Efficiency evaluation in the Urban Solid Waste Systems of Portugal using Data Envelopment Analysis

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Abstract

The present work evaluates the efficiency of collection, separation, valorisation and treatment of urban solid waste in the Urban Solid Waste Systems of Portugal by applying an econometric non-parametric technique: technical efficiency and cost minimisation of input needs were reached by the application of Data Envelopment Analysis. The data was obtained by requesting financial information for the year 2000. The sample covered almost 40% of the total population. This research aims to make a contribution to the evaluation of efficiency in the Urban Solid Waste Systems of Portugal.

Keywords: Urban Solid Waste, Data Envelopment Analysis, efficiency analysis

1. Introduction

Citizens make more demands on economy, efficiency and effectiveness in the management of public resources; so, it is the State's concern to establish measuring systems that facilitate the evaluation of the rationality and the results of management decisions, which are mainly related to restrictions of a budgetary nature or changes in legislation.

The evaluation of organisations that offer services of a public nature is a difficult task to carry out, as firstly, they pursue multiple objectives, which are sometimes ambiguous and contradictory, and secondly, there is the difficulty in measuring their outputs in quantitative terms. Those aspects make it difficult to choose indicators, which can offer an adjusted vision of the activity and performance of those organisations, instead of the use of profit as a measure, as happens in private companies.

The present work tries to evaluate efficiency in Urban Solid Waste Systems (collection, separation, valorisation and treatment services of Urban Solid Waste - USW), being motivated by the non-existence of empirical evidence regarding management performance in the sector, and trying in this way to identify efficient and inefficient USW Systems, besides the establishment of a relative order of merit.

The efficiency evaluation will be done using the Data Envelopment Analysis (DEA) method that enables the establishment of a relative efficiency indicator when comparing homogeneous Decision Making Units (DMU) that are characterised by the non-existence of previous suppositions regarding a production function and that obtain multiple outputs due to the contribution of multiple inputs.

Over the last two decades diverse studies have been published on the use of DEA in the public sector, mainly in the sectors of health, education, transport and local public services and more recently in the private sector as can be observed in the extensive bibliographical summary of articles, working papers and thesis carried out by Emrouznejad and Thanassoulis (1996). In particular, Ancarani (2000) applied the model to the water supply and residual water collection services in Sicily (Italy) and Prior et al (1993) have applied it in the evaluation of management efficiency in the urban solid waste collection services in a sample of municipalities in Catalonia (Spain).

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This paper has been structured in the following way: in the second section the Urban Solid Waste sector is characterised. The following point (section 3) describes the Data Envelopment Analysis method. In section 4, the methodology used is presented, proceeding to the determination of the characteristics of the sample, and, in the following section, the main results are presented. Finally, conclusions and references are presented.

2. The Systems of Urban Solid Waste in Portugal

In 1995, Urban Solid Waste (USW) management in Portugal related almost solely to garbage collection and deposit without differentiation, in the more than 300 non-controlled drains, making up the existing municipal systems (INR, 1999). Following Directive 94/62/CE of the European Commission, which imposed goals related to waste valorisation, and Directive 1991/31/CE, related to the norms of drain management, the reform process of USW management started, leading to the Strategic Plan of Urban Solid Waste (SPUSW).

The main objectives of the Plan's first phase, such as the closing of non-controlled drains and provision of USW management infrastructures, have already been reached. In the second phase, it is sought to optimise management of the existing systems through technical and legislative measures, in order to implement a model that assures the quality of the service and self-sustain the systems in the long term, in economic-financial terms.

That strategy presumes the rationalisation and optimisation of the available resources through the introduction of integrated management procedures, the creation of USW analysis methodologies and the establishment of performance indicators, which facilitate efficiency and effectiveness in performance and the evaluation of management results.

