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An application of DEA method for ranking different Tehran municipality branches

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A B S T R A C T

Measuring the performance of governmental organizations plays essential role on making strategic decisions. In this paper, we present an empirical investigation to measure the performance of 22 different branches of municipalities in city of Tehran, Iran. The proposed study uses data envelopment analysis (DEA) for measuring the relative efficiencies of various units. The proposed DEA uses fixed assets, employee expenses and total income as input and Green Space Development, Resumption and Waste, Development of Cultural Spaces as well as Improvement of Passages and highways are considered as the output of the model. The results indicate that 9 regions were operating efficiently and 14 regions were inefficient.

1. Introduction

For years, there have been outstanding attempts on applying various techniques for computing the relative efficiency of similar business units (Kuah et al., 2010; Cooper et al., 2011). Data envelopment analysis (DEA) is one of the most popular methods for measuring non-financial units (Charnes, 1978) and it has been successfully applied for measuring the performance of various technologies (Khouja, 1995), in airport industry (Roghanian & Foroughi, 2010), supplier selection (Levary, 2008; Azar et al., 2011; Nourbakhsh et al., 2013) and heath care (Ghotbuee et al., 2012; Khani et al., 2012). Charnes et al. (1978, 1985, 1990) are named as the first who introduced the idea of comparing non-financial units based on different inputs/outputs. There are various kinds of DEA methods including constant return to scale, variable return to scale, input/output oriented, etc.

DEA has been extensively implemented in rural industry for several years (Minciardi et al., 2008). Rogge and De Jaeger (2012) proposed an adjusted "shared-input" model of DEA, which helps evaluating municipality waste collection and processing performances in settings in which one waste costs are shared among treatment efforts of multiple municipal solid waste fractions. The proposed

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DEA not only provides an estimate of the municipalities overall cost efficiency but also provides forecasts on the municipalities' cost efficiency in the treatment of the various fractions of municipal solid waste.

lo Storto, C. (2013) presented findings of an exploratory study aimed at evaluating expenditure efficiency of 103 Italian major municipalities. The study applied DEA to calculate an efficiency score and investigated economies of scale. Their findings disclosed that there were some scale inefficiencies in a number of municipalities that need an in depth investigation. Rogge and De Jaeger (2013) proposed an adjusted version of the popular efficiency measurement DEA, which makes it possible to evaluate the cost efficiency of municipalities in the collection and processing of multiple household waste fractions. The method is also capable of robustifying the cost efficiency evaluations for the effect of measurement errors in the data or municipalities with outlying and atypical performances. The method also corrected the evaluations for differences in the operating environments of municipalities such as demography and median income of the municipality population.

2. The proposed study

In this paper, we present an empirical investigation to measure the relative efficiency of various units using data envelopment analysis (DEA).

2.1. DEA model

2.1. The DEA method

There are literally various DEA methods and the constant return to scale DEA (CCR) introduced by Charnes, et al. (1978, 1985, 1994) is explained in this paper for measuring the relative efficiency of various decision making units (DMU). In this method we form a set of production feasibility, which constituts of various principles such as fixed-scale efficiency, convexity and feasibility as follows,

$$T_C = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1, \cdots n \right\}, \tag{1}$$

where X and Y state the input and output vectors, respectively. The CCR production feasibility set border provides the relative efficiency where any off-border DMU is stated as inefficient. The CCR model can be measured in two types of either input or output oriented. The input CCR tries to decrease the maximum input level with a ratio of θ so that, at least, the same output is produced, i.e.:

$$\begin{aligned}
&\min \quad \theta \\
&\text{subject to} \\
&\theta X_p - \sum_{j=1}^{n} \lambda_j X_{ij} \geq 0, \\
&\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{rp}, \\
&\lambda_j \geq 0, \qquad j = 1, \cdots, n.
\end{aligned} \tag{2}$$

Model (2) is an envelopment form of input CCR where θ is the relative efficiency of the DMU and it is possible to demonstrate that the optimal value of θ, θ^*, is located between zero and one. In an input oriented DEA model, once the efficiency of a DMU unit, DMU_p, lies in case of inefficiency, one may directs it towards the border to change it efficient.

2.1.1 Input/output

The proposed study of this paper uses three inputs and four outputs for measuring the relative efficiencies of various units. Fig. 1 shows details of the propsoed study.

