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Efficiency Assessment of Municipal Solid Waste Management in Nepal

Hem Raj Lamichhane [1] and Govinda Tamang [2]

[1] Central Department of Economics
Tribhuvan University (TU), Kathmandu, Nepal

[2] Central Department of Management
Tribhuvan University (TU), Kathmandu, Nepal

Abstract - The main objective of the paper is to assess the relative efficiency in the public sector service delivery, i.e. *municipal solid waste management* (MSWM) in Nepal, using the non-parametric Data Envelopment Analysis (DEA) method. The relative efficiency assessment of solid waste management of 34 municipalities of Nepal has been carried out by using the two inputs i.e. MSW generation and budget spent for MSWM and one output namely estimated waste collection for the period of 2012. The population and geographic areas have been used as contextual variables. The output oriented approach has been employed to assess the relative efficiency of municipal solid waste management. Of the total 34 municipalities, only four municipalities viz. Biratnager, Mechinager, Ratnanagar and Tulsipur found technically efficient under constant returns to scale (CRS) model and nine municipalities i.e. Amargahi, Bhadrapur, Biratnagar, Kathmandu, Mechinagar, Putalibazar, Ratnanagar, Siraha and Tulsipur found technically efficient under variable returns to scale (VRS). Also, the nature of returns to scale of 14 municipalities found increasing returns to scale, 7 municipalities are constant returns to scale and remaining 13 municipalities are decreasing returns to scale. The Kalaiya municipality had collected only 547 metric ton solid waste in 2012 but, to be efficient, 4,333 metric ton solid waste should have been collected by this municipality.

Keywords - Municipal Solid Waste Management, Data Envelopment Analysis (DEA), Efficiency.

I. INTRODUCTION

Nepal is a least developed country situated between two giant countries in terms of population, geography and economy i.e. China in North and India in East, West and South. Because of the increasing population and the effect of rapid urbanization and industrialization in the cities, solid waste management has become critical problem for municipalities. This problem gets bigger in large cities related with large population and increased complexity. Collection of solid waste is the first and a critical phase of solid waste management for municipalities. According to the provision of Local Self Governance Act, 1999, the municipalities were responsible to carry out or cause to be carried out sanitation programs in the municipal area and to carry out and manage or cause to be carried out and managed the acts of collection, transportation and disposal of the garbage and solid wastes (LSGA, 1999). The constitution of Nepal has given mandate to municipality for the management of programs related to the environment protection and bio- diversity [1]. Moreover, the Local Government Operation Act, 2017 (2074 BS) also has given responsibility to municipality to collect and manage the garbage and solid waste within the municipal area [2].

The main objective of the paper is to assess the relative efficiency in the public sector service delivery, i.e. ***municipal solid waste management*** (MSWM), using the quantitative assessment of efficiency, the data envelopment analysis (DEA).

The conceptual framework of efficiency measurement is typically based on the “three Es” – economy, efficiency, effectiveness (Figure 1), where:

Corresponding Author: Hem Raj Lamichhane

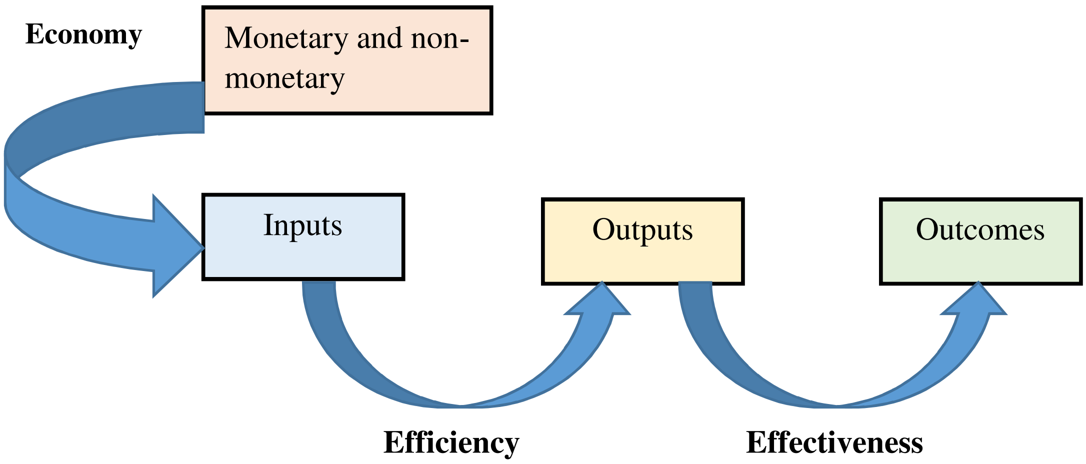

Figure1: 3E framework,

Source: [3]