Urban Solid Waste management as an economic activity is not accessible to private companies or other entities of the same nature, except under concession and managed through USW Systems. At the present time, exploitation and management of USW Systems, in terms of Act nº 379/93, of November 5, concerns:

- Multimunicipal Systems (MS) are characterised by their strategic nature and for investment rely predominantly on the State due to reasons of national interest. In general, their management and exploitation is made by concession to a company whose capital is distributed in 51% of a State holding and the remainder to all the municipalities of the System's affected area;
- Municipal Systems (MS) which make up all the others, whose management and exploitation can be made by the municipalities or municipality associations or attributed, by concession, to public or private companies of an entrepreneurial nature. When the company owner of the System is an association of municipalities, whatever its management model, we call it, Intermunicipal System (IS).

3. The Data Envelopment Analysis (DEA) Method

The use of primary indicators and performance or productivity ratios in the evaluation of USW Systems presents some limitations. Besides giving an incomplete picture of the companies' activity, resulting in aggregation problems, they hinder the clarification of the real explanatory factors of efficiency and especially of inefficiency.

However, bearing in mind the difficulty in determining and valuing the output and the lack of knowledge of each input participation level in obtaining the observed activity levels, it is impossible to determine a production function and consequently, to use deterministic models in efficiency measurement (Norman and Stoker, 1991). Consequently, the existence of other indicator categories of a synthetic nature that summarise a series of data regarding the multiple dimensions of the same output, elaborated from functional relationship or economical models (Pina Martinez and Torres Pradas, 1999) will allow an integral visualisation of the companies.

The Data Envelopment Analysis (DEA) method of Charnes, Cooper and Rhodes (1978), later referred to as CCR, based on studies of Farell in 1957, has tried to summarize, in relative terms, the global efficiency of the activities developed by non-profit units (Decision Making Units - DMU) using a numeric indicator that includes, besides the internal aspects, environmental variables outside its control which affect efficiency.

The DEA is framed in the set of the non parametric frontier production function models, which are particularly useful in evaluating public service activities, by building an efficient frontier starting from empirical observations, avoiding "the necessity to establish ponderability a priori and making previous presumptions on the form of the production function" (Prior et al.: 1993, 276). In the initial formulation of the problem CCR (1978) each segment of the efficiency frontier presumed that the average and marginal productivity are the same (constant returns to scale) (1).

The DEA methodology synthesises the group of efficient DMUs in a lineal production frontier; the efficient DMUs define a production limit that, in an economic sense, represent the maximum output that some DMUs can obtain from the combinations of their current input levels, or the minimum level of necessary inputs to maintain an established level of services (SDC, 1995).

The determination of relative efficiency indicators in the DEA formulation problem presumes the application of fractional lineal programming techniques that consist of maximising the efficiency ratio of each evaluated DMU that is characterised by the use of multiple inputs, independent of arbitrary ponderation, in obtaining or producing multiple outputs. Either the inputs or the outputs can adopt a great variety of forms and be expressed in any unit of measure, as long as they maintain their homogeneity in all the DMUs, that is to say, they should present common characteristics to be comparable.

The solution of the problem leads to a relative order of efficiency among the evaluated units, ensuring the highest valuation possible to each DMU, which does not mean that the DMU with the best classification has obtained its maximum possibilities, but rather those that are under can improve their level. This means that the optimal DMU requires less input to obtain the same output or, with the same input, obtains more output. That order only remains while the elected DMUs, the elected input and output variables and respective assumed values are constant, which presumes that this DEA generates optimal DMUs in those conditions; a change in one of these, presumes a change in the relative order produced.

For Pina Martínez and Torres Pradas (1995) the information facilitated by the DEA presents 4 components:

- the relative efficiency indicator, that is to say, a total productivity ratio of the factors which compares the productive activity of each evaluated DMU with the other technologically homogeneous ones (Lozano Chavarría and Mancebón Torrubia, 1999);
- the range that indicates the quantities of input and output to diminish and to increase respectively to make each evaluated DMU efficient, that is to say, the excess of consumed resources or the insufficient output production which is determined by subtracting the current values of inputs/outputs of the DMU from the ideal values of the optimal DMU (Al-Shammari, 1999);
- the DMUs that are taken as a reference point;

- the coefficients that point out the importance of each indicator in the determination of efficiency.

