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Trend Analysis for Organic Waste Generation at the Administration Cafe of UiTM Tapah Campus

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ABSTRACT

Decomposable organic waste is recognized as one of the main components of waste comprising between 42% to 80.2% of its composition. Organic waste is any biodegradable material originating from either plants or animals and the volume generated is expected to increase in the near future. This study examines a better prediction model for determining the trends in organic waste generation at the administration café of the UiTM Campus in Tapah. The data for organic waste generation was collected and recorded daily from two stalls at the café. The collection process was undertaken over five working days (Monday - Friday) from 4th March to 20th April 2019. The Least Square and Simple Moving Average Models were performed in this study. It was found that the Simple Moving Average Model was superior to the Least Square Model as it yielded consistently lower Root Mean Square Error (RMSE), Mean Square Error (MSE) and Mean Absolute Deviation (MAD) values. The Moving Average showed that the upward and downward trends in organic waste over time and the trend cycle were smoother than the original data.

Keywords: *Organic Waste Generation; Solid Waste Management; Least Square Model; Simple Moving Average Model.*

1. INTRODUCTION

Waste management is the process of managing waste to achieve a sustainable environment. It includes general procedures such as the collection, transportation, processing and disposal of residues in an economical and environmentally efficient way [1]. Solid waste management is one of the three major environmental issues in Malaysia due to the tremendous increase in the volume of waste being generated annually. It is influenced by rapid population growth, urbanization process, and changing lifestyles in many countries worldwide [2, 3]. As such, it is important for solid waste organizations to establish reliable predictions for the amounts of solid waste being generated [1].

Malaysia's average waste generation per capita is 1.17 kg/day with a population density of 327 million [4]. The annual generation rate is projected to increase by 3.3% in 2003 in line with the increase in electricity demand [5]. In 2019, the government spent RM1.2 billion on waste collection as Malaysians discarded about 33,000 metric tons (MT) of waste daily. Kuala Lumpur averaged 1.25 kg/person compared to the national average of 0.8 kg/person. It is recommended that each individual not exceed 0.8 kg of waste produced per day in order to achieve the national agenda of becoming an environmentally sustainable country set in 2020 [6]. Currently, almost 85% of waste collected in Malaysia is disposed of in landfills. The

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government expects about 49,670 MT per day of waste to be generated by Malaysians in the year 2020 [4]. Waste minimization must be practised by all individuals in order to increase the lifespan of landfills, ensure a greener environment, and manage climate changes [2].

At about 42% to 80% of the total, decomposable organic waste is one of the main components of waste. Types of waste include paper, plastic, cloth, metals, glass, ash, and others [7]. Organic waste is any material that is biodegradable and comes from either a plant or an animal. It includes green waste, food waste, food-soiled paper, non-hazardous wood waste, and landscape and pruning waste. Biodegradable waste is organic material that can be broken into carbon dioxide, methane, or simple organic molecules. The increase in waste generation has resulted in carbon dioxide (CO2) emissions per capita in Malaysia rising by 57.4% from 5.42 MT in 2000 to 8.53 MT in 2016 [8].

Most solid waste generated in the urban areas of many developing countries comprises biodegradable organics. For instance, such waste was 65% of the total in Jakarta [9] and 72.41% in Surabaya [10] whereas in developed Asian countries such as Japan, Singapore, Taiwan, and South Korea it was less than 45% [11]. In Malaysia, decomposable organics formed 61.5% of total solid waste generated [12]. For 2012, of the solid waste generated in Malaysia, 44.5% comprised of organic waste, followed by plastics (13.2%), diapers (12.1%), paper (8.5%), garden waste (5.8%), glass (3.3%), textile (3.1%), and other wastes (5.8%) [4, 13]. Figure 1 shows the composition of Malaysian waste generation. [14].

