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Research Article

The Development of Predictive Model for Waste Generation Rates in Malaysia

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Abstract: The purpose of this study is to describe the empirical method (statistical method) used to test the predictive model, which was developed for the survey on waste generation. The model used different types of houses such as Bungalow (B), Double Terrace (DT), Low Cost (LC), Flats (FL) and Village Type (VL) as variables. Using the predictive model, a comparison was made against actual data obtained from local authorities and data obtained from estimates manually calculated by the Ministry of Housing and Local Government. This comparison was to establish the accuracy of the prediction and the variation between the waste collected monthly and the predicted value of waste generated. The finding showed that the difference between actual amount of waste collected and the predicted amount was approximately 27%. The explanation from linear regression analysis showed that the quantity of waste generation using predictive model explains 63% of the variables selected for the regression gave good indicators for the analysis of waste generation rates in the study area.

Keywords: Linear regression analysis, Malaysia, predictive modeling, SPSS, waste generation rate, waste management

INTRODUCTION

The prediction of waste generation for waste management is a very important data set to understand the waste distribution in each area and can be used for strategic planning issues. The municipalities can introduce the treatment technologies such as composting, landfill and source reduction and also to understand the potential for material recycling, energy production and compost production.

Using the predictive model will give opportunities to predict waste generation rates, which is important for calculating the need for and size of waste disposal facilities such as landfills (Yu and Maclaren, 1995). Rhyner and Green (1988) agree that accurate projections for quantity of solid waste are essential for the planning of efficient and economical solid waste collection, processing and disposal systems. They also note that the estimates of waste generation rates are used by engineers and planners to determine the type, size, design and location of facilities, the transportation routes from the waste sources to the facilities, personnel needs and equipment requirements. The development of waste generation rates and composition estimation approach is typically the first task of any waste management study (Rhyner and Green, 1988). Niessen (1977) noted that estimates of the present and future waste generation rates are the basis for the design and planning of waste management systems.

Many predictive modelling studies (Brunner and Ernst, 1986; Lund, 1990; Everett and Jacobs, 1992; Movassaghi, 1992; Yu and Mclaren, 1995; Chang and Li, 1997) have been created over the last few decades to assist in developing more efficient waste management programs. The studies vary in their intents, assumption and solution procedures. However, the studies have the ability to provide significant insights into the design of waste management activities. A study by Lohani and Hartono (1985) tried to deal with the estimation of solid waste generation rates by an empirical method. A similar study was done by Rhyner (1992) but it focused more on the seasonal variation. An effort to develop empirical models of estimation of solid waste generation in typical housing dwelling is also found in research by Mohd *et al*. (1993) in a case study in South Johore, Malaysia. Furthermore, Daskolopoulos *et al*. (1998) discussed a prediction methodology for the generation rate and composition for municipal solid waste in the European Union countries and the United States of America. The result showed that the model developed can be used to predict both the future amount and more likely composition of the municipal solid waste stream in a country and that the gross domestic product and population data are available to the policy makers.

Generally, reviews for municipal solid waste generation rates focus more on the estimation of the amount of waste and composition material. The model developed in this study has been done because of the availability of data and information. Limited data and information specifically on waste collected and generation database in Malaysia has been a barrier to the

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Table 1: Variables selected with significance level at 95%

	Unstandardized coefficients		Standardized coefficients		
Model	B	S.E.	β	t	Significance
Constants	2.093	0.166		12.637	0.000
Flats	-0.187	0.041	-0.116	-4.491	0.000
Twopeo	0.332	0.154	0.106	2.157	0.031
Threepeo	0.252	0.144	0.126	1.753	0.080
Fourpeo	0.410	0.142	0.272	2.877	0.004
Fivepeo	0.495	0.151	0.255	3.271	0.001
Sixpeo	0.519	0.152	0.262	3.412	0.001
Sevenpeo	0.812	0.169	0.225	4.812	0.000
Percent working	-0.846	0.131	-0.331	-6.438	0.000
Age 44-59	-0.150	0.042	-0.102	-3.553	0.000
Single	-0.424	0.079	-0.269	-5.391	0.000

S.E.: Standard error; β: Beta

researcher to develop a model and to make comparisons between actual and prediction data. Furthermore, accurate data on waste composition in Malaysia also make it difficult to integrate municipal solid waste management in Malaysia. According to the reviews, the focus of the study is more to develop the predictive model to find the waste generation rate and waste composition. This study focuses to develop a predictive modeling for waste generation rate according to the waste demography based on Malaysian context such as life style, culture and etc. The discussion on this study tries to identify and explain a state of the art review for waste management models in general and will focused specifically on predictive model, which is the main issue highlighted for this research.

