

Efficiency of solid waste collection in Spain

I. M. García Sánchez

*Department of Administration and Business,
University of Salamanca, Spain*

Abstract

One of the major environmental problems for society is the great quantity of solid waste generated. The management of urban solid waste is one of the most important services and for this reason town councils have to maintain the cities in the proper hygienic and aesthetic conditions for their inhabitants as well as for tourists or visitors.

The loss of credibility of the Spanish municipal public sector as a manager of this service is accompanied by manifestations demanding and forcing the sector to act by applying the principle of efficiency. These new demands require the development and application of control techniques that provide relevant information for decision-making.

In the present work we examine the waste collection scheme in Spain using the Data Envelopment Analysis (DEA) methodology in terms of calculation of the efficiency, showing the vast information that may be provide by this technique.

The results of this study showed that the average technical efficiency of waste collection is situated at 56.94%. Out of the 34 towns examined, the 73.53% were found inefficient. The analysis of slacks reveals a resource excess of about 9% above the optimal collection activity.

Keywords: data envelopment analysis, solid waste collection, public sector, municipalities.

1 Introduction

One of the major environmental problems for society is the great quantity of solid waste generated. The management of urban solid waste is one of the most important services and for this reason town councils have to maintain the cities



in the proper hygienic and aesthetic conditions for their inhabitants as well as for tourists or visitors.

The loss of credibility of the Spanish municipal public sector as a manager of this service is accompanied by manifestations demanding and forcing the sector to act by applying the principle of efficiency. These new demands require the development and application of control techniques that provide relevant information for decision-making about the relation between the quantity of resources used in the production and development of the appropriate quantity and quality of goods or services in a suitable time. Owing to the scarce significance of the value of the public output, its measurement is defined as the estimation of technical efficiency by inputs and outputs expressed in physical terms.

The present work focuses on the study of the efficiency of urban solid waste collection. Hence, the technical efficiency of the service is calculated with the aim of detecting potential savings in the use of physical resources, which lead to an increase in productivity.

According with the evidence of the large number of studies carried out in various countries – e.g. Portugal [3], the United Kingdom [4], Australia [7], France [2], Switzerland [1], Finland [5] and America [6]- Data Envelopment Analysis (DEA) was utilized to estimate the efficiency.

2 Data Envelopment Analysis

DEA yields a *piecewise linear production surface* that, in economic terms represents the best practice production frontier. By projecting each unit onto the frontier, it is possible to determine the level of inefficiency by comparison to a single reference unit or a convex combination of other reference units. The projection refers to a hypothetical DMU which is a convex combination of one or more efficient DMUs and not an actual DMU.

The basic DEA model, named CCR is expressed as follows (1):

Given a set of J DMUs, the model determines for each DMU_0 the optimal set of input weights and output weights that maximizes its efficiency score δ_0 . A score less than one means that a linear combination of other units from the sample could produce the vector of outputs using a smaller vector of inputs. Mathematically, a DMU is termed *efficient* if its efficiency rating δ_0 obtained from the DEA model is equal to one. Otherwise, the DMU is considered inefficient.

3 Aims and selection of variables

3.1 Sample

In order to estimate the efficiency, the population selected comprised the 113 towns of over 50,000 inhabitants that exist in Spain in 1999. Specifically, we obtained information from 34 towns that make up 30.09% of the population. The



technique used for obtaining information was the questionnaire, which, forwarded to the population, guarantees randomness in the data obtained.

3.2 Inputs and outputs

In this section the indicators that represent the functions of this service will be selected, grouped in indicators of input and output.

3.2.1 Inputs

The production process of municipal solid waste collection is highly contingent upon the supply of capital and human resources. The latter is represented, in general, by *total staff* and our analysis will include the indicator expressed in terms of total workers. In relation to the capital goods, the basic element is the vehicles measured in physical units.

3.2.2 Outputs

The variables tonnage (*Output1*) and collection points (*Output2*) correspond to the most used indicators for identifying the final product of the activity of waste collection. They represent the volume of solid waste generated and the number of places where it is collected, respectively.

4 Empirical analysis

4.1 Efficiency index

In this stage, we estimate the technical inefficiencies of the Spanish towns for solid waste collection and street cleaning. The results are given in table 1.

According to the results, of the 34 units examined 25 are inefficient, that is, approximately 73.5% of the total of local authorities evaluated. Only nine towns were considered efficient: Guadalajara, Barcelona, Castellón, Hospitalet, Bilbao, Mieres, Ciudad Real, Tenerife and Madrid.

The technical inefficiency measured is situated at 56.94%, there being a significant slack of potential improvement, which is expressed in a possible average reduction of the inputs of around 9%. The greatest slack, figure 1, is basically correlated with the variable tonnage, collection points being carried out more optimally.