Therefore, the model facilitates information on "the input and output levels that could be reached in an efficient situation and the services level that could be made if they decreased the available resources, or contrarily, the resources that would be necessary to assist to an increment in the demand" (Pina Martínez and Torres Pradas: 1995, 184). The DEA is in this way a benchmarking technique that is gaining importance due to the possibility that it offers establish improvements in the inputs consumption or outputs production (Soteriou and Stavrinides, 2000) and in consequence in efficiency by the improvement in organisations' productivity indicators.

The initial formulation of the problem that presents a more direct relationship with the ratio analysis is

$$Máxh_0 = \frac{\sum_{r=1}^{s} u_{r0} y_{r0}}{\sum_{i=1}^{m} v_{i0} x_{i0}}$$

$$\text{s. a. } \frac{\sum_{r=1}^{s} u_{r0} y_{rj}}{\sum_{i=1}^{m} v_{i0} x_{ij}} \le 1$$

$$j = 1, ..., n \qquad u_{r0} \ge 0, r = 1, ..., s \qquad v_{i0} \ge 0, i = 1, ..., m$$

The unit whose efficiency is to be evaluated is denoted by the subindex 0; y_{rj} and x_{ij} represent, respectively, the quantities of output *r* and of input *i* of the DMU *j*; y_{r0} and x_{i0} represent the values of the DMU that we evaluate; and finally u_{r0} and v_{i0} reflect, respectively, the ponderability coefficients attributed to the output *r* and to the input *i* corresponding to the DMU whose efficiency is sought to evaluate. The value of h_0 indicates the pondered relation between the inputs and outputs of the efficient units and that employed by the evaluated unit.

When the estimated efficiency of a DMU is inferior to one it means that it is inefficient in relation to the subset of units, which it is compared with and constitutes its reference set (Prior et al., 1993). The optimal values u^*_{ro} e v^*_{io} obtained from the solution of the problem provide the evaluated unit with the highest possible estimate of efficiency (h_0) that can vary for each evaluated DMU. The set of values u^*_{ro} e v^*_{io} constitute the coefficients of the unitary isoquant segments in which the distinct units are situated, and their relation indicates the marginal productivity of the inputs of each DMU or DMUs located in the same segment.

It is important to observe that the organisation whose efficiency is sought to determine appears as much in the objective function as in the restrictions, always guaranteeing the existence of a solution for the fractional problem with a value for the objective function between 0 and 1 (Lozano Chavarría and Mancebón Torrubia, 1999).

As CCR have demonstrated, the initial problem can be linearized

$$Máxh_0 = \sum_{r=1}^{s} u_{r0} y_{r0}$$

$$\text{s. a. } \sum_{r=1}^{s} u_{r0} y_{rj} - \sum_{i=1}^{m} v_{i0} x_{ij} \leq 0$$

$$j = 1, \ldots, n \quad \sum_{i=1}^{m} v_{i0} x_{i0} \geq 1 \quad u_{r0} \geq 0, r = 1, \ldots, s \quad u_{r0} \geq 0, r = 1, \ldots, s$$

The dual problem offers a lineal approach to the optimal production function, by the minimisation of the m input quantities for the given production levels of the s outputs.

4. Methodology and Characteristic of the Sample

The operation of the USW sector in Portugal is carried out by 14 Multimunicipal Systems (MS) that are characterised by having organisational structures of identical operation, in spite of having different dimensions and consequently different infrastructures, by 16 Intermunicipal Systems (IS) property of the Associations of Municipalities and one Municipal System.

The MS are located mainly on the coast and in regions with greater population density, while the IS are located mainly in the interior and in the south, mainly in the regions with lower population density. The management and exploitation of the IS, in most cases, is in the hands of private companies, depending on concession or provision of services contracts and on the management and exploitation model adopted by the owner.

Although all the USW Systems are legally constituted, the management infrastructures are not completely implanted, that is to say, some work in an appropriate and full way, others work partially, and the remainder are in the phase of infrastructure construction.

Concerning the procedure used in obtaining data, the annual accounts were asked for from the Multimunicipal Systems concessionaire companies' managers through the State holding, from the Associations of Municipalities and from the concessionaire or service provider companies that manage them under contract.

