solid waste collection prediction using ann model and final waste disposal options. *Journal of Cleaner Production* **256**: 120387.

Hyndman R.J. 2014. Measuring forecast accuracy. In. M. Gilliland, L. Tashman. & U. Sglavo (Eds.). *Business Forecasting: Practical Problems and Solution*: 177–183. North California, USA: John Wiley & Sons.

Ismail S.N.S. & Latifah A. 2013. The challenge of future landfill: A case study of Malaysia. *Journal Toxicology and Environmental Health Sciences (JTEHS)* **5**(3): 2400–2407.

Kumar M. & Anand M. 2014. An application of time series arima forecasting model for predicting sugarcane production in India. *Studies in Business and Economics* **9**(1): 81–94.

Mahidin M.U. 2020. Current population estimates, Malaysia 2020. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=OVByWjg5YkQ3MWFZRTN5bDJiaEVhZz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09 (2 September 2020).

Makridakis S., Wheelwright S.C. & Hyndman R.J. 2008. *Forecasting Methods and Applications*. New York: John Wiley & Sons.

Momani P. & Naill P. 2009. Time series analysis model for rainfall data in Jordan: Case study for using time series analysis. *American Journal of Environmental Sciences* **5**(5): 599-604.

National Solid Waste Management Department. 2015. https://www.kpkt.gov.my/resources/index/user_1/Attachments/hebahan_slider/slaid_dapatan_makmal.pdf (18 August 2020).

Omran A., Mahmood A. & Aziz H.A. 2007. Current practice of solid waste management in Malaysia and its disposal. *Environmental Engineering & Management Journal* **6**(4): 295-300.

Owusu-Sekyere E., Harris E. & Bonyah E. 2013. Forecasting and planning for solid waste generation in the Kumasi metropolitan area of Ghana: An ARIMA time series approach. *International Journal of Sciences* **2**(4): 69-83.

Palachy S. 2019. Detecting stationarity in time series data. https://towardsdatascience.com/detecting-stationarity-in-time-series-data-d29e0a21e638 (13 August 2020)

Pariatamby A. 2017. Country chapter: State of the 3Rs in Asia and the Pacific. Kanagawa: United Nations Centre for Regional Development (UNCRD). https://www.uncrd.or.jp/content/documents/5691[Nov%202017]%20Malaysia.pdf .(18 August 2020)

Samsudin M.D.M. & Dona M.M. 2013. Municipal solid waste management in Malaysia: Current practices, challenges and prospect. Jurnal Teknologi **62**(1): 95-101.

Sriploy S. & Lertpocasombut K. 2020. Industrial wastes to wastes disposal management by using Box Jenkins-ARIMA models and created applications: Case study of four waste transport and disposal service providers in Thailand. *EnvironmentAsia* **13**(1): 124-139.

Sun N. & Chungpaibulpatana S. 2017. Development of an appropriate model for forecasting municipal solid waste generation in Bangkok. *Energy Procedia* **138**: 907–912.

Younes M.K., Nopiah Z.M., Basri N.A., Basri H. Abushammala M.F. & Younes M.Y. 2016. Landfill area estimation based on integrated waste disposal options and solid waste forecasting using modified anfis model. *Waste Management* **55**: 3–11.

Zafra C., Ángel Y. & Torres, E. 2017. ARIMA analysis of the effect of land surface coverage on PM10 concentrations in a high-altitude megacity. *Atmospheric Pollution Research* **8**(4): 660-668.

Zulkipli F., Nopiah Z.M., Basri N.E.A., Kie C.J. & Januri S.S. 2017. Multilinear regression analysis on solid waste generation quantity in Malaysia towards sustainable development. *International Journal of Advanced and Applied Sciences* **4**(9): 46–52.

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