The Impact of Economic Class on Solid Waste Generation Pattern in Capital City of Kuala Lumpur, Malaysia

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Abstract: Solid waste management has been recognized as the crucial urban environmental problem in Malaysia. In order to ameliorate waste management, it is essential to know the quantity of waste generated and the elements contributing to the generation of waste. This study was conducted to determine the association between socioeconomic factors and solid waste generation in Kuala Lumpur, to analyse the class of income that contribute the highest contribution of solid waste generation and to propose mitigation plan to local authority in controlling waste production in the study area. In this paper, the socioeconomic factors that lead to waste generation in Kuala Lumpur are presented. A seventeen years (2000-2017) secondary database obtained from the Department of Statistic Malaysia (DOSM), National Solid Waste Management Department (NSWMD) and National Property Information Centre (NAPIC) were statistically analysed by using Chemometric techniques which includes Principal Component Analysis (PCA) and Multiple Linear Regression (MLR). The study revealed that population, household income, GDP per capita, low cost flat, 2-3 storey terraced, town house, 2-3 storey semi-detached and apartment/condominium were positively strong correlated with solid waste generation. PCA analysis indicated that population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, town house, low cost flat, and condominium/apartment were the most potential contributors to waste generation. MLR revealed that population, GDP per capita, household income, high income class and middle-income class were the significant factor towards solid waste generation in Kuala Lumpur. This study gives new insight on the part of socioeconomic parameter in influencing the production of solid waste.

Keywords: Multiple linear regression, PCA analysis, Sosioeconomic, Solid Waste

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I. INTRODUCTION

Waste, trash or garbage is expounded under the Environment Protection Act 1993 as any rejected, precluded, abandoned, unwanted or surplus matter, whether intended for sale or for recycling, reprocessing, recovery or purification by a separate process from that which produced the matter [1]. Solid waste is material that has no use or become invaluable and is being thrown away [2]. According to [3], generation of solid waste per person has tremendously increased by about nearly 50% per person with 1.2 kg of waste per day globally. The solid waste formation in Malaysia is rising annually with approximately 3% to 4% [4]. The waste composition in Malaysia is dominated by municipal solid waste (MSW). Being one of the urban cities in Malaysia, the amount of solid waste generated in Kuala Lumpur is reported to be more than 4000 tonnes per day in the year 2000 [5]. Reference [6] has highlighted several contributing factor of the increasing waste generation in Malaysia that include high rate of population growth, expeditious urbanization, highly dense of urban population and brisk economic growth leading to higher income per capita. In managing solid waste in Malaysia, landfill dump is frequent option compared to other method. According to [7], out of 95% from 75% of waste collected is end up in the landfill. However, most of the landfill available now is reaching to its maximum capacity to hold the solid waste [4]. In addition, several problem arise in managing solid waste, which are population and tourism growth, economic advancement, insufficient waste legislation enforcement, infrastructure and facility and public behaviour toward waste [8]. In order to improve solid waste management, it is essential to know the amount of waste generated and the factor contributing to the waste generation. Increasing population, urbanization growth and economic growth are reported to be main contributing factor of solid waste generation [6]. Therefore, this study is intended to investigate on how the socioeconomic factors can contribute to solid waste generation trend.

II. METHODOLOGY

This study used the descriptive study design. The main purpose of this study is to analyse the impact of economic class on solid waste generation in Kuala Lumpur.

Study Area: Federal Territory of Kuala Lumpur or also known as Kuala Lumpur encompasses approximately 243km^2. Waste management in Kuala Lumpur was handled by Kuala Lumpur City Hall as its local municipality and Alam Flora Sdn. Bhd. acted as private concessionaire. The waste collected was transferred to Taman Beringin Transfer Station before final disposal at Bukit Tagar Sanitary Landfill.

Fig 1: Map of Federal Territory of Kuala Lumpur

Data Analysis: Secondary data was utilised in this study and it was obtained from authorized agencies, which are Department of Statistic Malaysia (DOSM), National Solid Waste Management Department (NSWMD) and National Property Information Centre (NAPIC). A seventeen year database (2000-2017) was used in this study and it contained fourteen variables namely population, household income (RM), GDP per capita (RM), single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, detached, town house, cluster, low cost house, low cost flat, flat, condominium/apartment and waste generation (tonnes/day). The variable of housing type used in this study is representing the income level of the household.

