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Original Article

Models of municipal solid waste generation and collection costs applicable to all municipalities in Thailand

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Abstract

The aim of this paper is to identify and measure the variables which influence municipal solid waste (MSW) generation and collection costs in Thai municipality. The empirical analysis is based on the information derived from a survey conducted in a sample size of 570 municipalities across the country. The results from the MSW generation model indicate that the population density, the household size and the size of municipality are the significant determinant of waste generation. Meanwhile, with regards to the MSW collection cost model, the results showed some existence of positive in the volume of MSW collected, population density, the distance between the center of municipality to the disposal site the hazardous sorting and the size of municipality whereas, there were no evidence of the frequency of collection and the ratio of recycled material to waste generation on cost.

Keywords: municipal solid waste, waste generation, waste collection costs, municipality, Thailand

1. Introduction

Due to a high level of urbanization, economic development, and an increase of population, there has been a period of continuous outcome in a large quantity of heterogeneous solid waste. The municipal solid waste (MSW) management has been trying to alleviate the increasing magnitude of the waste problem in many Thai municipalities, especially in rapidly urbanizing cities where these challenges are frequently exposed. Many municipalities are facing both large quantities of waste that has been overloading their capacity for management as well as creating a shortage of land for disposing the waste. Therefore, the study of the MSW generation and collection costsin Thai municipality, which is important for proper management planning, can lead to a reduction in pollution at the local level.

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The aim of this paper is to identify and measure variables which influence MSW generation and cost of collection in Thai municipality by using the municipalities of Thailand as a data set. The paper begins with acharacteristic description of the Thai municipality. This is followed by a brief literature review that touches upon the concerning determinants of the MSW generation and collection costs. From there, a model has been provided to characterize the influence of a number of variables on MSW generation and collection cost. Finally, the results indicating significant determinants of MSW generation and collection cost are presented, and implications related to municipal performance management are drawn for discussion.

2. Literature Review

There are two parts to this literature review. The first part covers the factors determining the amount of waste while the second partcovers the determinants of MSW collection cost.

2.1 Determinants of MSW generation

The MSW generation modeling classification in regional scale by Beigl *et al.* (2008) comprises offour factors, households, settlement areas, districts, and country level. The modeling definition of each category is based on the existing administrative units, except for the settlement areas where the socio-economic homogeneity of each area was considered by the author of this study. However, this paper aims to examine the determinants of MSW generation in the Thai municipality, which is focused on the relationship between the demographic and socio-economic factors of each municipality, and the volume of MSW generation by using the district level concept.

According to the district model, the previous studies have established the dependent variable on both of the collection quantities of MSW (Bach *et al.*, 2004) and its per capita (Hockett *et al.*, 1995). Aspects considered for selecting the independent variables are the demographic and socio-economic factors of each administrative unit. The characteristics of demographic variable are household size (Benitez *et al.*, 2008; Miller *et al.*, 2009), population density (Mazzanti and Zoboli, 2008; Miller *et al.*, 2009), education (Benitez *et al.*, 2008; Miller *et al.*, 2009) and age (Miller *et al.*, 2009), while the socio-economic issues are per capita income (Benitez *et al.*, 2008; Miller *et al.*, 2009), retail sales (Hockett *et al.*, 1995; Miller *et al.*, 2009) or employment (Bach *et al.*, 2004). The model estimation has a variety of techniques such as the time-series analysis (Leao *et al.*, 2001; Navarro-Esbrí *et al.*, 2002.) or system dynamics (SD) (Dyson and Chang, 2005; Karavezyris, 2002). However, the most popular technique applied for estimation is the regression analysis (Bach *et al.*, 2004; Beigl *et al.*, 2005; Hockett *et al.*, 1995; Mazzanti and Zoboli, 2008; Miller *et al.*, 2009).

2.2 Determinants of MSW collection cost

In recent years, the study of the relationship between the costs of collection to the amount of waste has been in the same direction and with the economies of scale. Based on the study of Bel and Costas (2006), this study showed that the economies of scale in municipalities with a lesser population tend to support this information.Likewise, Bel and Fageda (2009) showed that the economies of scale in municipalities with populations under 50,000 people also fall into this category. Meanwhile, the study by Callan and Thomas (2001) found no relationship to the economies of scale in any way. To test the differences in the collection cost between the public and private, the study by Reeves and Barro (2000) found that the cost of MSW collection is lower than the operation of the government. In their study, there was an opposite effect that was implemented by the private sector. In a work done by Ohlsson (2003), it was discovered that the costs are higher than the state. Meanwhile, the study found no significant difference in costs of collection between the private organization and public institution (Callan and Thomas, 2001; Bel and Costas, 2006; Bel and Fageda, 2009). Furthermore, environmental factors that are expected to be associated with the cost of collection found that the weekly frequency in the MSW was in line with the waste management costs (Bel and Costas, 2006). According to the work done by Reeves and Barro (2000), they did not find any relationship between the cost of collection and frequency of collection. The population density was found to be associated with the cost of garbage collection (Bel and Costas, 2006; Dijkgraaf and Gradus, 2011).