As for the concessionaire companies who manage Multimunicipal Systems, the balance sheet and the profit and loss sheet of the year 2000 was obtained, organised according to the accounting system for the private sector (Accounting Official Plan).

In relation to information from management organisations that run the Intermunicipal Systems, acquiring data presented some difficulties, mainly due to its confidential character. Concerning the characteristics of the collected USW, the information was obtained from the available data in the Waste Institute.

The initial sample of USW Systems was characterised like this:

Table 1 – Initial sample of Urban Solid Waste management Systems

System	Nº	%	Sample	%	% of the group
Multimunicipal	14	45,2	10	62,5	71,4
Intermunicipal	16	51,6	6	37,5	37,5
Municipal	1	3,2	0	–	–
Total	31	100,0	16	100,0	51,6

Source: Own elaboration

Answers from companies that manage MS were obtained through the holding company, concerning 62,5% of the universe. With relation to the 4 companies that have not responded, 3 of them were formed at the end of 2000 and at the beginning of 2001. With relation to the IS, for the reasons already mentioned, the rate of response was less.

It should be mentioned that the financial data obtained from the companies that run the Intermunicipal Systems presents several limitations. Concerning the Systems managed by the Municipalities' Associations, these have their accounting organised according to public accounting rules, making their records on a cash basis (receipts and expenses), which limits the possibility of establishing comparisons with respect to the activity costs. As for the Intermunicipal Systems managed under concession or a provision of services contract, each Municipal Association possesses its own management model for the USW System, implying the existence of different contract modalities and different types of service given by the companies involved, resulting in different cost structures.

In addition, although the companies have their accounting organised according to the rules of managerial accounting, their economic-financial states may not reflect exclusively the aspects of the System's management, nor the personnel employed by them, for which it was necessary to obtain these data by asking those responsible directly.

The selection of the final group of Systems to analyse was made according solely to the availability and reliability of the information. Therefore, keeping in mind the lack of consistency and homogeneity of the data, 3 IS and one MS, which was in the phase of infrastructure construction, were eliminated. The sample to consider and which constitutes the database for the application of the DEA is the following.

Table 2 – Final Sample of Urban Solid Waste management Systems

System	Nº	%	Sample	%	% of the group
Multimunicipal	14	45,2	9	75,0	64,3
Intermunicipal	16	51,6	3	25,0	18,8
Municipal	1	3,2	0	–	–
Total	31	100,0	12	100,0	38,7

Source: Own elaboration

As can be observed, the data concern almost two thirds of the universe of Multimunicipal Systems and 19% of Intermunicipal Systems, corresponding to 38,7% of the total existing USW Systems in Portugal.

5. Analyses and Discussion of the Results

The implementation of the DEA method begins by establishing the most representative indicator group of the productive and the activity factors that best define the basic objectives and the performance of the USW Systems, as Prior et al (1993) referred to, although for Pina Martínez and Torres Pradas (1999, 182) "the results show that, habitually, a reduced number of indicators is enough to explain the behaviour of the evaluated units", so the less outstanding ones should be eliminated.

Regarding the inputs the following indicators were chosen:

- current costs of the service, that is to say, operational costs and financial costs (in euros);
- personnel costs (in euros);
- number of USW Systems employees, which, in spite of also being a variable, is a non financial indicator.

In relation to outputs, the indicators are the following:

- total USW production in the area attached to each System (in tons);
- quantity of selective collection, that is to say, waste collected separately for later recycling (in tons);
- USW Systems' beneficiaries, or in other words, the number of people resident in its geographical area.

The selection of the variables was kept as in Prior's et al (1993) study, who chose the beneficiaries of the service and the USW production as outputs and the cost of the service and the employed personnel in relation to the inputs, as this was found to be appropriate to our study.

In this work, we have added only two more variables, one of input and another of output for two reasons. Firstly, the limitation of the data obtained concerning availability, comparability and reliability. Secondly, for the DEA to operate more powerfully, the number of DMUs needs to be at least double the sum of the input and output variables (Drake and Howcroft, 1994) or even triple as Stern et al (1994) refer to, mentioned in Avkiran (1999). However, Avkiran (1999) considers that the DEA, to discriminate effectively between efficient and inefficient DMUs, hardly needs the sample to be superior to the product of the variable input by the variable output, that is, the ratio $\frac{N^{o}\,DMU's}{N^{o}\,inputs * N^{o}\,outputs}$ should be superior to the unit. In this study, the ratio assumes a minimum of 1,33 and a maximum of 3,00 meeting the requirement established by the author.

