Evaluating the Success of Waste Collection Programs of Municipalities with Data Envelopment Analysis

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***Abstract*- Because of the increasing population of cities and the affects of industrialization, solid waste management becomes an important problem for cities. 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 programs. This paper aims to evaluate the success of solid waste collection programs of large cities in Turkey with data envelopment analysis. By using data envelopment analysis, municipalities can benchmark the efficiency of their waste collection programs and can evaluate what they should do for increasing the efficiency of their waste collection programs.**

Keywords- Waste Collection; Waste Management; Data Envelopment Analysis

I. INTRODUCTION

For the success of waste minimization programs, the waste must be collected appropriately and be transported to the recycling and recovery facilities or disposal areas. For a successful solid waste management first of all, there must be efficient waste collection methods and good programs for waste collection. The collection methods of waste and the selection of collection centers affect the success of waste management programs significantly.

In general, there is a lack of organization and planning in waste management due to insufficient information about regulations and due to financial restrictions in many developing countries[1,2]. In developing countries local authorities spend 77-95% of their revenue on collection and the balance on disposal but can only collect almost 50-70 % of municipal solid wastes[3]. The collection of solid waste can be very difficult in municipalities because of the waste collection resources which are blowsy and lacking of a systematical methods for waste collection. Since population in municipalities and the number of manufacturing plants increase rapidly, the logistics problems related with waste collection become more complicated. The cost of collection of solid waste can be an important percentage of solid waste services. Collection of solid waste doesn't guarantee the success of solid waste management programs. After collection of solid waste, appropriate activities must be applied. However without successful waste collection activities, it is not possible to gain value from waste by recycling or reuse.

II. WASTE MANAGEMENT

Wastes come from many directions and sources: people, farms, manufacturing plants, office buildings, households, and nature. Either as solids or liquids, these materials follow a variety of routes toward specific disposal sites: recycling centers, landfills, incineration plants, or sewage treatment plants[4]. Solid waste management has become a considerable issue, in addition to other environmental problems, especially for densely populated cities in developing countries[5]. Solid waste management is one of the most difficult environmental problems in the urban centers of developing countries. Rapid urban growth, accompanied by the increasing density of population, traffic congestion, air and water population, increasing per capita generation of solid waste and the lack of land conveniently situated for waste disposal are difficulties of solid waste management in urban centers[6]. Municipal solid waste management refers to collection, transfer, treatment, recycling, resources recovery, and disposal of solid waste in urban areas[3].

III. MUNICIPAL WASTE COLLECTION

Solid waste collection is taken to include the initial storage of waste at the household, shop or business premises, the loading, unloading and transfer of waste and all the stages of transporting the waste until it reaches its final destination: a treatment plant or disposal site[6]. Current collection systems are often not conducive to waste separation at source and hence must be revised and adapted accordingly. Dual collection systems for recyclable and non-recyclable waste can entail multi-compartmentalized vehicles or separate collection rounds on the same or different days[7].

Street collectors is the most common waste collection method in Turkey. For instance, 25-30 % of all recyclable waste is estimated to be collected by individual collectors. The individual collectors generally separate recyclable matters that were bought from sellers or collected in the streets or garbage containers[8]. Recovery of plastics, paper, glass, and metal from municipal solid waste is mostly conducted, by the scrap dealers and individual collectors. These individual collectors and scrap dealers purchase the used packaging (mostly paper and cardboard) from commercial units, markets and business centers and reprocess (sort and bale) these materials to sell directly to the industrial recycling facilities. In addition, scavenging and collection from the waste bins is a widespread activity[9].

Transport costs are very important for waste management programs of the municipalities. Many municipalities thus struggle to meet their legal mandate of providing at least a weekly waste collection service to all households due to limited budgets[7]. Solid waste services in most developing countries do not satisfy the full demand in urban areas. In the poorest countries, the service sometimes reaches only 10% to 40% of the urban population. In the better-organized middle-income countries, the services reach 50% to 85% of the urban population[10].

There is a growing concern about the insufficiencies of solid waste management in developing countries. Waste disposal in developing countries is still largely random and uncontrolled. The issue of increasing population growth, changes in habits and lack of awareness of the impact of solid

waste on the environment are some of the problems for municipal solid waste collection services[11].

IV. DATA ENVELOPMENT ANALYSIS

Data Envelopment analysis (DEA) is a methodology based on linear programming for measuring and evaluating the relative performance of organizations that consume identical inputs for producing identical outputs. The roots of DEA principles were based on the research done by Farrel in 1957 and the studies in literature on DEA were started with the article written by Charnes -Cooper -Rhodes in 1978. The CCR model developed by Charnes-Cooper-Rhodes was the first mathematical model of DEA.

Data envelopment analysis is an approach for evaluating the performance of a set of peers called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs[12]. The performance of DMUs is assessed in DEA using the concept of efficiency which is the ratio of total outputs to total inputs. Efficiencies estimated using DEA are relative to the best performing DMU[13]. DEA is a methodology directed to frontiers rather than central tendencies. DEA proves particularly adept to uncovering relationships that remain hidden from other methodologies. It doesn't require formulated assumptions and variations with various types of models such as linear and non linear regression models[12].

The formulation can be either input-oriented or output-oriented. For the input oriented case the linear programming formulation checks whether a hypothetical DMU exists whose outputs are as great as the DMU under consideration by consuming lesser input. For the output oriented model, the linear programming formulation checks whether it is possible to create a hypothetical DMU which uses the same quantities of input resources and produces more outputs than the output quantities produced by the DMU under consideration[14].