4.2 Best-practice in solid waste collection and inefficient units

DEA displays performance information relating to inefficient towns and shows the difference between their performance and the “best practice” (100% efficient) municipalities to which they have been compared.

Potential improvements indicate by how much and in what areas an inefficient town needs to improve in order to be efficient. For example, Figure 2 shows what percentage Salamanca needs to either decrease its inputs or increase its outputs in order to become 100% efficient: it needs to reduce its number of



staff by nearly 40% or its vehicles around 7%, while maintaining the same level of outputs.

Table 1: Technical Efficiency Index.

MUNICIPALITIES	Technical Efficiency Index	MUNICIPALITIES	Technical Efficiency Index
GUADALAJARA	100	SEVILLA	38.60
BARCELONA	100	TORREJON	36.62
CASTELLON	100	MANRESA	35.29
HOSPITALET	100	MALAGA	35.12
BILBAO	100	OVIEDO	32.21
CIUDAD REAL	100	SANTA COLOMA	31.30
MIERES	100	FUENLABRADA	29.36
TENERIFE	100	VITORIA	29.34
MADRID	100	EL FERROL	27.60
SALAMANCA	92.14	SAGUNTO	27.17
LLEIDA	84.33	LORCA	23.99
GRANADA	80.95	MELILLA	22.22
GIJÓN	70.49	CORDOBA	21.37
PAMPLONA	67.74	ALCALA DE GUADAI	19.73
A CORUÑA	48.12	ALGECIRAS	12.34
PALMA DE MALLOR	45.16		
MARBELLA	42.81	AVERAGE EFFICIENCY	56.94
VILANOVA	42.76	EFFICIENT UNITS	9 (26.47%)
VALENCIA	39.04	INEFFICIENT UNITS	25 (73.53%)

If the assessment of a town as inefficient is felt to be justified then the information provided can be used as a basis for setting targets for the municipality. As a first step in setting targets, the inefficient unit should be compared with the towns in its reference set.

The reference set is the set of efficient municipalities to which the unit has been most directly compared when calculating its efficiency rating, table 2. Salamanca has efficient towns Barcelona, Ciudad Real and Tenerife.

However the reference set towns do not all contribute equally to the target-values for an inefficient municipality. Some reference set town are more important than others. Figure 3 shows all the towns in Salamanca's reference set and how much in percentage terms they have each contributed to forming the target values for each of Salamanca's inputs and outputs.



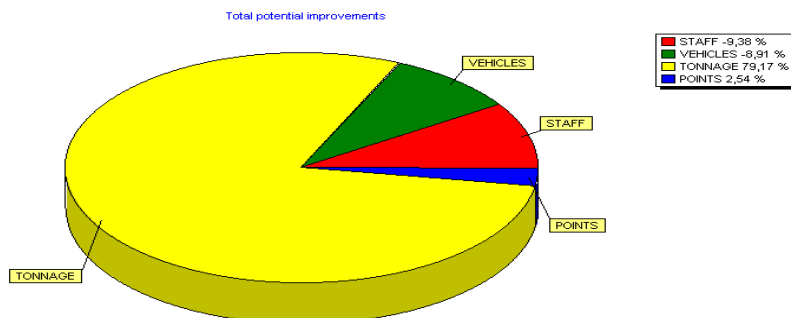


Figure 1: Potential average savings and increases.

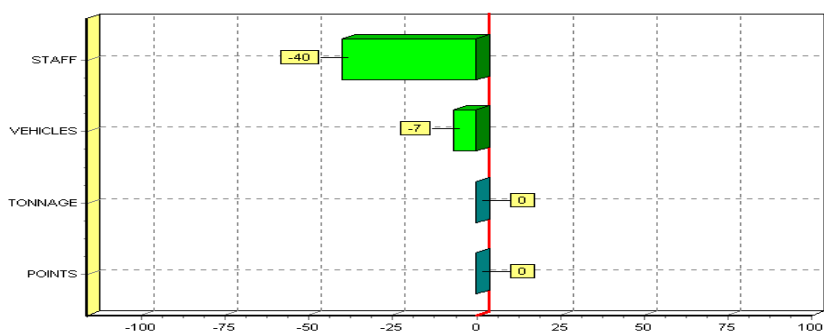


Figure 2: Salamanca: potential improvements.

Table 2: Group of references.