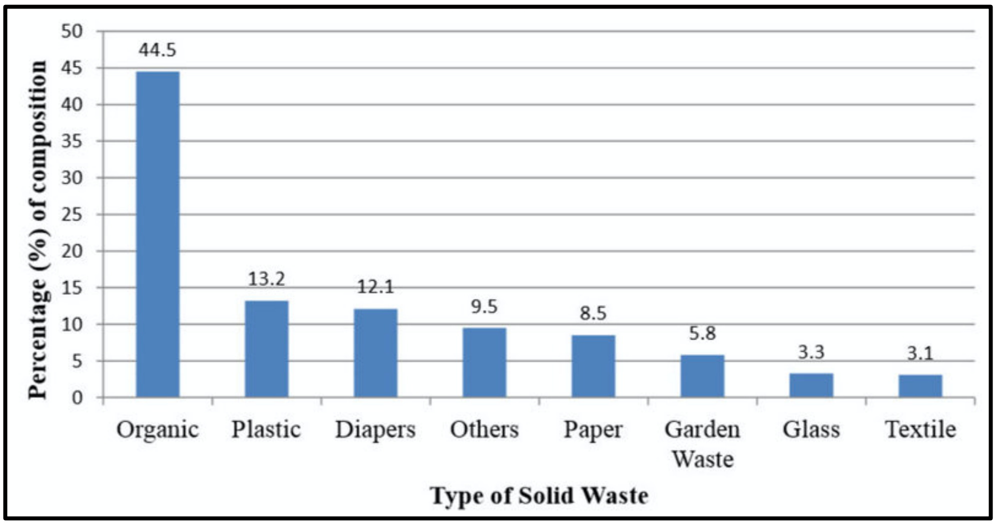

Figure 1: Waste Composition in Malaysia, 2012

In general, solid waste generation models can be grouped into two classes, namely descriptive and predictive. There are various models for forecasting short and long term waste quantities [15]. According to [16, 17], forecasting the quantity of organic waste generation is essential and is an important element in the planning, designing and operations of waste management systems. Thus, a reliable dataset on waste composition and generation must be developed to support the implementation of waste minimization programmes in Malaysia [18].

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Forecasting models used in a study by [19], revealed that the Simple Moving Average is the best fit for organic waste generation modelling due to the smallest values of Root Mean Square Error (RMSE), Mean Square Error (MSE), and Mean Absolute Deviation (MAD) compared to Double Exponential Smoothing, Single Exponential Smoothing, Holt-Winter's Additive, and Double Moving Average. This study seeks to identify a better prediction model for trend analysis and to determine the trend in organic waste generation at the administration café of the UiTM Tapah Campus using the Least Square and Simple Moving Average Models.

2. METHODOLOGY

2.1 Source of Data

A time series dataset is used in this study comprising the quantity (in kg) of organic waste generated at the administration café in UiTM Tapah Campus. The types of organic waste included in this study were vegetables, fruits and foods generated from two stalls at the café operating from 7.30am to 4pm.

The data was primarily collected and recorded daily after the stalls closed their operations. The weight of the wastes in each bin measured using a digital scale and recorded in a form by the researchers. The collection process covered five working days (Monday - Friday) from 4th March until 20th April 2019 (seven weeks). A garbage bin and plastic bags were provided for every stall and the owners and workers of the stalls were briefed before the data collection process began. The data collection process is illustrated in Figure 2.

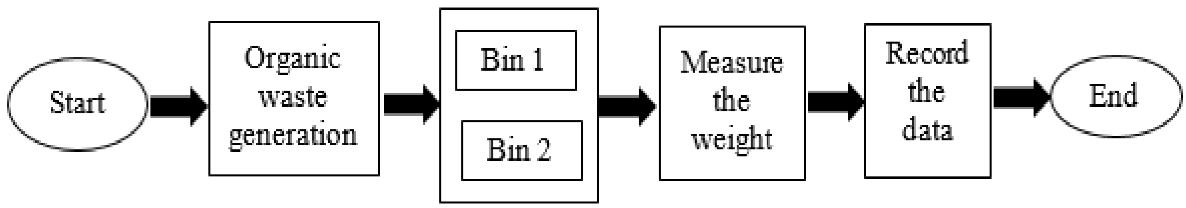

Figure 2: Data Collection Process

2.2 Procedures of Analysis

The independent and dependent variables for this study are time (days) and amount of organic waste collected (in kg), respectively. Two analyses performed in this study using Least Square Simple Moving Average Model. Then, a better model was selected based on smaller values of RMSE, MSE and MAD to describe the trends in organic waste generation.