MATERIALS AND METHODS

Model development:

Statistical relationships: The relationship for determining the waste generation rate for Municipal Solid Waste (MSW) is derived by statistical analysis using the linear regression analysis of the following form:

$$Y = \beta_0 + \beta_1 (\chi_1) + \beta_2 (\chi_2) + \beta_3 (\chi_3) + \dots + \beta_n (\chi_n)$$

In which

y : The dependent variable of MSW generation (kg/day)

β_0 : Constant

$\beta_1, \beta_2, \beta_3, \dots, \beta_n$: Coefficients

$\chi_1, \chi_2, \chi_3, \dots, \chi_n$: Independent variables

Out of 20 variables selected during the household survey that was analyzed, only 10 of them were really significant. Table 1 shows the coefficient among the variables with 95% as the highest level of significance. The variables included types of flats such as flat, apartment, condominium and shop house, followed by the number of people in a household, for example, two people, three people, four people, five people, six people and seven people. The percentage of working people was also a very significant variable. Households with members older than 44 years played significant roles in the waste generation rate. Single status of household was also an important variable in the waste demographic to see a correlation between status and waste generated.

RESULTS AND DISCUSSION

Waste generation model based on demographic characteristic variables: According to multiple linear regression analysis, a predictive model for waste generation in the study area has been identified and developed as:

Model developed:

$$Y = \beta_0 + \beta_1 \text{(Flats)} + \beta_2 \text{(Twopeo)} + \beta_3 \text{(Threepeo)} + \beta_4 \text{(Fourpeo)} + \beta_5 \text{(fivepeo)} + \beta_6 \text{(sixpeo)} + \beta_7 \text{(sevenpeo)} + \beta_8 \text{(percent)} + \beta_9 \text{(age40)} + \beta_{10} \text{(single)}$$

Note:

Y = Dependent variable of MSW generation (kg/day)

β_0 = Constant

$\beta_1, \beta_2, \beta_3, \dots \beta_{10}$ = Coefficients

Flats, twopeo, threepeo,.. Single = Independent variables

The result of multiple linear regression analysis of the study area by the predictive model (1) is presented in the following equation:

Model equation:

$$Y = 2.093 - 1.906 \text{ (flats)} + 2.425 \text{ (twopeo)} + 2.345 \text{ (threepeo)} + 2.503 \text{ (fourpeo)} + 2.588 \text{ (fivepeo)} + 2.612 \text{ (sixpeo)} + 2.905 \text{ (sevenpeo)} - 1.247 \text{ (percent)} - 2.2434 \text{ (age40)} - 1.669 \text{ (single)} \quad (1)$$

The results of this Eq. (1) yielded a high significant regression with r^2 of 0.63 and with an overall F-ratio of 116.34 (Fig. 1). The relationship was significant at the 95% level and it showed that the coefficient of standard error of the estimate was moderate with 0.450. Apart from this, it shows that 63% of the variables selected

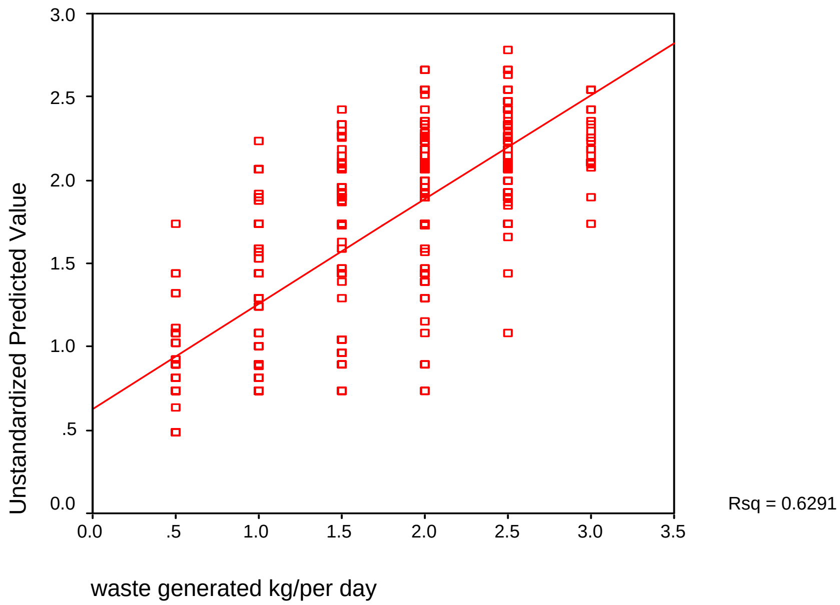

Fig. 1: Shows the scatter plot of waste generation data with a linear model fitted using predictive model (1)