- economy is concerned with reducing the cost of inputs (cost-minimizing);
- efficiency requires avoiding unnecessary waste when using the resources to produce goods and services (hence the economy and efficiency criteria combined understood as a measure of cost-efficiency
- effectiveness shows whether the resources were used to successfully achieve the set goals (i.e. the final objectives of a policy).

Efficiency is related only to the transformation of inputs into outputs – the most basic efficiency measure thus being an input-to-output ratio. A clear difference between outputs (actual goods or services produced) and outcomes (long-term effects of a project or policy, often linked to welfare or growth) should therefore be established to properly distinguish efficiency from effectiveness. Unfortunately, coupled with the general difficulty in defining output itself, this is rarely the case in practice and efficiency and effectiveness tend to get confused [4].

1.1 Solid waste management in Nepal

That is if the waste in particular has a value for selling and can be re-used, re-cycled or recovered for energy. Objects of value are e.g. paper, metals, glass and plastics. Collectors bicycle around, on so called hawk cycles, from door to door in the cities in search for waste of value. The collectors can either be self-sufficient or connected to private scrap dealer's shops, so called Kawadi shops. Municipalities generally apply the waste collection methods i.e. door to door collection, vehicle collection and road based collection. The solid waste is being collected from household level, institutional and commercial levels. The main types of the wastes are organic waste, plastic, paper, glass, construction and demolition waste, textile, rubber, metals and others [5].

On average, the 58 municipalities in the country are spending about 13 percent of their total budget on waste management related activities [6], but in most cases this amount is not being spent in an efficient manner. Private sector participation (PSP) in solid waste management can improve efficiency, reduce the need for municipal investment, and share risks associated with introducing a new technology or system. In spite of these clear benefits, many municipalities have not been able to take advantage of PSP in waste management [7].

II. Literature Review

Municipal solid waste management meant the collection, transfer, recycling, resource recovery, and disposal of solid waste in urban area [8]. A study found that efficiency and quality of services increase when high density populated area are served [9]. It was argued that high per capita income does not promote firm efficiency because greater taxation revenues can cover some inefficiencies [10]. It was found that municipal population does not affect efficiency in Spanish municipalities with population over 50,000 [11]. Few previous studies related to the solid waste management of municipalities are presented in Table 1.

Table 1: Collection of MSW services through DEA method

Authors	Title	Focus	Input/output variables
[12] Bosch et al. (2000)	Measuring the efficiency of Spanish municipal refuse collection services. Local Government Studies	MSW collection services (parametric and non-parametric technique)	I: Containers, Vehicles and workers O: Waste collected
[13] Wothington and Dollery (2001)	Measuring efficiency in local government: An analysis of New South Wales municipalities' domestic waste management function. Policy Studies Journal	SWM by local governments, including municipalities	I: Collection expenditure O: Garbage and recyclables collected
[14] Moore et al. (2005)	Putting out the trash measuring municipal service efficiency in US cities. Urban Affairs Review	Municipal management in general, MSWM including (46 largest US cities)	I: MSWM costs, waste products O: Citizen served
[15] Marques and Simoes (2009)	Incentive regulation and performance measurement of the Portuguese solid waste management services. Waste Management & Research	Solid waste disposal operators (effective of national regulation)	I: Waste treated O: Waste recycled
[16] Benito et al. (2010)	The determinants of efficiency in municipal governments. Applied Economics	Municipal management in general, MSWM included	I: MSWM costs O: Waste collected
[17] Simões et al. (2010)	Regulatory structures and operational environment in the Portuguese waste sector. Waste Management	Influence of operational environment on urban solid waste services	I: MSWM costs O: Waste treated, Waste recycled
[3] Mgr. (2014)	Efficiency evaluation of municipal solid waste management in the CZECH Republic using DEA method	Municipal solid waste management	I: MSWM expenditures O: Population, area MSW production, per capita collection, per container collection, collection cycle

Note: I=Input variable; O=Output variables

Source: [3] Mgr. Kristýna DOSTÁLOVÁ (2014)

III. Data and Methods

The municipal solid waste general in ton and budget spent for solid waste collection in 2012 have been used as input variables and estimated waste collection in ton has been used as output variable. For the purpose of the regression analysis, the efficiency score has been used as explained or dependent variable and total population and geographic area have been used predictor variables. Of the total 58 municipalities, 34 municipalities have been used as decision making units (DMUs) in this study based on the availability of the data.