3. Methodology

Based on the multivariate empirical studies, the authors of this study propose a general model for estimating the factors that determine the MSW generation and collection. This model is as followed:

3.1 Determinants of MSW generation model

Empirical studies made it possible to propose a general model for estimating the factors that determine MSW generation:

$$W = f(D, O, Z) \tag{1}$$

where W is the MSW generation, D is the characteristic of demographic, O the characteristics of municipality, and Z the uncontrollable characteristics that affect the amount of MSW generation. The empirical model to be estimated is as followed:

$$W = \alpha + \beta_1 DEN + \beta_2 HOS + \beta_3 D^{TOW} + \beta_4 D^{CIT} + \varepsilon \tag{2}$$

In this equation the dependent variable is the total of MSW generation, W the volume of MSW which was generated in each municipality during one year: expressed in tons. Further,

- DEN - Population density in the municipality: expressed in the number of citizen per square kilometer.
- HOS - Households' size, measures the ratio of population to number of household in each municipality: it is expressed in an average of number of household membership.
- D^{TOW} - This term is the dummy variable that takes the value of 1 if the organization was a town municipality and 0 otherwise. In fact, the size of the municipality was the proxy of urbanization that represents the density of economic activity in areas such as commerce, manufacturing and services.
- D^{CIT} - This term is the dummy variable that takes the value of 1 if the organization was a city municipality and 0 otherwise. This variable reflects that urbanization refers to the growth of economic activities in that area, so that the by-product of activities was a MSW generation.

3.2 Determinants of MSW collection cost model

This study focuses only on the cost of solid waste collection and does not include the disposal cost. The total cost of solid waste collection consists of fixed cost (vehicle, wages, and welfare) and variable costs (maintenance fee, fuel cost, and lubricant cost). Thus, the basic function of the MSW collection cost takes the following form:

$$C = f(Q, M, Z) \quad (3)$$

where C is the total cost (cost borne by the municipality), Q is the volume of MSW, M the characteristics of management, and z the uncontrollable characteristics that affect to the service. The empirical model to be estimated is by taking logarithms of both the dependent variable and the explanatory variables:

$$\ln C = \beta_0 + \beta_1 \ln WAS + \beta_2 \ln REC + \beta_3 \ln DIS + \beta_4 \ln FRE + \beta_5 \ln DEN + \beta_6 D^{HAZ} + \beta_7 D^{SIZ} + \varepsilon \quad (4)$$

In this equation the dependent variable is the total cost of MSW collection, lnC is the total cost understood as the set of activities implied by these terms: a) sweeping, b) collection, and c) transport. Also included are the following explanatory variables with respect to municipal costs or spending:

lnWAS - The volume of MSW collected in the municipality; expressed in tons per year.
lnREC - The percentage of the proportion of recycled waste to total waste.
lnDIS - The distance from the municipality center to the disposal site, which is expressed in kilometers.
lnFRE - The frequency of waste collection, in other words, the number of days per week on which waste is collected.
lnDEN - The population density in the municipality, expressed in the number of citizen per square kilometer.
DHAZ - Represents the dummy variable that takes the value of 1 in the event that there is hazardous waste separation, and 0 otherwise.
DSIZ - This term is the dummy variable that takes the value of 1 if the organization was a town and city municipality and 0 otherwise.

3.3 Data collection

Data collection was approached with collecting accurate and reliable data by using questionnaires and surveys that were sent by mail to the responsible unit (mayor, senior executives, etc.). 570 questionnaires were completed and returned for an estimated model which covered 75 provinces across the country. All returned questionnaires which comprised of 515, 46, and 9 questionnaires from the sub-district, town and city municipality, respectively, were completed and returned for estimation with the model. This study examines the determinants of MSW generation and collection cost using the ordinary least square regression (OLS) technique to model the estimation.

4. Results

4.1 Estimation of the determinants of MSW generation

The coefficient of determination (R^2) was one of the measures of the goodness of fit which displayed a figure of 0.569. This means that the independent variables explained approximately 56.9% of the variability in the MSW generation. Other factors that were not included in the model could explain the remaining variation. The independent variables were statistically significant at the level 0.01, including population density (DEN), household size (HOS) and size of municipality was a dummy variable that represented the town municipality (TOW) and city municipality (CIT). The sign of the coefficients of the explanatory variables were positive. This represents that the variation of the dependent variable was a direct change of independent variables. This is explained in Table 1.