2.2.1 Estimation Trend using Least Square Model

The Least Square Model is employed to obtain the line of the best fit from the data [20]. Besides, it can also generate an equation of the Least Square line that helps in forecasting future organic waste generation. The general linear trend pattern is described using the equation (1).

$$Y_t = \alpha + \beta t + \varepsilon_t \tag{1}$$

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where
Y_t is the value of the dependent variable at time t
t is the time variable
α is the estimated trend at time zero (intercept)
β is the slope parameter
ε_t is the error term usually assumed as identically, independently and normally distributed with mean zero and variance σ_e^2.

As the respective estimated values are obtained, equation (1) can now be written as (2),

$$\hat{Y}_t = \hat{\alpha} + \hat{\beta} t \tag{2}$$

2.2.2 Estimation Trend using Simple Moving Average Model

The Simple Moving Average is a technique where the data trend is best represented by mean values of past observations. These trend results are obtained when a series of values move from one time period to the next, over the entire period covered by the data series. The general formula for the Simple Moving Average is shown in (3) below. This study applied a 5-period moving average since the time measured is in five working days. An example of the trend calculation for the first two weeks is shown in Table 1.

$$M_t = \frac{y_t + y_{t+1} + y_{t+2} + \ldots + y_{t+(n-1)}}{n} \tag{3}$$

where
y_t is the actual value in time t
n is the number of terms included in the moving average

Table 1: Trend Calculations using the Simple Moving Average for Two Weeks.

Week	Time (days)	y_t	Trend, M_t
1	Monday	y_1	-
	Tuesday	y_2	-
	Wednesday	y_3	$M_1 = \frac{y_1 + y_2 + y_3 + y_4 + y_5}{5}$
	Thursday	y_4	$M_2 = \frac{y_2 + y_3 + y_4 + y_5 + y_6}{5}$
	Friday	y_5	$M_3 = \frac{y_3 + y_4 + y_5 + y_6 + y_7}{5}$
2	Monday	y_6	$M_4 = \frac{y_4 + y_5 + y_6 + y_7 + y_8}{5}$
	Tuesday	y_7	$M_5 = \frac{y_5 + y_6 + y_7 + y_8 + y_9}{5}$

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Wednesday	y_8	$M_6 = \frac{y_6 + y_7 + y_8 + y_9 + y_{10}}{5}$
Thursday	y_9	-
Friday	y_{10}	-

2.2.3 Error Measures

This study employed three types of Error Measures namely Root Mean Square Error (RMSE), Mean Square Error (MSE), and Mean Absolute Deviation (MAD) to determine a better fitted forecasting model. A prediction model with lower RMSE, MSE and MAD considered a better means for forecasting purposes. The formulae for these Error Measures are shown in (4), (5), and (6).

a) RMSE

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}\right)^2}\ ,\quad i = 1,2,3,\ldots,n \tag{4}$$

where
Y_i is the actual value for period i
$\hat{Y}$ is the predicted value for period i
n is the number of periods

b) MSE

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}\right)^2\ ,\quad i = 1,2,3,\ldots,n \tag{5}$$

where
Y_i is the actual value for period i
$\hat{Y}$ is the predicted value for period i
n is the number of periods

c) MAD

$$MAD = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}\right|\ ,\quad i = 1,2,3,\ldots,n \tag{6}$$

where
Y_i is the actual value for period i
$\hat{Y}$ is the predicted value for period i
n is the number of periods

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3. RESULTS AND DISCUSSIONS

3.1 Descriptive Statistics

As seen in Table 2, the mean of organic waste collection was 3.53 kg. It means that, on average, organic waste generation was 3.53 kg for the two week period. The minimum amount of collection was 0.42 kilograms while the maximum was 6.80 kilograms.