In aggregated terms, we have chosen a series of 6 DEA models, defined from different combinations of input and output indicators, through which efficiency is evaluated.

Table 3 – DEA Models applied in the USW Systems

		DEA 1	DEA 2	DEA 3	DEA 4	DEA 5	DEA 6
Outputs	USW production	X	X	X	X	X	X
	Selective collection		X		X		X
	Beneficiaries	X	X	X	X	X	X
Inputs	Nº employees	X	X			X	X
	Personnel costs			X	X	X	X
	Operative costs	X	X	X	X	X	X

The difference between the models is centred on the use, alternatively, of the personnel variable in terms of operative cost or the number of operatives in the service, and another model with the combination of the two variables. Another aspect was to observe what is the specific impact of the selective collection output variable.

The development of the DEA technique resorted to the Frontier Analyst software, through the dual formulation of the problem, which consists of minimizing the consumption of resources given a set of fixed outputs, as Prior et al (1993) did, bearing in mind that USW management is a service to the population with some standard characteristics. The results obtained are shown in table 4.

Table 4 – Estimated efficiency of DEA Models

SYSTEM	DEA 1	DEA 2	DEA 3	DEA 4	DEA 5	DEA 6	AVERAGE
MS-A	0,63	0,63	0,55	0,55	0,63	0,63	0,60
MS-B	1,00	1,00	0,99	1,00	1,00	1,00	1,00
MS-C	1,00	1,00	1,00	1,00	1,00	1,00	1,00
MS-D	0,73	0,87	0,74	0,85	0,75	0,87	0,80
MS-E	0,83	0,84	0,78	0,80	0,83	0,84	0,82
MS-F	0,75	0,75	0,69	0,70	0,75	0,75	0,73
MS-G	0,87	1,00	0,69	0,70	0,87	1,00	0,86
MS-H	0,94	1,00	1,00	1,00	1,00	1,00	0,99
MS-I	0,47	0,47	0,56	0,56	0,56	0,56	0,53
IS-J	1,00	1,00	1,00	1,00	1,00	1,00	1,00
IS-K	0,60	0,60	0,74	0,74	0,74	0,74	0,69
IS-L	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Source: Own elaboration

The most efficient DMU is the one that needs lowest input quantities to produce an output unit, observing that the inefficient units are always the same in all the models, with the exception of the MS-G unit that is efficient in the DEA 2 and 6 and the MS-H unit that is inefficient only in the DEA 1.

With the purpose of reinforcing the extracted conclusions of the 6 models, from the variable data used in the DEA and the data regarding the population of the area served by each unit, the input and output indicators shown below were elaborated.

Table 5 – Output indicators of USW systems

SYSTEM	USW production/ inhabitant (Kg)	Selective collection/ inhabitant (Kg)	Recycling rate	USW collection (2)/ employee (Kg)
MS-A	346	9,8	2,8%	1.967
MS-B	322	13,0	4,0%	2.619
MS-C	348	8,3	2,4%	2.809
MS-D	390	19,3	4,9%	2.504
MS-E	365	12,5	3,4%	2.504
MS-F	355	9,8	2,7%	2.327
MS-G	551	24,1	4,4%	4.702
MS-H	574	28,7	5,0%	2.950
MS-I	723	19,4	2,7%	1.666
IS-J	301	5,9	2,0%	18.277
IS-K	372	6,4	1,7%	1.943
IS-L	513	16,4	3,2%	3.681