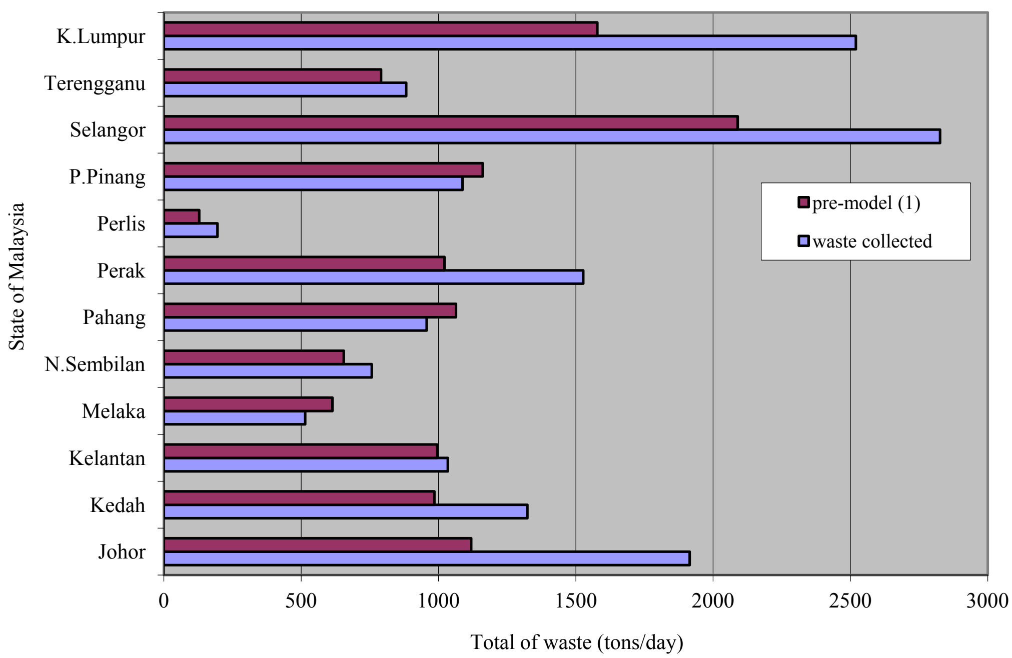

Fig. 2: Variation of waste collected (actual data) and waste predicted using predictive model (1) for the state of Malaysia

for the regression gave good indications for the analysis of waste generation rates in the study area. For example, according to the equation, it is clear that an increase in the number of types of residential flats would increase the MSW generation rate to 1.906 kg/day.

The number of people still shows as a good predictor for waste generation rate for future purposes. The strong correlation between population and the generation of waste in this study are similar to the findings of research (Mohd *et al*., 1993; Daskolopoulos *et al*., 1998). But in this study, other waste demographic variables which were used to identify showed strong correlations and are good predictors of waste generation rates in Malaysia. For example, the types of flats such as flat (low cost), apartment (medium cost), condominium (luxurious) and shop house showed a negative correlation effect with waste generation but still significant enough.

The implementation of predictive model for waste generation: Based on the model developed using the variables from the household survey and equation formulated in Eq. (1), a comparison was made. Figure 2 shows the predicted amounts of MSW in 2010 was 12,201.61 tons/day, compared to actual waste collected from every state for that year, which was 15,540.82 tons/day (MOHLG, 2011). The difference between the predicted and the actual amount of MSW collected by local authorities was approximately 27% or 3,339.21 tons/day.

But the comparison between the amount of waste collected (actual data) and the estimated value using the manual calculation based on population indicator with assumption of waste generation rate of 1.5% annually showed that the amount was approximately 78% higher. Total amount of estimated waste for the states of Malaysia was 27,662.76 tons/day, but the actual waste collected was 15,540.82 tons/day. Table 2 shows the actual amount of waste collected compared to the estimated amount using manual calculation. Figure 3 also shows the variation between the actual waste collected and waste predicted using manual calculation (by Ministry of Housing and Local Government) based on population indicator.