Table 1: Socio-economic status and housing stratification matrix

	Low Income	Medium Income	High Income
Landed units	Low cost houses, squatters, kampong and traditional houses	Terrace, town house	Detached, semi-detached
High rise units	Low cost flat	Apartments and condominiums	

To interpret the result, descriptive analysis, correlation test, Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) were applied in this study. The analyses were computed using the XLSTAT 2017 add-in software.

Correlation Test: Correlation test was utilised in this study to identify the affiliation between two variables and the strength of the relationship by the establishment of correlation coefficient, *r*.

Principal Component Analysis: PCA can be applied as it works by forming new variables called principles components (PCs) which are linear composite of the original variables [9]. Sometimes, PCs formed from PCA are not promptly interpreted. Therefore, varimax rotation is necessary to rotate the PCs. PCs with eigenvalues equal or more than 1 is considered to apply varimax rotation on it to acquire new variables called varimax factors (VFs) or factor loading [10]. Varimax factors (VFs) with correlation of 0.30 to 0.49 was considered weak significant factor loading, VFs with correlation 0.50 to 0.74 was assumed as moderate significant factor loading and VFs with correlation of 0.75 and more was classified as strong significant factor loading [10].

Multilinear Regression Analysis: Analyses the relationship between dependent variable and many independent variables and the model aim to create the relationship between a dependent variable and two or more independent variables by fitting a linear equation to observed data as shown in equation 1 below.

$$y_i = b_{0i} + b_{1i}x_1 + b_{2i}x_2 + b_{ni}x_n + .. + b_{ni}x_{n1} + \varepsilon_i \qquad (1)$$

Where y_i is the dependent variable, x_1, x_2, x_n..., are the independent variables, ε_i is the residual term and $b_{0i}, b_{1i}, b_{2i}, \ldots, b_{ni}$ are the regression coefficients [11].

III. RESULT AND DISCUSSION

All available data was analysed with the statistical analyses which include Pearson correlation test, Principal Component Analysis (PCA) And Multiple Linear Regression (MLR).

The association between socioeconomic factors and solid waste generation: Based on the findings obtained from Table 2, there was positive strong correlation between population and solid waste generation ($r=0.99$, $p<0.05$). This finding indicates as population increase, the solid waste generations also increase. In accordance with the present results, previous study also has demonstrated that there was strong positive correlation between population and quantity of solid waste produced [12]. Besides, positive strong correlation was established between household income and solid waste generation ($r=0.96$, $p<0.05$). Therefore, it implies that as household income increases, solid waste generation also increases. This finding was in agreement with [13] which reported that waste generation has a positive correlation with household income. Furthermore, there was positive correlation between GDP per capita and solid waste generation. The coefficient value of 0.98 reflects a strong correlation between GDP per capita and solid waste generation. This was interpreted to mean as GDP per capita increases, solid waste generation also increases. These findings corroborated the ideas of [14] describing that there was a positive correlation between waste generation and GDP per capita.

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Table 2: Pearson's correlation coefficient (*r*) between all variables for seventeen years (2000-2017)