Source: Own elaboration

Table 6 – Input indicators of USW systems

SYSTEM	Operative costs/ USW collection (€)	Operative costs/ inhabitant (€)	Personnel costs/ USW collection (€)	Productivity (VAB/ Nº employees) (€)
MS-A	22,5	7,8	8,6	82.839
MS-B	13,4	4,3	5,5	59.348
MS-C	12,3	4,3	4,5	53.321
MS-D	18,0	7,0	5,5	61.712
MS-E	15,2	5,5	6,7	63.288
MS-F	18,1	6,4	6,5	64.715
MS-G	21,0	11,6	5,3	216.766
MS-H	9,9	5,7	4,5	53.442
MS-I	20,0	14,4	7,6	55.351
IS-J	31,7	9,5	0,3	36.829
IS-K	22,2	8,3	4,7	9.787
IS-L	9,3	4,8	5,0	26.330

Source: Own elaboration

It is observed that the input variable of personnel costs has a negative impact on the DMUs MS-A, MS-E, MS-F and MS-G that is explained by having the highest personnel cost per collected ton. On the contrary, the variable number of employees has a negative impact on the DMUs MS-I and IS-K.

In general terms, we can affirm that the selective collection variable does not produce outstanding effects in the analysis, except in the systems managed by units MS-D and MS-G, bearing in mind the USW recycling rate and the quantities of selective collection per inhabitant, as can be observed in table 5.

Another conclusion refers to the Systems managed by units MS-A, MS-I and IS-K being the most inefficient in average terms, mainly due to the low population of its area of influence when compared to the remaining systems, so the number of collected tons by employee is significantly smaller. In addition, this is also due to the fact that operative and personnel costs per collected ton, in general terms, are the highest in the sample, as is demonstrated in table 6.

Therefore, it can be seen that models 5 and 6 which include all the input variables, are those that register the highest coefficients of efficiency, keeping in mind that they show the best aspects in each DMU. Considering the unit MS-I result in DEA 6 (0,56) which is relatively the most inefficient DMU, this means that the efficient DMUs (MS-B, MS-C, MS-G, MS-H, IS-J and IS-L) can obtain at least the level of each output of DMU MS-I using as a maximum 56% of the resources (inputs) used by the latter. Or then that the DMU MS-I should produce its current output level with 56% of the available resources, or using 44% less consumption.

In tables 7 and 8, the optimal values associated with each variable of the DEA 6 are shown in both output and input terms, as well as the positive or negative variation, in absolute and relative terms.

Table 7 – Increase in the output variable values for relatively inefficient DMUs

	Production of USW				Selective collection				Beneficiaries			
	Real value	Optimal Value	Vari-ation	%	Real value	Optimal Value	Vari-ation	%	Real value	Optimal Value	Vari-ation	%
MS-A	27.537	27.537	0	0,0	779	779	0	0,0	79.480	79.480	0	0,0
MS-D	165.276	187.446	22.170	13,4	8.167	8.167	0	0,0	423.538	423.538	0	0,0
MS-E	107.692	107.692	0	0,0	3.691	3.691	0	0,0	295.087	295.087	0	0,0
MS-F	344.390	344.390	0	0,0	9.466	9.466	0	0,0	969.803	969.803	0	0,0
MS-I	283.166	283.166	0	0,0	7.619	13.660	6.041	79,3	391.819	519.697	127.878	32,6
IS-K	79.653	79.653	0	0,0	1.365	2.377	1.012	74,1	213.984	213.984	0	0,0

Source: Own elaboration

In spite of the DEA model being guided towards the minimisation of inputs, bearing in mind some fixed outputs, it still determines what is the possible increment regarding each one of the DMU variables. It is observed that it is possible to register a 32,6% population increase in the geographical area of the MS-I unit. As for selective collection, very significant increases of 79,3% and 74,1% can be registered, in the geographical area of units MS-I and IS-K.