Data envelopment analysis (DEA), occasionally called frontier analysis, was first put forward by Charnes, Cooper and Rhodes in 1978 which is known as CCR model and BCC model was propounded by Banker, Charnes and Cooper in 1984. The both models provide a radial (or ratio) measure of efficiency [18].

It is a performance measurement technique which, can be used for evaluating the relative efficiency of decision-making units (DMU's) in organizations. DEA represents a non-parametric deterministic efficiency measure. This means that, on the one hand, it has the advantage of omitting a priori assumptions of functional forms of the production or cost functions, which have to be modelled in parametric approaches (e.g. linear and nonlinear regression models or the closely related stochastic frontier analysis-SFA [19]. Efficient units are identified by a DEA efficiency rating of 1 (i.e. 100%) and form the efficiency frontier (or "envelope") around the rest. While it is not indicated whether a DMU has reached economic efficiency, the generated efficiency rating (or efficiency percentage) gives a realistic and practical measure of what has been and can be achieved by others.

The evaluation of the organizations' activity can be tackled through a variety of indicators. Some of them are established as a quotient or proportion:

$$\text{Efficiency} = \frac{Input}{Output}$$

Usually this ratio is used in order to assess the organizations' efficiency. One of the advantages of DEA is that it does not require a previous specification of the weights of each input/output. Furthermore, it does not require assumptions about the form of the production function, which are so common in statistical regressions and in many other circumstances. That is why relationships between variables are evaluated by means of bivariate statistical tests. Eventually, since it uses mathematical programming techniques, it is able to handle a high number of variables and relationships (restrictions). Thus, DEA is usually used in the evaluation of the efficiency of a certain number of producers, comparing each one of them only with the best producers. Unlike usual statistical approaches evaluating units in reference to their average, DEA is a method of extreme point, defining a border where efficient units are located. Inefficiency is established in relation to this efficiency border [10].

As multiple inputs are generally transformed into multiple outputs, however, weights are assigned first – promoting DEA from a partial (e.g. output per worker hour, basic financial statements) to a total factor productivity measure, where all feasible input/output ratios are combined into one [18]. A common measurement of ***relative efficiency*** or the concept of efficiency in DEA can be therefore simplified as:

$$\text{Relative Efficiency} = \frac{\text{Sum of weighted ouputs}}{\text{Sum of weighted inputs}}$$

With introducing the usual notation can be written as:

$$\text{Efficiency of unit j} = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots}{v_1 x_{1j} + v_2 x_{2j} + \ldots}$$

where;

u_1 = the weight given to output i; y_{1j} = the amount of output 1 from unit j; v_1 = the weight given to input 1; x_{1j} = the amount of input 1 to j

Relative efficiency means a DMU is to be said as fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs do not show that some of its inputs and outputs can be improved without worsening some of its other inputs and outputs.

The Figure 1 shows that the Firms A, B, C, and D found efficient and they provide an envelope round the entire data set, whereas, the firm E is within this envelop and is inefficient. The inefficient unit/firm means that which is characterized by excessive inputs or insufficient output. If the firm 'E' would like to be efficient it will have two options i.e. (i) it should increase its output from the point of 'E' to 'C' with the same inputs or (ii) it should decrease its inputs from the point of 'E' to 'A' with the same output. In other word, under output oriented method, the firm E must increase its output from the point of E to C.

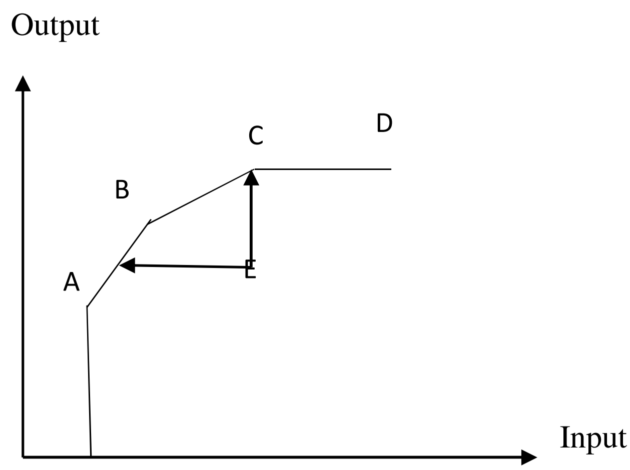

Figure 2: Projection of an inefficient DMU to the efficiency frontier

Source: Researchers' design

DEA thus in fact models a virtual efficient unit [3].