Variables	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	-	**0.94***	**0.96***	-0.72*	**0.90***	**-0.82***	**0.97***	-0.52*	**0.77***	0.14	-0.06	**0.92***	-0.06	**0.94***	**0.99***
B	**0.94***	-	**0.98***	**-0.74***	**0.78***	**-0.85***	**0.90***	**-0.61***	**0.71***	0.04	-0.05	**0.83***	-0.09	**0.91***	**0.96***
C	**0.96***	**0.98***	-	**-0.79***	**0.85**	**-0.79**	**0.93***	-0.57*	**0.81***	0.02	0.04	**0.87***	-0.17	**0.96***	**0.98***
D	-0.72*	-0.74*	**-0.79***	-	-0.60	0.39	-0.70*	0.47*	**-0.83**	0.49*	-0.55*	-0.60*	0.68*	**-0.89***	-0.74*
E	**0.90***	**0.78***	**0.85***	-0.60*	-	-0.63*	**0.96***	-0.23	**0.83***	0.27	0.00	**0.96***	-0.05	**0.88***	**0.90***
F	**-0.82***	**-0.85***	**-0.79***	0.39	-0.63	-	**-0.76***	0.73*	-0.36	-0.37	0.51*	-0.72*	-0.36	-0.63*	**-0.81***
G	**0.97***	**0.90***	**0.93***	-0.70*	**0.96**	**-0.76***	-	-0.42	**0.82***	0.21	-0.03	**0.96***	-0.07	**0.94***	**0.97***
H	-0.52*	-0.61*	-0.57*	0.47*	-0.22	0.73*	-0.42	-	-0.26	0.13	0.14	-0.33	0.02	-0.45	-0.54*
I	**0.77***	0.71*	**0.81***	**-0.83***	**0.83**	-0.36	**0.82***	-0.26	-	-0.21	0.49*	0.74*	-0.55*	**0.91***	**0.81***
J	0.15	0.04	0.02	0.49*	0.27	-0.37	0.21	0.13	-0.21	-	**-0.75***	0.33	**0.84***	-0.10	0.12
K	-0.06	-0.05	0.04	-0.55*	0.00	0.51*	-0.03	0.14	0.49*	**-0.75***	-	-0.11	**-0.97***	0.25	-0.02
L	**0.92***	**0.83***	**0.87***	-0.60*	**0.96**	-0.72*	**0.96***	-0.33	0.74*	0.33	-0.11	-	0.55	**0.88***	**0.93***
M	-0.06	-0.09	-0.17	0.68*	-0.05	-0.36	-0.07	0.02	-	**0.84***	**-0.97***	0.05	-	-0.36	-0.10
N	**0.94***	**0.91***	**0.96***	**-0.89***	**0.88**	-0.64*	**0.94***	-0.45	**0.91***	-0.10	0.25	**0.88***	-0.36	-	**0.96***
O	**0.99***	**0.96***	**0.98***	-0.74*	**0.90**	**0.81***	**0.97***	-0.54*	**0.81***	0.12	-0.02	**0.93***	-0.10	**0.96***	-

Note: * = $p < 0.05$; Bold = $r \geq 0.75$; A=Population, B=Household income, C=GDP per capita, D=Single storey terraced, E=2-3 storey terraced, F=Single storey semi detached, G=2-3 storey semi detached, H=Detached, I=Town house, J=Cluster, K=Low cost house, L=Low cost flat, M=Flat, N=Condominium/Apartment, O=Waste generation.

Low cost flat (low income class) has a significant positive strong correlation of 0.93, 2-3 storey terraced and town house which classified as middle income class show a significant positive strong correlation with coefficient value, r, 0.90 and 0.81 respectively, 2-3 storey semi-detached (high income class) also has the strong positive correlation (r=0.97, p<0.05) and condominium/apartment which lies in between middle income and high income has the strong positive correlation too (r=0.96, p<0.05). The coefficient indicated a positive relationship between some of the housing type according to their class income category and solid waste generation. This finding showed that as housing type improve from low income class to high income class, the solid waste generation also increases. There were similarities between the solid waste generation in this study and those described by [15] which reported as income by different socioeconomic group increases, waste generation also constantly increases. **Principal Component Analysis (PCA)** was used on the database that contain the variables of population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, detached, town house, cluster, low cost house, low cost flat, flat, condominium/apartment and waste generation. Two PCs with eigenvalue more than one (>1.0) that accounted 88.84% of the total variance on the database. Therefore, varimax rotation process was carried out based on the PCs. As for eigenvalue less than 1, it was ignored because of the redundancy with the main factors. Two factor loadings were obtained after varimax rotation which described the 88.84% of the cumulative variance of the data. In this study, factor loadings more than 0.75 were assumed stable and strong loading and be selected for interpretation. In first factor loading (F1), the loading account for 66.62% of the variance. Examining the details, population (0.980), household income (0.955), GDP per capita (0.984), 2-3 storey terraced (0.905), town house (0.842), low cost flat (0.920), condominium/apartment (0.976) and waste generation (0.994) have strong positive factor loadings.