DEA has two basic models; constant returns to scale (CRS) and variable returns to scale (VRS) models. CRS model developed by Charnes et al (1978) assumes constant return to scale. Banker et al (1991) suggested VRS model that assumes variable returns to scale.

V. COMPARING EFFICIENCIES OF WASTE COLLECTION PROGRAMS OF MUNICIPALITIES

Waste collection programs of fifteen large cities in Turkey have been evaluated by data envelopment analysis. The main goal of waste collection programs is to collect the maximum solid waste according to the population and current cost so that output oriented CCR model was used in this paper. Constant returns to scale was assumed.

The inputs were determined as waste management environmental current costs and population of the city. The output was determined as waste collected in the current year. The data for 2008, gathered from The State Institute of Statistics in Turkey, has been used for this analysis.

The model can be stated as:

$$\text{Min } h_0 = \sum_{i=1}^{m} v_i x_{i0}$$

$$\sum_{r=1}^{t} u_r y_{r0} = 1$$

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{t} u_r y_{rj} \geq 0 \quad j=1,2,\ldots\ldots n$$

$$u_r, v_i \geq 0$$

r=1,2,…..t i=1,2,……m.

The dual of the model is as following:

$$\max \Phi + \varepsilon \left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{t} s_r^+ \right)$$

$$\sum_{j=1}^{n} x_{ij} \mu_j + s_i^- = x_{i0} \quad i=1,2,\ldots..m$$

$$\sum_{j=1}^{n} y_{rj} \mu_j - s_r^+ = \Phi\, y_{r0} \quad r=1,2,\ldots..t$$

$$\mu_j, s_i^-, s_r^+ \geq 0 \qquad j=1,2,\ldots..n.$$

DEA online software (http://www.deaos.com/login.aspx?ReturnUrl=%2fWelcome.aspx) was used for solving the problem. The efficiency scores for waste collection programs was shown in Table Ⅰ. According to the table, the efficiencies of waste collection programs of the cities of Antalya and Kayseri are the highest. Waste collection programs of the cities of Antalya and Kayseri are efficient and the others are inefficient.

TABLE Ⅰ OUTPUT ORIENTED CCR EFFICIENCY SCORES FOR WASTE COLLECTION PROGRAMS OF 15 LARGE CITIES

15 Large Cities of TURKEY	**CCR Efficiency Scores**
Adana	0,88
Ankara	0,99
Antalya	1
Bursa	0,79
Diyarbakır	0,77
Erzurum	0,73
Eskişehir	0,85
Gaziantep	0,62
Mersin	0,92
İstanbul	0,76
İzmir	0,77
Kayseri	1
Kocaeli	0,64
Konya	0,82
Samsun	0,72

Peer group analysis has been performed to compare the waste collection programs of large cities that are not efficient with the ones that are efficient. The performance of the inefficient waste collection programs of large cities can be improved by comparing the waste collection programs of large cities that are efficient. Table Ⅱ shows reference sets for inefficient waste collection programs of large cities.

TABLE II REFERENCE SETS FOR INEFFICIENT WASTE COLLECTION PROGRAMS OF LARGE CITIES

Inefficient Waste Collection Programs of Large Cities	Antalya	Kayseri
Adana	X	X
Ankara	X	X
Bursa	X	X
Diyarbakır	X	X
Erzurum	X	X
Eskişehir	X	X
Gaziantep	X	X
Mersin	X	X
İstanbul	X	
İzmir	X	X
Kocaeli	X	
Konya	X	X
Samsun	X	X

Table III shows output efficient targets for output oriented model. For the output orientations, CCR model the efficiency score of inefficient waste collection programs can be increased and improved by increasing the output to a certain level. According to Table III, the waste collection program of Ankara can easily be efficient with increasing the waste collected in a year with an average small amount. However, for increasing the efficiency of waste collection programs of Gaziantep and Kocaeli, waste collected in a year must be increased more than a half of the waste collected in a year.

TABLE III OUTPUT EFFICIENT TARGETS FOR OUTPUT ORIENTED MODEL CCR

Inefficient Waste Collection Programs of Large Cities	Current Waste Collection	Waste Collection Target for Becoming Efficient	Increase at the Output of Waste Collected (%)
Adana	771361	875540	13,5
Ankara	2165987	2180602	0,67
Bursa	848534	1079125	27,17
Diyarbakır	360275	470740	30,66
Erzurum	204979	278899	36,06
Eskişehir	273231	320136	17,16
Gaziantep	410554	661383	61,09
Mersin	599112	647749	8,11
İstanbul	5215122	6906411	32,43
İzmir	1351376	1765960	30,67
Kocaeli	480415	746110	55,30
Konya	643493	789045	22,61
Samsun	291599	405414	39,03

VI. CONCLUSION

The success of municipal solid waste collection is strongly related with public participation. The collection methods, collection equipments and vehicles, collection times and routes all affect the success of collection of solid waste.

The efficiency of the waste collection programs that are inefficient can be improved by analyzing the collection methods, transportation ways, collection vehicles, and collection times of the waste collection programs of the efficient ones.

In this paper, data envelopment analysis was used to analyze the efficiency of solid waste collection programs of large cities in Turkey. By using data envelopment analysis, the efficiency of waste collection programs of large cities were benchmarked. The waste collection programs of the cities of Antalya and Kayseri were determined as the best. The other cities can improve their outputs, stated as the waste being collected annually, to reach the efficiency level of waste collection programs of Antalya and Kayseri.

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