Table 1. Regression estimation of the determinants of MSW generation

Variable	Coefficient	Std. Error	Beta	t-statistic
Constant	1,472.960	264.048		5.578
DEN	0.456**	0.075	0.205	6.121
HOS	102.518**	26.894	0.141	3.812
TOW	8,349.640**	960.731	0.279	9.701
CIT	32,291.488**	2,079.024	0.494	15.532

Dependent Variable : MSW generation (ton per year)
$R^2 = 0.569$ Adj $R^2 = 0.566$ F – Statistic = 186.590 Observation = 570

Note : * Significant at level 0.01

Population density has a positive coefficient that describes the growth of population density that would cause an increase in the amount of MSW generation. Likewise, the household size was measured by the number of family members. This variable has a positive coefficient which represents the larger household size or number of members increased which would cause an expansion in the amount of MSW generation. In regards to this event, there was a consensus in the literature about high population density (Mazzanti and Zoboli, 2008; Miller *et al.*, 2009) or household size (Benitez *et al.*, 2008; Miller *et al.*, 2009) that have led to an increase of the MSW generation. In addition, the municipality size was a dummy variable that represented the town or city municipality that has a positive coefficient; this explains that if an organization was a town or city municipality then the volume of MSW also increases. From the coefficient of independent variable, it was found that the town or city municipality will have 8,349.64 tons or 32,291.48 tons of MSW per year more than the sub-district municipality, respectively.

With regards to the coefficient of determination (R^2) it is not at a high level. This reduces the ability in making a prediction of the MSW generation model. Therefore, the developing model in the future should have additional variables that are correlated with household consumption, which is the main cause of waste generation such as income per capita(Hockett *et al.*, 1995) or tenure of property (Dennison *et al.*, 1996).

4.2 Estimation of the determinants of MSW collection cost

The coefficient of determination (R^2) was one of the measures of the goodness of fit. The determinant is a figure of 0.749. This means that the independent variables explained approximately 74.9% of the variability in the MSW collection cost. Other factors not included in the model could explain the remaining variation. The independent variables were statistically significant, including the volume of MSW collected in the municipality (lnWAS), distance from municipality center to disposal site (lnDIS), population density (lnDEN), hazardous waste separation (HAZ) and the size of municipality (SIZ). The sign of the coefficients of the explanatory variableswere positive. This represents that the variation of the dependent variable was from a direct change of independent variables. This is explained in Table 2.

The volume of MSW collected in the municipality has a positive coefficient that describes the growth of the amount of waste collected which caused an increase in MSW collection cost. These results are consistent with previous findings (Callan and Thomas 2001; Bel and Costas 2006; Bel and Fageda, 2009). Meanwhile, the distance from municipality center to disposal site caused an increase in the cost of MSW collection (Ohlsson, 2003). Similarly, the growth of population density has caused an increase in the collection cost (Bel and Costas, 2006; Dijkgraaf and Gradus, 2011). As for hazardous waste separation, the coefficient associated with this variable was positive which represents that if an organization has hazardous waste separation before disposal then it causes an increase in the cost of MSW collection. In addition, the size of municipality was a dummy variable that represented the town or city municipality that has a positive coefficient; this explains that if an organization was the town or city municipality then the collection cost of MSW also increases.

However, this model does not attempt to explain the difference of MSW collection cost, whereas the local government has been providing delivery service directly instead of outsourcing it to a private firm. In this regard, there was no consensus in the literature about the ability of private delivery to reduce the costs of solid waste collection services (Bel, Hebdon and Warner, 2007).Therefore, future studies should determine the types of management factors into the model to provide a more complete understanding of the work.

Table 2. Regression estimation of the determinants of MSW collection cost

Variable	Coefficient	Std. Error	Beta	t-statistic
Constant	9.744	0.291		33.523
lnWAS	0.561**	0.020	0.743	27.464
lnREC	0.023	0.056	0.009	0.408
lnDIS	0.039*	0.016	0.055	2.501
lnFRE	0.056	0.080	0.016	0.700
lnDEN	0.091**	0.016	0.128	5.637
HAZ	0.152**	0.041	0.084	3.679
SIZ	0.155*	0.071	0.061	2.178

Dependent Variable : lnC (MSW Collection Cost)
$R^2 = 0.749$ Adj $R^2 = 0.745$ F – Statistic = 239.078 Observation = 570

Note : ** , * Significant at level 0.01 and 0.05 respectively

5. Conclusions

Considering the variation in the amount of MSW generated in Thai municipality, this study discovered that the population density, the household size, and size of municipality are the significant determinants of MSW generation. Meanwhile, The MSW collection costs correlated with an increase in the amount of municipal solid waste, distance to disposal site, population density, and the hazardous waste separation before disposal. Moreover, it seems that the local government providing the direct service has a negative relationship with solid waste management costs. There is a relationship between cost and waste quantity, the population density for economies of scale, and economies of the concentration of municipal waste management. The study found that there are economies of scale and economies of concentration or population density of solid waste management.

The results of this study found that the predictability of the MSW generation model is at average. There are mainly expectations, the model, and there is no variable representing the economic activities. This limitation is due to lack of gathering the capita income of municipality. However, the advantage of this model is to use the database of the Department of Local Administration is forecasting. The collection cost model, although a high predictive. But there is a need to improve is to add a variable to explain the difference in the cost of collecting by local governments and the private firm delivery. The cost savings will be helpful in planning for waste management that appropriate action by local or private.

This study showed the important link between population growth and urbanization will increase the amount of waste and the collection cost. This can be a problem in the future for the management of local government with limited budget. Therefore, recycling activities to reduce waste and transportation planning to reduce costs are the key factors that local governments should be encouraged to do as they are beneficial for the enhancement of the local waste management.

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