Furthermore, the total variance of second factor loading (F2) was 22.22% with one strong negative factor loading which was for low cost house (-0.971) and two strong positive factor loadings which was for cluster (0.881) and flat (0.980). The plot diagram for factor loading after varimax rotation was shown in Figure 2.

Table 3: Factor loadings after varimax rotation for factors contributing to waste generation in Kuala Lumpur

Variable	F1	F2
Population	**0.980**	0.112
Household income	**0.955**	0.075
GDP per capita	**0.984**	-0.002
Single storey terraced	**0.796**	0.550
2-3 Storey terraced	**0.905**	0.103
Single storey semi detached	**0.779**	-0.514
2-3 storey semi detached	**0.973**	0.105
Detached	0.543	-0.091
Town house	**0.842**	-0.413
Cluster	0.057	**0.881**
Low cost house	0.054	**-0.971**
Low cost flat	**0.920**	0.207
Flat	0.174	**0.980**
Condominium/Apartment	**0.976**	-0.200
Waste generation	**0.994**	0.076
Eigenvalue	10.660	3.555
Variability (%)	66.622	22.220
Cumulative (%)	66.622	88.842

Note: Bold = Factor loading > 0.75

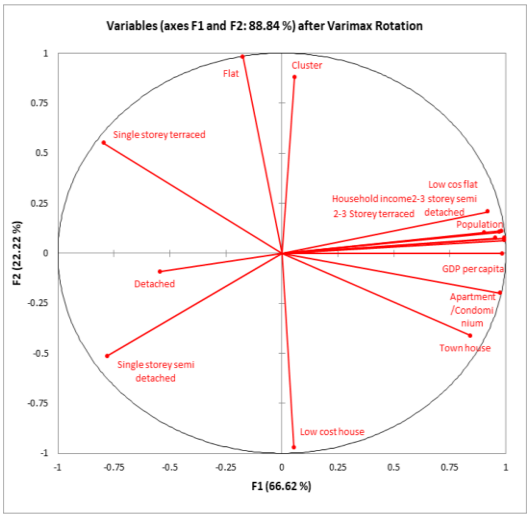

Fig 2: Factor loadings plot after varimax rotation

Thus, population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, town house, low cost flat and condominium/apartment with strong factor loadings in VF1 are classified as the most potential contributors towards waste generation in Kuala Lumpur.

Determinants of Quantity Waste Generation: The waste generation rate and its determinant were further analyzed by **Multilinear Regression Analysis**. The model considered analyzing factors such as population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, detached, town house, cluster, low cost house, low cost flat, flat, and condominium/apartment to describe the waste generation. The multiple linear regression of socio-economic variables and waste generation rate was presented in table 4. The study assessed the relationship between the socio-economic variables and the quantity of waste produced. The socio-economic variables such as population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, detached, town house, low cost flat and condominium/apartment have been found to be significant. The coefficient value of population was positive with value of 0.992 and it was significant. This was interpreted to mean that as population increases, the solid waste generation also increases. With R^2 of 0.983, signifying the variation in solid waste generation is related with population, therefore, 98.3% of the variation in solid waste generation is adjudged by population. In addition, household income had a positive coefficient value of 0.957. This meant solid waste generation increases as level of income increases. With R^2 of 0.916, the solid waste generation account for 91.6% of the variation in household income. As for GDP per capita, it also had positive coefficient value of 0.982 which indicated as economy is growing, the more waste is generated. 96.3% of the variation in the GDP per capita is explained by solid waste generation with R^2 of 0.963. Single storey semi-detached, 2-3 storey semi-detached and detached had a positive coefficient value of 0.811, 0.971 and 0.619 respectively. 2-3 storey semi-detached was found to more influential towards solid waste generation compared to single storey semi-detached and detached. With R^2 of 0.657, 0.943 and 0.363 for single storey semi-detached, 2-3 storey semi-detached and detached respectively, solid waste generation is significant predictors for all of the mentioned high income class housing type. Based on this finding, it was interpreted that people with higher income generate more waste. This finding was contrary to the finding by [16] that implies higher income people generating less waste. Based on table 4, it showed that both 2-3 storey terraced, town house and single storey terraced had a positive coefficient value of 0.904, 0.817 and 0.741 respectively. As for condominium and apartment housing type which lies between high income areas and middle-income areas, it showed a positive coefficient of 0.956. From all of middle-income class house, 2-3 storey terraced and condominium/apartment showed greater relevance to the solid waste generation. The R^2 for both 2-3 storey terraced and condominium/apartment accounted for 0.817 and 0.914 respectively which referring to 81.7% and 91.4% of the variation in solid waste generation is explained by 2-3 storey terraced and condominium/apartment which was considered high and dependable. The finding showed that most of the people living in medium income class house had positive relationship with waste generation which referring to medium income class generates more waste.