The comparison between the waste collected, waste predicted by manual calculation and waste predicted used predictive model (1) showed very large differences between them (Fig. 4). As mentioned above, the difference between the actual amount of waste collected and the amount of waste predicted using manual calculation was 78% higher than when compared to actual amount waste collected and the amount of waste using the predictive model (1) was only 27%. In this case, it was found that using the predictive model (1) was more accurate than using the manual calculation based on population, which is currently used by the Ministry of Housing and Local Government, where the difference was very much higher. In this case, it was found that manual calculation was not an accurate method to predict waste generation in Malaysia. Field (2000) noted that the model developed was useful and practical in making predictions because the results were accurate. The results for waste prediction and waste collection using the predictive model (1) for all the states in Malaysia also showed that the difference in totals was very small (Fig. 2).

Table 2: Comparison between waste collected (actual data) and waste estimated using manual calculation in Malaysia, 2010

State of Malaysia	Waste collected (tons/day)	Waste predicted * (tons/day)
Johor	1914.95	4110.94
Kedah	1323.67	2474.63
Kelantan	1034.25	1969.52
Melaka	514.560	953.690
N. Sembilan	757.010	1289.89
Pahang	957.100	1932.56
Perak	1527.09	3076.85
Perils	195.500	306.670
P. Pinang	1087.55	1970.17
Selangor	2826.47	6283.31
Terengganu	882.670	1348.24
Kuala Lumpur	2520.00	1946.289
Total	15,540.82	27,662.76

Ministry of Housing and Local Authority (2011); *: The data present a forecast of daily waste generated per state for the year 2010 based on annual rate increase 1.5 kg/person/day

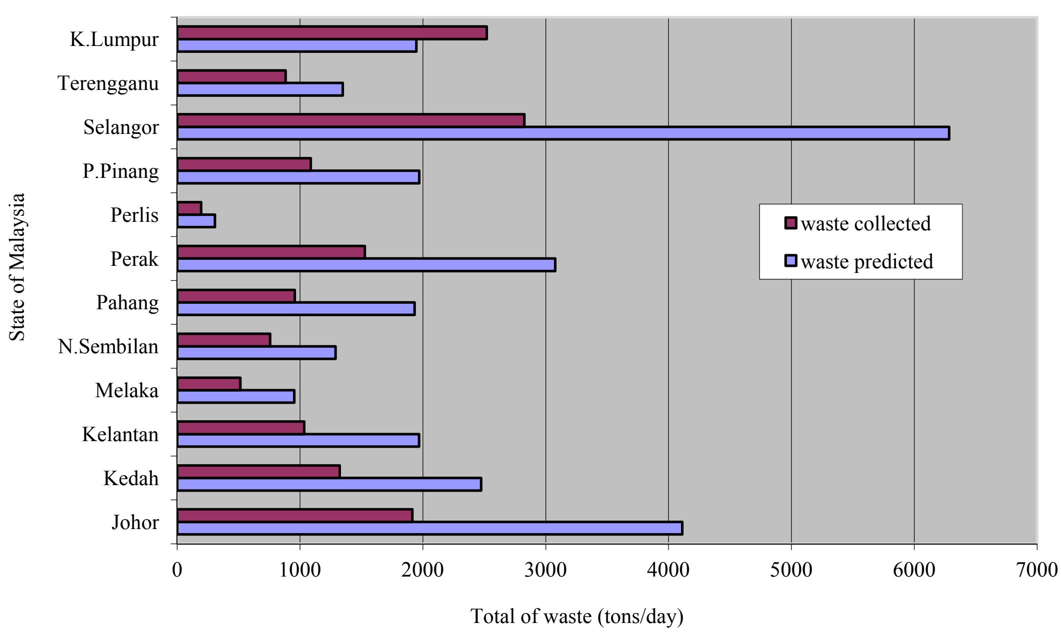

Fig. 3: Variation of waste collected (actual data) and waste predicted using manual calculation for the state of Malaysia

