Decision Support of Waste Management Expenditures Efficiency Assessment

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Abstract. This paper is devoted to the development of methodology and information and communication technology tools for decision support in the public sector. It analyses appropriate metrics for a municipal solid waste management expenditure (MSWE) efficiency assessment using cost-effectiveness Analysis (CEA). In addition to many other methodological issues, finding a proper output (performance, outcome) measurement is important. From the point of view of municipalities, such a measurement ought to be as clear and simple to use as possible. We analyse three possible criteria – total generated municipal solid waste, population, and municipality area – for evaluating MSWE efficiency in order to examine their appropriateness for municipal administration. The analysis covers three years, from 2009 to 2011, and municipalities from the South Moravian Region of the Czech Republic. We focus on a sample of 21 municipalities with specific administrative status. Expenditures were estimated using open public data from the Czech Ministry of Finance municipal accounts database. Correlation analysis showed a very strong relationship between the three chosen criteria. Public administration can certainly use all of the criteria for an efficiency assessment of MSWE to aid in decision making. However, the most suitable criterion to be population, since efficiency analysis results showed a strong correlation between population and both CEA for waste amount and CEA for municipality area. Moreover, population has a stronger relationship with MSWE than either of the other two criteria.

Keywords: cost-effectiveness analysis, municipal expenditures, efficiency, waste management, decision support, ICT, municipal solid waste.

1 Introduction

Defining and measuring the efficiency of environmental protection expenditures in the process of using public resources and their transformation into outputs and outcomes is an important issue of decision support in the public sector [22-23], [26]. Efficiency evaluation and its methodology and use of information and communication technology (ICT) tools have greatly improved and advanced in recent decades.

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However, efficiency evaluation still remains a conceptual challenge in relation to public expenditures. Although the amount of expenditures spent in a specific area is important, another key characteristic for decision support in public administration is (or should be) the efficiency of the spending. The efficiency affects the extent of a utility and the rate of satisfying people's needs. Efficiency can be perceived as a rational criterion for the actions of involved subjects and a key category of the economic approach for analysing and evaluating social processes [20], [34]. This economic rationality comes from the idea that rational action consists of the efficient use of limited resources for the purpose of maximizing goals or achieving desired use [34]. This is complicated by the fact that public sector outcomes (especially in environmental protection) are often off-market, lacking relevant data, and thus difficult to quantify, as stated by a collective group at the European Commission [21]. In such cases, cost-effective Analysis (CEA) appears to be the most useful tool for efficiency assessment [5], [19]. Quite a few studies dealing with this topic have been published in economic journals. A CEA of environmental protection expenditures was examined by [1], [9-11], [24], [28], [32-33]. A CEA for the centralized waste treatment industry was discussed in [9], [11] and [32]. Anderson [1] conducted a CEA of proposed effluent limitations and standards for industrial waste combustors [10] focused on remediation. Papageorgiou, Barton and Karagiannidis [24] focused on the impact of technologies used for energy recovery from municipal waste. Market structure and refuse collection of municipal waste was studied in [28]. Willan and Briggs [33] compared the results of relevant CEA studies.

Studies [7], [22-23], [27], [29-30] dealing with issue of efficiency in the field of waste management in the Czech Republic and Slovakia have been focused on contractual issues and on the impact of competitiveness on efficiency [27]. Data envelopment analysis for evaluating MSWE was used in [7] and [23]. We developed a simple model for calculating an ideal amount of municipal solid waste expenditures [29] based on the characteristics of the municipality.

Municipal solid waste management costs (and consequently the expenditures (MSWE) that are at the centre of our concern) are determined by numerous variables. There is extensive literature dealing with this issue, including [1], [11-12], [17-18], [24], [27]. The following variables have the largest impact:

- total generated solid municipal waste [t];
- population [number of inhabitants];
- area of municipality [km^2];
- distance from the municipality to the waste facility site [km];
- competitive environment;
- ownership type of collecting company (private, public);
- size of household;
- impact of income;
- other socioeconomic variables.