Table 2: Descriptive Statistics

Variable	Mean	Minimum	Maximum
Organic waste (kg)	3.53	0.42	6.80

3.2 Results of Trend Estimation using Least Square Method

The linear equation for this data is shown in (7) below.

$$\hat{y} = 3.771 - 0.013t \tag{7}$$

where
$\hat{y}$ is the amount of organic waste at time t
t is the time variable (in days)

This Least Square equation is useful in forecasting values for the amount of organic waste generated in the future. The estimation can be changed as the time frame changes. Based on equation (7), the slope is -0.013, that is if time increase by 1 day, the weight of organic waste can be expected to decrease by 0.013 kg. The obtained intercept is 3.771, meaning that if the time is zero, the weight of organic waste can be forecast to be about 3.771 kg. The trend values obtained using Least Square Method show a downward trend in organic waste against time (Table 3).

Table 3: Trend Results using Least Square Method

Week	Day	Trend, $\hat{Y}$	Week	Day	Trend, $\hat{Y}$
1	Monday	3.721	5	Monday	3.757
	Tuesday	3.757		Tuesday	3.733
	Wednesday	3.733		Wednesday	3.741
	Thursday	3.733		Thursday	3.714
	Friday	3.706		Friday	3.703
2	Monday	3.709	6	Monday	3.765
	Tuesday	3.737		Tuesday	3.760
	Wednesday	3.734		Wednesday	3.735
	Thursday	3.719		Thursday	3.721
	Friday	3.738		Friday	3.735
3	Monday	3.720	7	Monday	3.749
	Tuesday	3.720		Tuesday	3.721
	Wednesday	3.681		Wednesday	3.712
	Thursday	3.699		Thursday	3.715

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	Friday	3.720		Friday	3.726
4	Monday	3.688			
	Tuesday	3.722			
	Wednesday	3.700			
	Thursday	3.710			
	Friday	3.712			

The data is illustrated by constructing a line chart to determine the components that exist in the time series (Figure 3). A linear trend component was found in the time series data as a generally downward movement along the linear line can be seen in the line chart.

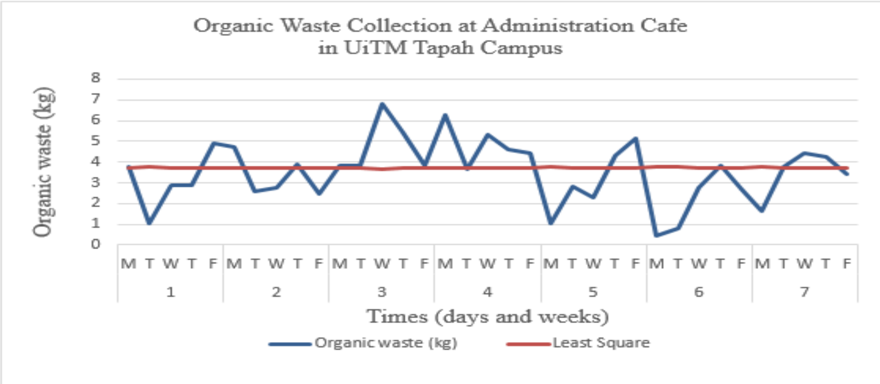

Figure 3: Line chart of Organic Waste (kg) against Time (days and weeks) at Admin Cafeteria in UiTM Tapah

3.3 Results of Trend Estimation using Simple Moving Average

A Moving Average of order 5 is shown in Table 4 which provides an estimate of the trend cycle. There were no values for the first two days in Week 1 and the last two days in Week 7 because there were no two observations on either side. The values for the Simple Moving Average show the upward and downward trend cycles in organic waste generation against time.