 minimizing inputs, while keeping outputs constant, in ***input-oriented models*** (I),

- maximizing outputs, while keeping inputs constant, in ***output-oriented models*** (II), or

- combining maximization of outputs and minimization of inputs, in ***slack-based models***

The analysis allows each unit to establish its own set of weights, in order to reach the most favorable combination in comparison with the rest of the units. Thus, the efficiency of the unit (j_0) can be obtained by solving the following problem: To maximize the efficiency of unit j_0, conditional to that the efficiency of all the units is ≤ 1 [20].

The unknown quantities of this problem are the weights, and the solution shows on the one hand, the most favorable weights to the unit, and on the other, the efficiency measurement of each unit. The mathematical model is as follows [16]:

$$\text{Max } h_0 = \frac{\sum_r u_r y_{rjo}}{\sum_i v_r x_{ijo}}$$

$$\text{s.t} = \frac{\sum_r u_r y_{rj}}{\sum_i v_r x_{ij}} < 1 \quad j = (1, 2, \ldots N)$$

$$u_r, v_i \leq \varepsilon$$

Where; y_{rj} and x_{ij} represent outputs and inputs of unit j respectively. The variables of the problem are u_r and v_i (weights). These latter are supposed to be greater or equal than a certain small positive amount, in order to prevent some input or output from being totally ignored in the efficiency assessment.

The solution to this problem yields a value of h_0 between 0 and 1, which is a measurement of the relative efficiency of unit j_0. If h_0= 1, then unit j_0 is efficient in relation to the other units, and if h_0 <1, other units are more efficient than j_0.

3.1 Output target

A fundamental assumption of relative efficiency is that if a give firm, A is capable of producing Y (A) units of output using X (A) units of inputs, then other firms should also be able to do the same if they were to operate efficiently. Therefore, performance target is set for inefficient firms to enable them to reach 100 per cent relative efficiency in comparison with the Firm A, which is the most efficient firm among others. The output target for inefficient firm can be fixed as follow [21].

$$\text{Output taget} = \frac{\text{Actual Output}}{\text{Relative efficiency \% /100}}$$

3.2 Return to scale

Under constant return to scale, the manufacturer is able to scale the inputs and outputs linearly without increasing or decreasing efficiency. The returns to scale properties of DMUs can be obtained by observing corresponding values of λ^* [21].

(a) If $\lambda^*_{bp} < 1 \Rightarrow$ Increasing Returns to scale

(b) If $\lambda^*_{bp} > 1 \Rightarrow$ Decreasing Returns to scale

where *bp* denotes the *best practice* DMU. Note $\lambda^*_{bp} = 1$ for the best practice DMU.

In case of greater number of inputs and outputs, the foregoing conditions will be modified as follows [22].

$$\sum_{n=1}^{N} \lambda_n < 1 \Rightarrow \text{Increasing returns to scales, IRB}$$

$$\sum_{n=1}^{N} \lambda_n > 1 \Rightarrow \text{Decreasing returns to scales, DRB}$$

Note that, the efficient firms

$$\sum_{n=1}^{N} \lambda_n = 1$$

IV. Results and Discussion

The result and discussion is presented into three categories i.e. relative efficiency, output target and regression analysis.

4.1 Relative efficiency

The efficiency results show that Amargadhi municipality found 45.85 per cent efficient under CCR model and 100 per cent efficient under VRS model whereas it has only 0.46 scale efficiency. The sum of Lamda is less than 1 (0.09) it means that the nature of returns to scale is increasing. However, Biratnager, Mechinagar, Rantnagar, and Tulsipur municipalities found 100 per cent efficient in CCR and BCC model and scale efficiency. The mean efficiency score indicates that on average, there was 56.15 per cent efficiency of 34 municipalities in utilization of available resources (inputs) for waste collection. Birendranagar municipality was found the lowest efficient because its efficiency score is only 11.74 per cent. The value 1 of Sum Lamda means the nature of returns to scale is constant (Table 2).