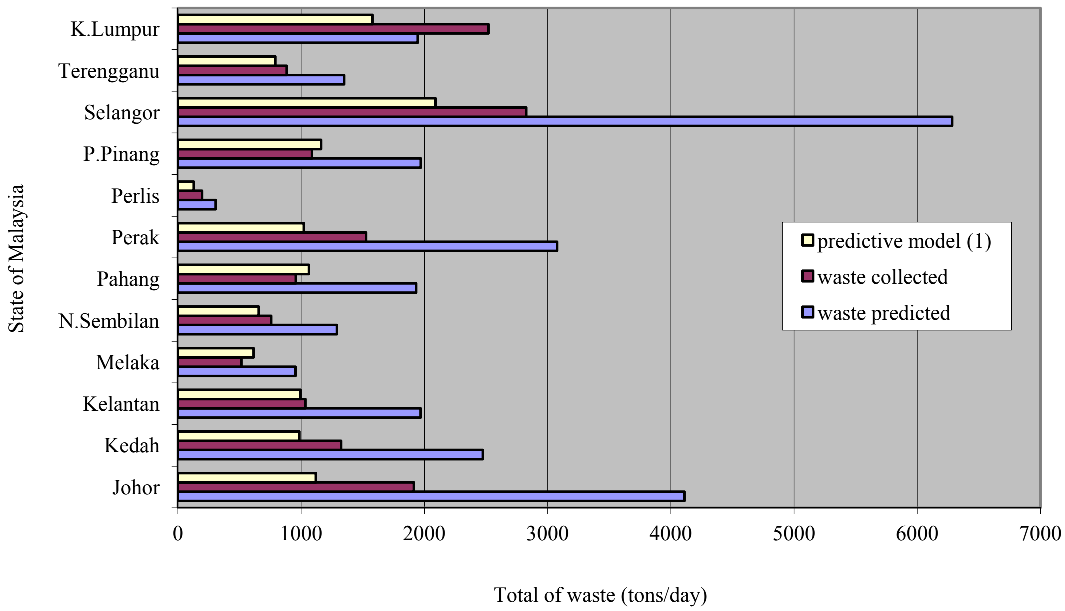

Fig. 4: Comparison between wastes collected (actual data), waste predicted (manual calculation)*, and waste predicted (predictive model (1))

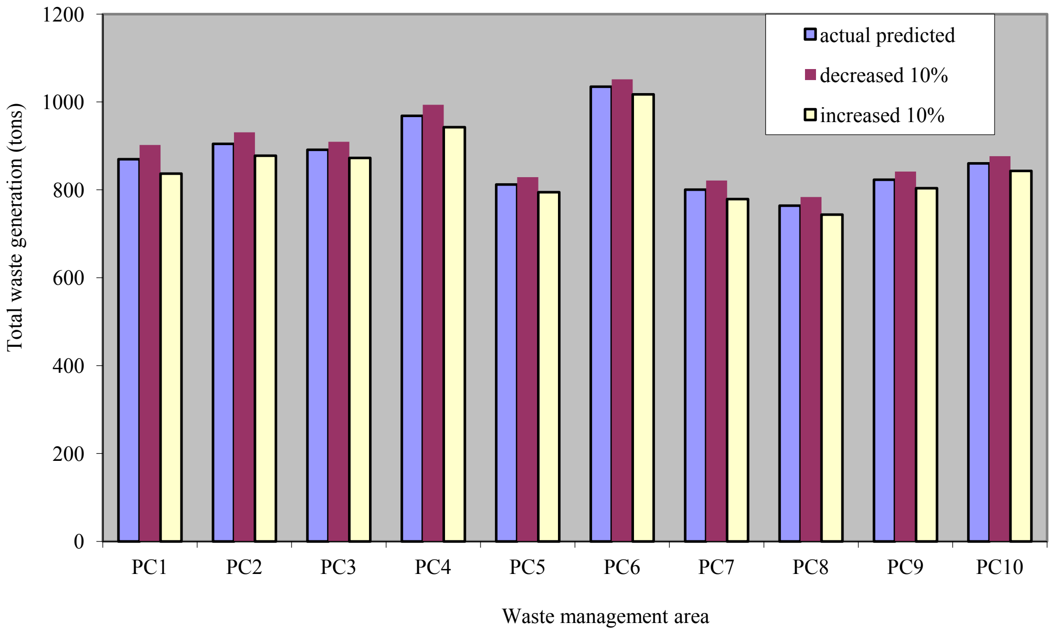

Fig. 5: Comparison between actual predicted, increase predicted and decrease predicted for MSW generation in Proton city

The development of scenario-implementation of predictive model (1) for the development of new township: This section attempts to determine and develop the future scenario for MSW generation based on current waste management systems, population estimates, housing development, current socio-economic distribution and basic demographic characteristics. The development of this scenario is based on the predictive model (1) and the scenario for the new township is based on Proton City.