Given this number of variables, it could be quite costly to obtain the information needed for a serious efficiency assessment for public administration bodies such as municipalities. It is necessary to decide how much and what type of information is worth gathering [26]. Even a simple comparison in order to obtain a benchmark could be complicated. However, municipality representatives cannot conduct a complicated and sophisticated analysis on a daily basis in order to understand if they are doing well with their budgets and receiving good value for their money. A simple and robust efficiency assessment tool is needed to support their decision making.

There is a wide range of indicators for measuring *output* in waste management and in any other infrastructure service, as well as for measuring *outcomes* (defined as the impact of a service on its recipients [26] – for example, the impact of solid waste collection on environment protection). Esfahani [26] offers more than ten "performance measures" for sanitation infrastructure; some of them can be easily adapted to waste management.

We analyse a) *amount of solid waste*; b) *population*; and c) *municipal area* as criteria for "effectiveness measures" [26] in a CEA evaluating MSWE efficiency, in order to examine the use of these criteria for municipalities. The analysis covers three years, from 2009 to 2011, and the selected analysed sample consists of all the municipalities from the South Moravian Region of the Czech Republic. We focus on 21 municipalities with specific administrative status. Expenditures were estimated using open government data from the Czech Ministry of Finance municipal accounts database [2], [31]. The aim of this paper is to create a methodology and ICT tools for decision support of municipality decision makers enabling benchmarking with other municipalities.

2 Methods and Data for Decision Support

We chose cost-effectiveness analysis (CEA) as a simple metric for evaluating MSWE efficiency in public sector decision support. We intended to find the simplest method for considering and evaluating select criteria c_{ij} , $i = 1,..,k$ for j-municipality of a set of n municipalities of a given region.

The basic algorithm for decision support in MSWE efficiency consists of the following steps:

1. collecting the set of MSWE data $\boldsymbol{e} = \{e_1, e_2\ldots, e_n\}$ from linked open data, where n is the number of considered municipalities;
2. setting the matrix C of selected criteria $\{c_{ij}\}$, $i = 1\ldots k$, $j = 1\ldots n$ for the evaluation of cost-effectiveness of MSWE in n municipalities;
3. collecting data of criteria c_{ij}, $i = 1...k$, $j = 1\ldots n$ from linked open data;
4. calculating the ratios $\text{CEA}_{ij} = e_j/c_{ij}$, $i = 1\ldots k$, $j = 1\ldots n$ for each individual criterion c_{ij} and each municipality expenditure e_j;
5. trimming values (reducing extreme values within samples) by chosen statistical tests;
6. comparing CEA_{ij} results in analysed samples of n municipalities;
7. choosing individual criteria c_{mj} in CEA m from $\{1,2,\ldots,k\}$, for $j = 1\ldots n$ and their utilization.

The above algorithm for decision support in evaluating MSWE efficiency was implemented in Maple [8], [13] connected with MS Excel. We analyse current MSWE e_j, $j = 1\ldots n$. The idea behind CEA is either minimizing CEA_{ij} i.e. e_j/c_{ij} ratio or maximizing $1/CEA_{ij}$, i.e. c_{ij}/e_j ratio, for i=1,..,k, j=1,…,n.

The most efficient municipality administration of the given region is then considered as the administration that attains either the lowest e_j/c_{ij} ratio or the highest c_{ij}/e_j ratio [19].

When we use the e_j/c_{ij} ratio, the cost-effectiveness of a given expenditure can be expressed as follows:

$$\min \{CEA_{ij}\} \tag{1}$$

There are several sources of linked open data in the above algorithm: *municipal area* and *population* were taken from the Czech Statistical Office (CZSO); *amount of generated municipal solid waste* was taken from the information system of the waste management database [16] provided by CENIA (Czech Environmental Information Agency): and MSWE were downloaded from the Czech Ministry of Finance's ARIS [2] and ÚFIS [31] databases. CZSO publishes a MSWE database as well, however, these linked open data are published only for larger administrative municipality units and are not exactly those we need. Such slight differences among data provided by CZSO and the Ministry of Finance in terms of expenditures have been noted by [3] and are most likely results of either incorrect reporting or differences in methodology.