Table 2: Descriptive statistics

SN	DMUs	CCR (CRS)	BCC (VRS)	SE (CRS/VRS)	Nature of returns to scale	Sum Lambda
1	Amargadhi	45.85	100	0.46	IRS	0.09
2	Baglung	47.65	48.34	0.99	DRS	1.2
3	Bhadrapur	52.98	100	0.53	IRS	0.27
4	Bhaktapur	91.2	97.39	0.94	DRS	3.92
5	Biratnager	100	100	1.00	CRS	1
6	Birendranagar	11.74	11.81	0.99	DRS	1.06
7	Butwal	66.06	70.72	0.93	DRS	3.68
8	Damak	67.83	80.95	0.84	CRS	1
9	Dhasarathchandra	19.66	40.48	0.49	IRS	0.21
10	Dharan	85.15	92.85	0.92	CRS	1
11	Ghorahi	82.43	85.52	0.96	DRS	1.73
12	Hetauda	43.17	46.35	0.93	DRS	2.98
13	Ilam	57.81	58.19	0.99	IRS	0.96
14	Inaruwa	36.37	36.55	1.00	IRS	0.94
15	Itahari	26.78	27.3	0.98	DRS	1.57
16	Janakpur	25.45	26.81	0.95	DRS	2.25
17	Kalaiya	12.52	12.63	0.99	IRS	0.25
18	Kamalamai	79.37	85.71	0.93	IRS	0.84
19	Kathmandu	91.6	100	0.92	DRS	63.16
20	Kirtipur	53.06	62.01	0.86	CRS	1
21	Lalitpur	77.11	97.2	0.79	DRS	9.73
22	Malangawa	17.93	18.09	0.99	IRS	0.46
23	Mechinagar	100	100	1.00	CRS	1
24	Panauti	45.21	50.87	0.89	IRS	0.34
25	Pokhara	52.17	81.99	0.64	DRS	9.62
26	Putalibazar	93.77	100	0.94	IRS	0.26
27	Rajbiraj	50.33	50.61	0.99	IRS	0.51
28	Ramgram	43.01	60.09	0.72	IRS	0.49
29	Ratnanager	100	100	1.00	CRS	1
30	Sidharthanagar	30.04	31.55	0.95	DRS	1.9
31	Siraha	41.67	100	0.42	IRS	0.4
32	Tansen	23.2	23.22	1.00	DRS	1.01
33	Tulsipur	100	100	1.00	CRS	1
34	Waling	37.88	75	0.51	IRS	0.44
	Mean	56.15	66.83	0.87		
	Minimum	11.74	11.81	0.42		
	SD	28.19	30.82	0.18		

Note: IRS= Increasing returns to scale, DRS=Decreasing returns to scale, CRS=Constant returns to scale, VRS=Variable returns to scale, SE=Scale efficiency, MPSS=Most productive scale size, MPSS implies that a DMU's production of outputs is maximized per unit of inputs.

Source: Authors' calculation

4.2 Output target

The set targets have been determined for a relatively inefficient unit to guide them towards improved performance. This set of targets is output -oriented as the main changes are to the output levels. The necessary value of the inputs and outputs that make each inefficient investment program become efficient. Therefore, the efficiency score of inefficient municipalities can be increase and improved by increasing the output to a certain level. For example, Baglung municipality had collected only 1,460 metric ton solid waste in 2012 but to be efficient, 3,020 metric ton solid waste should have been collected by this municipality. Birendranagar municipality should have been collected about 747 per cent more solid waste to become an efficient municipality. Similarly, the waste collected by Butwal municipality must be increased by more 41 per cent. For the remaining DMUs, interpretation of target results can be done at the same way (Table 3).