Based on data developed for the new township of Proton City in year 2010 with the estimation that all variables are constant with the exception of a SINGLE variable that the total of MSW generation predicted will decrease by 10%, which is 8,939.35 tons/year. Conversely, if the variable SINGLE increases by 10%,

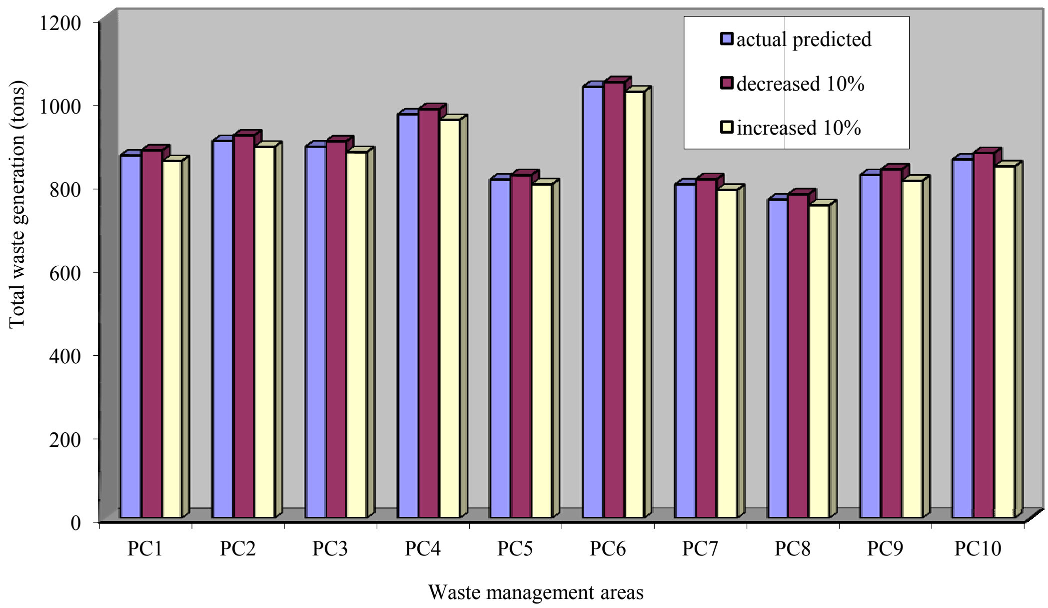

Fig. 6: Comparison between actual predicted, decreased and increased of MSW generation for the new township Proton city

the total of MSW generation predicted would be 8,511.17 tons/year. Figure 5 shows the comparison between the actual MSW predicted and the total predicted with increased and decreased number of single variable. In this phenomenon, it was found that the increased number of single households in Proton City would decrease the total of MSW generation. Conversely, the decreased number of single households will increase the total of MSW generated in Proton City.

Furthermore, using the same data in scenario 1 but with the variable AGE40 is decreased and increased by 10%. It was found that an increase of 10% in the number of households with age 40 years and above will decrease the total of MSW generation predicted to 8,595.04 tons/year, compared to the actual total for MSW generation of 8,728.80 tons/year. On the other hand, a decrease in the total of households with age 40 years and above resulted in an increase in the total of MSW generation predicted to 8,854.56 tons/year. The same scenario was found with the increase and decrease total of single households in Proton City. Whereas, an increase in the total number of single households with age above 40 years, will decrease the total amount of MSW generated. Similarity, a decrease in total of single households with age above 40 years will increase the total of MSW generation. Figure 6 shows the histogram for MSW generation for Proton City.

CONCLUSION

It is clear that the formation of the predictive model for MSW generation has some benefits to all institutions involved in waste management, such as the Federal Government, State Government, Local Authorities, developer and private contractors. The Noodles predictive model formed clearly shows that the model is extremely suitable to be implemented to overcome the basic MSW problems in Malaysia. The development to determine the effectiveness of the predictive model also shows the importance of planning approach in managing MSW in the future.

Referring to the explanation from linear regression analysis showed that the quantity of waste generation using predictive model (1) explains 63% of the variables selected for the regression gave good indicators for the analysis of waste generation rates in the study area. This shows that the model developed based on demographic characteristics can result in accurate data in predicting the amount of waste generation in the future. In order to obtain a more meaningful result for future waste management planning, when developing a new township, further studies should be carried out to include and consider other socio-economic factors. The study should also consider the different lifestyles between the urban and the rural environment to indicate the comparison between different types of houses.

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