Our sample from all of the municipalities of the Czech Republic consists of 672 municipalities[1] from the South Moravian Region (SMR) of the Czech Republic. We analysed municipalities in the whole SMR, and then conducted a more detailed analyses on a selected sample of 21 municipalities with specific administrative status usually abbreviated as ORPs. These municipalities are former county administrative capitals and represent over 50% of total population of the SMR.

3 Outcomes and Discussion

We chose the following three criteria for the CEA:

- c_{1j} – total generated solid municipal waste [t] for the first CEA_1,
- c_{2j} – population for the second CEA_2 [number of inhabitants]

c_{3j} – area of municipality [km^2] for the third CEA_3We next calculated the individual CEA_{ij} for a selected sample of municipalities. We used data trimming [16] to reduce the original sample to an appropriate size. The following table contains the calculated ratios for municipalities of the SMR.

[1] The South Moravian Region officially has 673 municipalities. One of them, Březina, is a former military area that still operates under a special regime and has only a few permanent residents. We did not include it in our analysis. Some municipalities did not report certain characteristics, and are thus not included in sample for certain analyses.

Table 1. Results of CEA for all municipalities from the South Moravian Region

	CEA_1			CEA_2			CEA_3		
Year	2009	2010	2011	2009	2010	2011	2009	2010	2011
Sample siz n	595	602	542	672	672	672	672	672	672
mean	3 126.6	2 779.4	93 376.1	565.9	578.5	577.2	59 044.2	61 071.5	60 986.2
σ	10 993.5	3 282.0	1 737 375	258.0	257.4	258.9	103 130.8	102 731.2	100 421.6
γ_2	515.3	460.6	517.8	70.7	55.2	58.9	151.5	96.9	92.6
γ_1	22.2	20.3	22.6	6.5	5.7	5.9	10.5	8.6	8.4
$mean_{(0.05)}$	2 526.6	2 587.2	2 740.5	546.5	559.7	557.8	49 115.4	50 576.2	50 665.6
$\sigma_{(0.05)}$	749.8	678.8	951.0	132.5	140.1	139.1	40 479.2	41 475.4	41 737.6
$\gamma_{2(0.05)}$	0.9	0.0	9.4	0.2	0.5	0.3	5.8	5.7	6.0
$\gamma_{1(0.05)}$	0.8	0.5	2.3	0.7	0.8	0.8	2.2	2.2	2.3

Source: Authors *σ - standard deviation, γ_2 – kurtosis, γ_1 – skewness, (0.05) – 5% trimmed sample

When considering c_{1j} criterion, we can see that CEA_1 values show significant differences, especially in 2011[2]. We used data trimming methods [33] to provide results for a 5% trimmed sample, using Maple [13] for the whole SMR. The following table contains calculated ratios CEA_i , i=1,2,3 for 21 ORPs of the SMR.

Table 2. Results of CEA for 21 ORPs from the South Moravian Region

	CEA_1			CEA_2			CEA_3		
Year	2009	2010	2011	2009	2010	2011	2009	2010	2011
Sample size n	21	21	21	21	21	21	21	21	21
mean	2 836.3	3 006.3	3 109.9	673.1	683.4	681.9	318 123.2	315 086.3	308 977.9
σ	1 081.0	1 222.4	1 106.1	209.0	219.7	197.5	353 421.2	294 602.2	270 815.1
γ_2	2.4	3.7	1.5	4.8	4.6	5.7	16.6	11.1	11.9
γ_1	0.1	0.7	-0.5	-1.1	-0.5	-1.6	3.9	3.1	3.1
$mean_{(0.1)}^*$	2 841.6	2 971.9	3 168.7	684.6	690.0	700.9	255 775.4	271 115.9	268 670.5
$\sigma_{(0.1)}^*$	689.2	700.4	803.4	115.8	116.1	116.7	257 434.8	247 240.9	258 790.1
$\gamma_{2(0.1)}^*$	0.2	0.1	-0.8	-0.2	0.3	0.0	0.4	5.2	1.1
$\gamma_{1(0.1)}^*$	0.6	1.0	0.7	0.4	0.9	0.9	0.4	1.8	1.0