Table 8 – Decrease in the output variable values for relatively inefficient DMUs

	Nº employees				Personnel costs				Current costs			
	Real value	Optimal Value	Vari-ation	%	Real value	Optimal Value	Variation	%	Real value	Optimal Value	Variation	%
MS-A	14	9	-5	-35,7	237.932	119.996	-117.936	-49,6	620.111	393.596	-226.514	-36,5
MS-D	66	57	-9	-13,6	916.656	772.528	-144.128	-15,7	2.977.724	2.593.420	-384.304	-12,9
MS-E	43	36	-7	-16,3	718.084	535.719	-182.365	-25,4	1.633.164	1.366.103	-267.061	-16,4
MS-F	148	111	-37	-25,0	2.231.103	1.514.041	-717.062	-32,1	6.250.421	4.702.023	-1.548.398	-24,8
MS-I	170	91	-79	-46,5	2.165.152	1.215.486	-949.666	-43,9	5.658.274	3.176.470	-2.481.804	-43,9
IS-K	41	22	-19	-46,3	371.724	276.783	-94.941	-25,5	1.769.156	1.317.305	-451.851	-25,5

Source: Own elaboration

As for the inputs, the possibility of having reductions is observed both in operational and personnel costs, as well as in the number of employees, which always show very significant values as is the case of the number of employees in units MS-I and IS-K, with respectively, 46,5% and 46,3%, the personnel costs in units MS-A and MS-I, of 49,6% and 43,9% and current costs in the case of the companies MS-I and MS-A, of 43,9% and 36,5%.

Finally, based on the average of the models, the following table was also obtained:

Table 9 – Resumed table of average efficiency of DEA Models

Systems	Efficiency		Inefficiency				Total
			> 0,8		< 0,8		
	Nº	%	Nº	%	Nº	%	
Multimunicipal	2	22,2	4	44,5	3	33,5	9
Intermunicipal	2	66,7	0	–	1	33,3	3
Total	4	33,3	4	33,3	4	33,3	12

Source: Own elaboration

Regarding the average of the sample, 33,3% of the companies that manage USW Systems are efficient and 33,3% have an inefficiency index superior to 0,8. As for Multimunicipal Systems, which represent 75% of the total sample, only 2 are efficient, in spite of the System MS-H having an average of 0,99, meaning that 44,5% of the companies that manage the MS possess inefficiency superior to 0,8.

Conclusions

The good function of USW Systems supposes that the citizens have means that facilitate the correct garbage collection, maximising selective collection, with the appropriate periodicity and with minimum costs. So for that to happen, infrastructures and equipment should be adapted and managed in a rational way, assuring the effectiveness and self-sustainability of the Systems.

The establishment of a widely accepted set of indicators for the activity and quality evaluation of the services provided to the population will allow to compare and evaluate the most outstanding aspects over time.

This work has tried to give a first approach to efficiency evaluation in USW Systems in Portugal using the DEA method that contemplates the multiple dimensions of companies when evaluating the influence of the diverse factors on efficiency, providing a relative efficiency valuation for each DMU and suggesting lines of action for a better use of resources in the inefficient Systems, while still being of use as a complementary indicator of other indicators.

In conclusion, in spite of the established indicators showing that a third of the companies that run USW Systems are efficient, these data can be influenced regarding the Intermunicipal Systems, bearing in mind the reliability of the economic-financial data. In fact, according to Avkiran (1999) one of the main disadvantages of the DEA method, is that, when the integrity of the data is breached, information cannot be interpreted with trust. However, we believe that the fact that most Systems have not finished their investments can influence negatively their efficiency evaluation.

In spite of the pioneering nature of this work, in the use of the DEA method in Portugal, where we do not know of any other study that makes use of this methodology, as well as in the novel character of the analysis in the USW sector, this work presents diverse limitations that allow for further investigation in this area.

The establishment of mechanisms that allow the comparability of efficiency indicators of Multimunicipal Systems and Intermunicipal Systems, can be resolved with the implantation of the Accounting Plan for the Local Municipalities in Portugal in the Intermunicipal Systems.

Furthermore, the non existence of reliable data could be solved through the compulsory delivery of the annual accounts to the Waste Institute, leading in consequence, to the publication of annual indicators, to the dissemination of those indicators in the companies and to the widespread implementation of standard systems of management accounts.

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(1) The initial position has evolved for the model of Banker, Charnes and Cooper (BCC, 1994), based on variable returns to scale, that is to say, the growth of the outputs related to the inputs is more than proportional, although this methodology will not be developed here.

(2) The variable USW production is the same as the variable USW collection, once all the produced waste is collected. The reason for the change is the fact that they are aspects of different analyses.

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