Table 4: Results of the Simple Moving Average

Week	Day	Trend, M_t	Week	Day	Trend, M_t
1	Monday	-	5	Monday	3.042
	Tuesday	-		Tuesday	2.986
	Wednesday	3.086		Wednesday	3.132
	Thursday	3.276		Thursday	3.006
	Friday	3.584		Friday	2.598
2	Monday	3.564	6	Monday	2.692
	Tuesday	3.774		Tuesday	2.588
	Wednesday	3.29		Wednesday	2.104
	Thursday	3.12		Thursday	2.346
	Friday	3.366		Friday	2.934
3	Monday	4.174	7	Monday	3.272

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	Tuesday	4.48	Tuesday	3.362
	Wednesday	4.752	Wednesday	3.502
	Thursday	5.234	Thursday	-
	Friday	5.206	Friday	-
4	Monday	4.914		
	Tuesday	4.748		
	Wednesday	4.862		
	Thursday	3.82		
	Friday	3.654		

Figure 4 is depicting the Moving Average in organic waste collection shows that the trend cycle (Moving Average) is smoother than the original data and captures the movement of the main time series.

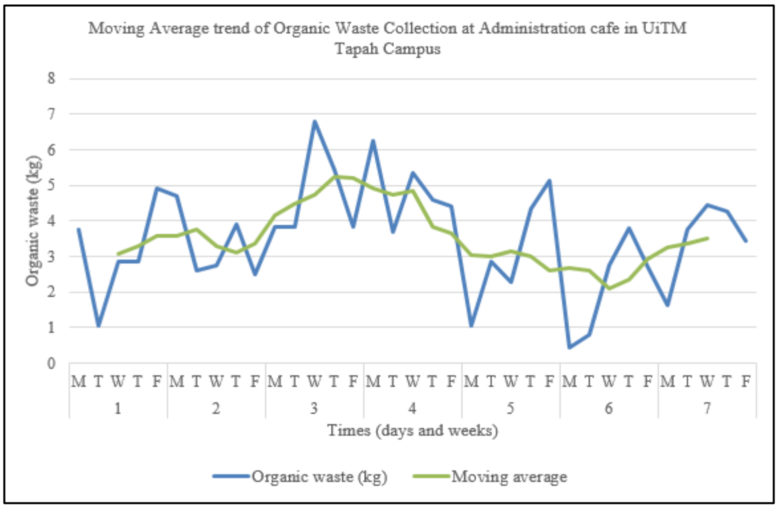

Figure 4: Moving Average chart of Organic Waste (kg) against Time (days and weeks) at Admin Cafeteria in UiTM Tapah

3.4 Results of Error Measures

The best model with the lowest error values is chosen. Table 5 presents the error measure values. The results indicate that the RMSE, MSE, and MAD for the Least Square Method were 1.498, 2.245, and 1.158 while those for the Simple Moving Average were 1.482, 2.198, and 1.083, respectively. It can be seen that the Simple Moving Average Method had consistently lower error measure values compared to the Least Square Method. In conclusion, the Simple Moving Average Method can be deemed the best for predicting organic waste generation at the Administration Café in UiTM Tapah Campus.

Table 5: Results of Error Measures

Trend	RMSE	MSE	MAD
Least Square Method	1.498	2.245	1.158
Simple Moving Average Method	1.482	2.198	1.083

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4. CONCLUSION

The increasing amounts of organic waste generated could lead to adverse and inefficient waste management processes. The limitations in landfill capacity will indirectly cause unbalanced environmental ecosystems. This study shows that compared to the Least Square Model, the Simple Moving Average Model is a better predictor of future waste generation due to its lower RMSE, MSE, and MAD error measures of 1.482, 2.198, and 1.083, respectively. In addition, the trend values of the Simple Moving Average Model, indicates the upward and downward trends in organic waste against time. Also, the trend cycle is smoother than the original data and captures the main movement of the time series. It is hoped that this research will be a valuable contribution to the literature on forecasting and analyzing time series data. This will help enhance awareness of the factors involved in waste disposal and increase the efficiency of organic waste management processes in the future.

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