Source: Authors *σ - standard deviation, γ_2 – kurtosis, γ_1 – skewness, (0,1) – 10% trimmed sample

Table 2 shows that the presented data do not have a high value of standard deviation. We calculated results for a 5% trimmed sample of ORPs as in Table 1; however, due to the low number of municipalities the results were not different from the original sample. We also analysed values for a 10% trimmed sample. Even this adjusted sample did not show significant differences in results. Therefore we used the original sample of 21 ORPs for further analyses. We compared the calculated values

[2] The extreme values of mean and σ in 2011 (CEA_1) are mainly due to the municipalities Zbýšov and Telnice, both of which have a population of around 600 and relatively high MSWE, reporting just 60 and 150 kg of collected municipal solid waste. This resulted in extreme CEA_{ij} ratios that affect the mean of the whole sample.

among selected municipalities. We assume that CEA$_i$ results for criteria c_{1j}, c_{2j} and c_{3j} j=1,..,n will not differ significantly among n municipalities, and thus they can be used for MSWE efficiency evaluation. The strength of the relationship between calculated criteria $\mathbf{c}_i = (c_{i1},\ldots, c_{in})$ is shown in the following table, with $\boldsymbol{c}_1$ and $\boldsymbol{c}_2$ having strongest relationship.

Table 3. Correlation coefficients between analysed criteria for different municipality samples

	$\boldsymbol{c}_1$ & $\boldsymbol{c}_2$			$\boldsymbol{c}_1$ & $\boldsymbol{c}_3$			$\boldsymbol{c}_2$ & $\boldsymbol{c}_3$		
Year	2009	2010	2011	2009	2010	2011	2009	2010	2011
SMR	0.9979	0.9972	0.9990	0.8096	0.8061	0.8026	0.7781	0.7767	0.7767
ORPs	0.9987	0.9981	0.9997	0.9475	0.9498	0.9417	0.9384	0.9379	0.9378

Source: Authors

The following table contains comparison between CEA$_i$ results for all three variables in 2009-2011 for a 5% trimmed sample of municipalities from the SMR and then for all 21 ORPs of the SMR.

Table 4. Correlation coefficients between CEA$_i$ for different municipality samples

	CEA$_1$ & CEA$_2$			CEA$_1$ & CEA$_3$			CEA$_2$ & CEA$_3$		
Year	2009	2010	2011	2009	2010	2011	2009	2010	2011
SMR	0.4224	0.4379	0.4473	0.0603	0.0102	0.0852	0.2102	0.1868	0.1647
ORPs	0.8185	0.8764	0.9140	0.7025	0.6205	0.5144	0.6055	0.5124	0.4112

Source: Authors

Table 4 shows that CEA$_i$ results for the variables of solid waste amount and population are significantly similar, especially in the ORPs. Moreover, in the ORPs all three criteria can be used, as correlations between CEA$_i$ acquire significant values. For this reason, we tested CEA$_i$ rankings for individual i-criteria among ORPs to see whether there were significant differences among them. The average rankings and standard deviations of rankings between 2009 and 2011 are presented in Table 5.

Table 5 shows that municipalities acquire relatively stable positions if comparing efficiency in individual categories among the sample. To verify whether municipalities acquire similar positions in individual efficiency categories, we calculated standard deviations of differences among the positions that municipalities acquired in different categories.The majority of municipalities acquired positions in individual years that vary only by one or two positions. Larger standard deviations were rather rare. Municipalities acquired very close positions especially in CEA$_3$, where the largest standard deviation was 1.7 and the sum of standard deviations for 21 ORPs was only 15.3.