Table 3: Output and input target of inefficient municipalities under VRS model

SN	Municipalities	MSW Generation (Ton)	Current MSW collection (Ton)	MSW collection target for becoming efficient (Ton)	Increment of the estimated MSW collection (%)
1	Baglung	3230.25	1460	3020	107
2	Bhaktapur	10548.5	9125	9369	3
3	Birendranager	3328.8	365	3091	747
4	Butwal	9902.45	6205	8774	41
5	Damak	6405.75	2555	3156	24
6	Dhasarathchandra	1208.15	182	450	147
7	Dharan	18585.8	12775	13759	8
8	Ghorahi	4668.35	3650	4268	17
9	Hetauda	8022.7	3285	7088	116
10	Ilam	2595.15	1423	2445	72
11	Inaruwa	4190.2	1095	2996	174
12	Itahari	9168.8	2190	8022	266
13	Janakpur	6048.05	1460	5447	273
14	Kalaiya	5106.35	547	4333	692
15	Kamalamai	3737.6	1460	1703	17
16	Kirtipur	6201.35	2190	3532	61
17	Lalitpur	30769.5	21900	22530	3
18	Malangawa	3463.85	547	3023	453
19	Panauti	1799.45	730	1435	97
20	Pokhara	42745.15	18250	22259	22
21	Rajbiraj	5296.15	2190	4327	98
22	Ramgram	1868.8	547	910	66
23	Sidharthnagar	5124.6	1460	4627	217
24	Tansen	4321.6	912	3928	331
25	Waling	2011.15	365	487	33

Source: Source: [23] ADB (2013) and authors' calculation

4.3 Regression analysis of DEA efficiency score

The regression analysis is attempted to find out the effects of non-discretionary inputs on the DEA efficiencies. The objective of the regression analysis is to check whether the impact of the non-discretionary on the efficiency scores is significant, if so, to understand the nature and extent of their influence on the efficiencies.

The following inputs are considered for the purpose of the analysis.

(a) The Size of the municipalities: In terms of size of population and size of geographic area

(b) Size of household

Regression equation is as follow:

$$y_i = \beta_0 + X_i^{i} \beta + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

with individual DEA scores as the dependent variable, y_i, X_i as a matrix of explanatory variables, e_i denoting the error term, β_0 the intercept and β a vector of slope coefficients.

The regression analysis is applied to the results, where the dependent variable is the efficiency score from the first stage and the independent variables are selected explanatory factors. The ordinary least squares (OLS) method was applied and simple OLS are mostly equivalent.

The OLS regression is ran separately for each input, with efficiency score as the dependent variable, using the model,

EFF = (α * variable) + intercept

where, EFF is the VRS efficiency and variable refers to inputs such as area size, population size and household size.

Table 4: Descriptive Statistics

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Estimated Waste Collection	34	182	147825	8071.76	4342
Budget 2012 (Rs.)	34	500000	443100000	20647647	12944192
MSW Generation (Ton)	34	2	466	32.85	13.768
Efficiency Score (VRS)	34	11.81	100.00	66.8303	30.81576
Average HH Size	34	4	7	5.32	.684
Area Size	34	1.00	4.00	2.2059	.91385
Pop Size	34	1.00	3.00	1.2941	.67552
Valid N (list-wise)	34				

Source: Authors' calculation

The result indicates that the efficiency is greatly influenced by the size of geographic area and the population because both the variables are significant at 5 per cent confident level. The larger municipality in terms of population and geographic size tend to be more efficient. There is positive influence of size of geographic area and population in the municipal solid waste management efficiency score. Although the household size has a significant influence but it seems to be negative. The coefficient can be lightly interpreted to mean that there is an additional 16.84 per cent efficiency for population size and 13.16 per cent efficiency for area size.

Table 5: Results of the regression analysis with efficiency scores as the dependent variable

Variable	Area Size	Population Size	Household Size
Intercept/constant	37.799 [a] (2.891)	45.032 [a] (4.129)	164.858[a] (4.227)
Coefficient 'a'	13.161[b] (2.398)	16.844 [b] (2.248)	-18.414 [b] (-2.534)
R squared	0.152	0.136	0.167
F-statistics	5.750	5.051	6.419
p-value of F statistics	0.022	0.032	0.016

Notes: Figures within the parentheses indicate the t-statistic

[a] Significance at 1 per cent confident level

[b] Significant at 5 per cent confident level

Source: Authors' calculation

V. CONCLUSION

The public and private sectors' participation in the solid waste management is very crucial factor to make municipality more efficient in waste collection and disposal. Moreover, the success of waste collection of municipalities also depends on the collection methods, collection equipment, efficient human resources, vehicles for transportation, collection time and routes. Therefore, the solid waste collection efficiency of the inefficient municipalities can be improved and increased by analyzing and addressing these areas. The municipalities those are found inefficient, they should have been efficient if they had achieved the target amount of outputs which is presented in Table 3. The larger municipality in terms of population and geographic size tend to be more efficient for municipal solid waste management.

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