INEFFICIENT MUNICIPALITIES	EFFICIENT MUNICIPALITIES								
	Guadalajara	Barcelona	Hospitalet	Castellon	Bilbao	Ciudad Real	Mieres	Tenerife	Madrid
SALAMANCA		X				X		X	
LLEIDA	X		X	X	X				
GRANADA	X	X				X		X	
GIJÓN		X				X			
PAMPLONA		X	X	X	X				
A CORUÑA		X		X		X			
PALMA DE MALLOR	X	X	X	X	X			X	
MARBELLA			X						
VILANOVA		X		X			X	X	
VALENCIA								X	X
SEVILLA	X	X				X		X	X
TORREJON	X			X		X	X		
MANRESA	X				X		X		
MALAGA							X		
OVIEDO	X	X	X	X	X				
SANTA COLOMA	X	X	X						
FUENLABRADA	X	X	X						
VITORIA	X		X		X				
EL FERROL	X			X		X	X		
SAGUNTO	X				X		X		
LORCA	X				X		X		
MELILLA	X								
CORDOBA		X	X	X	X				
ALCALA DE GUADAI	X	X	X	X					
ALGECIRAS		X							
FREQUENCY	15	14	10	10	9	7	7	6	1
Percentage	60%	56%	40%	40%	36%	28%	28%	24%	4%



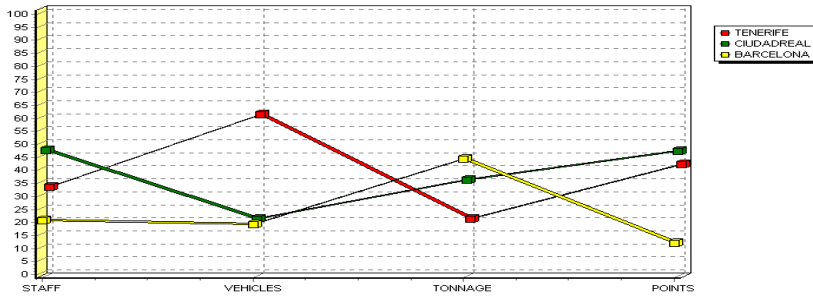


Figure 3: Salamanca: reference contributions.

5 Conclusions

A methodology of evaluation of the efficiency of waste collection has been established in this work. It provides not only an efficiency score for each town but also indicates by how much and what areas an inefficient municipality needs to improve in order to be efficient. As regards the results reveals that:

- Of the 34 towns examined, 25 are inefficient, 73.53%.
- The average technical efficiency is relatively short, 56.94.
- The analysis of slacks reveals surplus resources of around 9%.
- The collection activity being carried out more optimally.

$$\text{Max } \delta_o = \frac{\sum_i u_i y_{io}}{\sum_j v_j x_{jo}} \quad (1)$$

Subject to:

$$\frac{\sum_i u_i y_{ik}}{\sum_j v_j x_{jk}} \leq 1 \quad \text{for all DMUs } K=1, \dots, n$$

$$u_i, v_j \geq 0$$

where,

δ_o = the efficiency score of the DMU 0 under analysis; n = number of DMUs under analysis;

i = number of outputs; j = number of inputs;

$Y_k = (y_{1k}, y_{2k}, \dots, y_{ik}, \dots, y_{lk})$ is the vector of outputs for DMU k with y_{ik} being the value of output i for DMU k ;

$X_k = (x_{1k}, x_{2k}, \dots, x_{jk}, \dots, x_{lk})$ is the vector of inputs for DMU k with x_{ik} being the value of input j for DMU k ;

μ and v the vector on multipliers respectively set on Y_k and X_k where μ_i, v_j = the respective weights for output i and for input j ;



References

- [1] Burgat, P. and Jeanrenaud, C., *Measure de l'efficacité productive*, Working Paper IREER, Universitat de Neuchatel, 1990.
- [2] Distexhe, V., *L'Efficacité Productive des Services D'Enlèvement des Immondices en Wallonie. Cahiers Economiques de Bruxelles* 137, p.p. 119-138, 1993.
- [3] Gaiola, A.J.F., Efficiency Evaluation in the Urban Solid Waste Systems of Portugal Using Data Envelopment Analysis, *Symposium at a Glance*, Moscow, 2002.
- [4] Haas, D.A., Murphy, F.H., and Lancioni, R.A., Managing Reverse Logistics Channels with Data Envelopment Analysis. *Transportation Journal* 42(3), p.p. 105-113, 2003.
- [5] Jenkins, L. and Anderson, M., A Multivariate Statistical Approach to Reducing the Number Variables in Data Envelopment Analysis. *European Journal of Operational Research* 147, p.p. 51-61, 2003.
- [6] Segal, G.F., Moore, A.T. and Nolan, J., *California Competitive Cities: A Report Card on Efficiency in Service Delivery in California's Largest Cities*, Reason Public Policy Institute, California, 2002.
- [7] Whortington, A.C. and Dollery, B.E., Measuring Efficiency in Local Government: An Analysis of New South Wales Municipalities Domestic Waste Management Function. *Policy Studies Journal* 29(2), p.p. 4-24, 2001.