Table 5. CEA average ranking among ORPs and standard deviations of rankings in years

Municipality	CEA_1		CEA_2		CEA_3	
Brno	20	0.8	19	1.6	21	0.0
Znojmo	20	0.8	20	1.2	19	0.5
Hodonín	11	1.7	15	2.2	15	0.8
Břeclav	**7**	**4.1**	**16**	**0.5**	10	0.5
Vyškov	9	4.2	5	2.5	10	1.7
Blansko	17	0.5	14	0.9	17	0.5
Veselí n. M	8	0.5	10	0.5	7	0.5
Kyjov	2	0.5	4	2.4	8	1.2
Boskovice	12	1.2	10	1.7	12	0.9
Kuřim	5	1.4	4	1.9	17	0.8
Ivančice	15	1.7	17	1.2	5	0.8
Tišnov	6	1.9	10	3.6	16	1.2
Mikulov	17	0.9	20	0.5	5	0.8
Šlapanice	5	0.8	6	0.5	14	0.8
Bučovice	10	0.9	12	2.1	3	0.0
Slavkov u Brna	**17**	**1.7**	**4**	**0.8**	10	1.2
Moravský Krumlov	1	0.0	1	0.0	1	0.0
Hustopeče	11	5.4	12	2.6	5	1.2
Rosice	10	2.1	6	3.3	12	1.2
Pohořelice	8	3.3	8	0.8	2	0.0
Židlochovice	20	1.2	18	2.9	20	0.5

Source: Authors

The observation that the results are closest between CEA_1 and CEA_2 was further verified by correlation analysis (see Table 5). Average rankings for the majority of municipalities did not differ by more than 3 positions. In the ORPs, Hodonín, Tišnov, and Rosice municipalities differed by 4, resulting in a standard deviation value of around 2. We can see significant differences in rankings only in the ORPs Břeclav (9 positions) and Slavkov u Brna (13 positions)[3]. These two municipalities acquired more similar results between CEA_2 and CEA_3. For this reason, we examined the relationships of individual criteria and MSWE.

Table 6. Correlation coefficients between analysed criteria and MSWE for different municipality samples

	e & c_1			e & c_2			e & c_3		
Year	2009	2010	2010	2009	2010	2011	2009	2010	2011
SMR	0.9128	0.8900	0.9237	0.9232	0.8775	0.9583	0.5077	0.5062	0.5050
ORPs	0.9128	0.8959	0.9731	0.9626	0.9087	0.9767	0.7957	0.7980	0.7773

Source: Authors

[3] Bold values in Table 5.

Correlation analysis shows that municipalities can use all three examined criteria for MSWE efficiency evaluation. Nevertheless, based on Tables 4, 5, and 6 we suggest that the most suitable criterion for CEA evaluation is $\boldsymbol{c}_2$ – *population*. Population has strongest correlation with MSWE. The results of CEA_2 are in strong correlations with CEA_1, but compared to results of CEA_1 the results of CEA_2 have stronger correlation with CEA_3, if taking into account the sample of all municipalities from the SMR.

The amount of solid municipal waste criterion is a generally recommended indicator for measuring efficiency of MSWE, see for instance [1], [9-11], [27], [29] and [32]. This makes the results of our analysis and the optimization of the decision making process of municipal administration using CEA even more interesting, as the most suitable criterion seems to actually be population. This criterion can be recommended for two more reasons – it has a very significant relationship with the amount of solid municipal waste verified by many analyses (e.g. [4], [14-15], [27]), and the criterion is easy to acquire from open linked data [2], [25], [31] databases and generally available for all municipalities and public.

4 Conclusion

Managing the information resources in decision making processes is one of the most prominent challenges of the public sector. Better methodology and internal information management create opportunities for innovation in reducing bureaucracy and diminishing administrative costs. Local governments (municipalities) face the complexities of uncertain and evolving environment protection, including external constraints such as the changing legal framework or the evaluation of public expenditure, especially in municipal waste management. Using linked open government data in current economic theory (CEA) together with advanced ICT brings new ideas in decision support for public administration about MSWE efficiency that allow decision makers to create benchmarks for municipalities in a given region.

The completed results of the paper:

- designed an appropriate methodology for rating the cost-effectiveness of MSWE, which was implemented with the use of ICT tools;
- concluded that in similar communities (ORPs) it is possible to use any of the selected three criteria and the evaluation results (order) are similar (very distinctive colinearity);
- from the perspective of different municipalities and in terms of benchmarks, the best metric to use is *per capita expenditure*.

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