Table 4: Multiple linear regression analysis of socio-economic variables and waste generation.

Variables	Coefficient	Std. Error	t	p-value	R^2
Population	0.992	0.033	29.820	<0.0001	0.983
Household income	0.957	0.075	12.790	<0.0001	0.916
GDP per capita	0.982	0.050	19.828	<0.0001	0.963
Single storey terraced	0.741	0.173	4.274	0.0007	0.549
2-3 storey terraced	0.904	0.110	8.187	<0.0001	0.817
Single storey semi detached	0.811	0.151	5.361	<0.0001	0.657
2-3 storey semi detached	0.971	0.062	15.680	<0.0001	0.943
Detached	0.619	0.203	3.052	0.0081	0.383
Town House	0.817	0.149	5.478	<0.0001	0.667
Cluster	0.113	0.257	0.440	0.666	0.013
Low cost house	0.006	0.258	0.025	0.981	0.000
Low cost flat	0.933	0.093	10.060	<0.0001	0.871
Flat	0.106	0.257	0.413	0.685	0.011
Condominium/Apartment	0.956	0.076	12.593	<0.0001	0.914

This finding was in agreement with [17] indicated that middle income group generates more waste due to the fact that middle income had enough money and time for consumption. For low income class house (low cost house, low cost flat and flat), only low cost flat was significant and has a positive coefficient value of 0.933 while low cost house and flat were insignificant with coefficient value of 0.006 and 0.106 respectively. Among these three low income class houses, low cost flat was more decisive variable towards the solid waste generation. With R^2 of 0.871, it indicates that 87.1% of the variation in solid waste generation can be explained by low cost flat. This value was high, thus it was fairly reliable. In conclusion, it was clear from the analysis that population, household income, GDP per capita, high income and middle income class became the significant factor that contribute to the solid waste generation in Kuala Lumpur. By referring to table 3, population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, town house, low cost flat and condominium/apartment were classified as the most potential contributors to solid waste generation in Kuala Lumpur. By conducting multiple linear regression, it narrowed down to see which variable was significant towards the generation of waste and it was concluded the significant factor to solid waste generation in Kuala Lumpur were population, household income, GDP per capita, high income class and middle-income class.

IV. CONCLUSION

Hence, it could be concluded that there were significant association in the socioeconomic factors and solid waste generation in Kuala Lumpur. Some of the socioeconomic variables were significantly positive correlated with solid waste generation, which includes population, household income, GDP per capita, low cost flat, 2-3 storey terraced, town house, 2-3 storey semi-detached and condominium/apartment. PCA analysis indicated that population, household income, GDP per capita, single storey terraced, 2-3 storey terraced, single storey semi-detached, 2-3 storey semi-detached, town house, low cost flat, and condominium/apartment were the most potential contributors to waste generation in Kuala Lumpur.

Multiple linear regression also revealed that population, GDP per capita, household income, high income class and middle-income class were the significant factor towards solid waste generation in Kuala Lumpur. The study concluded that there are variations in the generation of solid waste across different level of economic class.

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