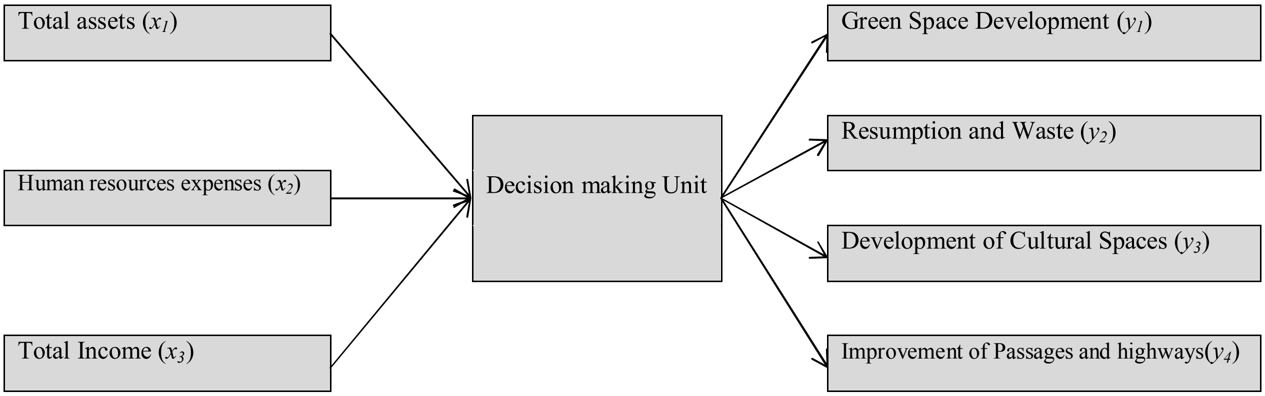

Fig. 1. The structure of the proposed study

Next, we present details of the DEA implementation based on model (2).

3. The results

We first present the optimal weights of input/output parameters computed by input oriented DEA method. Table 1 shows details of our results.

Table 1
The optimal weights of input/output

Input			Output			
x_1	x_2	x_3	y_1	y_2	y_3	y_4
0.8375001	0.623456	0.7862921	0.934251	0.5656783	0.683901	0.7745301

In addition, Table 2 demonstrates the summary of relative efficiencies of 22 units along with the values of dual variables associated with input/output.

Table 2
The results of DEA implementation

Score			Inputs			Output			
		z	V(i1)	V(i2)	V(i3)	V(i1)	V(i2)	V(i3)	V(i4)
DMU	**1**	**1.00**	**0.000**	**0.000**	**0.089**	**0.000**	**0.000**	**0.000**	**0.021**
DMU	**2**	**1.00**	**0.000**	**0.078**	**0.000**	**0.000**	**7.923**	**0.008**	**0.000**
DMU	3	0.84	0.000	0.000	0.091	0.000	0.000	0.021	0.011
DMU	**4**	**1.00**	**0.000**	**0.081**	**0.000**	**3.135**	**0.000**	**0.031**	**0.000**
DMU	**5**	**1.00**	**0.000**	**0.078**	**0.000**	**0.000**	**1.262**	**0.000**	**0.020**
DMU	6	0.93	0.018	0.000	0.070	0.000	0.000	0.020	0.012
DMU	7	0.93	0.000	0.000	0.091	0.000	0.000	0.025	0.009
DMU	8	0.89	0.000	0.082	0.000	0.000	0.000	0.013	0.016
DMU	9	0.92	0.000	0.084	0.000	0.000	0.000	0.038	0.000
DMU	10	0.81	0.000	0.000	0.000	0.000	0.000	0.038	0.000
DMU	11	0.97	0.039	0.044	0.000	0.000	0.000	0.015	0.016
DMU	12	0.90	0.000	0.082	0.000	0.000	0.000	0.014	0.016
DMU	**13**	**1.00**	**0.084**	**0.000**	**0.000**	**4.651**	**0.000**	**0.026**	**0.000**
DMU	14	0.63	0.083	0.000	0.000	0.000	1.238	0.000	0.022
DMU	**15**	**1.00**	**0.084**	**0.000**	**0.000**	**0.000**	**0.000**	**0.037**	**0.000**
DMU	16	0.93	0.019	0.000	0.071	0.000	0.000	0.020	0.012
DMU	17	0.89	0.040	0.045	0.000	0.000	0.000	0.015	0.016
DMU	18	0.94	0.083	0.000	0.000	0.000	0.000	0.011	0.018
DMU	**19**	**1.00**	**0.085**	**0.000**	**0.000**	**1.554**	**0.000**	**0.016**	**0.014**
DMU	20	0.97	0.083	0.000	0.000	0.000	0.230	0.010	0.017
DMU	**21**	**1.00**	**0.061**	**0.022**	**0.000**	**4.515**	**0.000**	**0.026**	**0.000**
DMU	22	1.00	0.079	0.000	0.000	7.042	0.000	0.000	0.000

According to the results of Table 1, 9 units are detected as efficient units and 14 units are found inefficient. The average efficiency of these 14 inefficient units is equal to 0.93, which means they have to reduce approximately 7% of their inputs. Based on the optimal weights computed for inefficient units, we may find efficient amount of inputs for the 14 inefficient units. For instance for unit 3, we have

$$x_1 \leftarrow \theta^* \text{x1} - s^{-*} = 0.84 \times 12.939 - 0.07 = 10.8,$$
$$x_2 \leftarrow \theta^* \text{x2} - s^{-*} = 0.84 \times 12.460 - 0.04 = 10.42,$$
$$x_3 \leftarrow \theta^* \text{x3} - s^{-*} = 0.84 \times 11.035 - 0 = 9.3.$$

As we can observe, unit 3 has to reduce its fixed assets, employee expenses and total income from 12.939, 12.460 and 11.035 to 10.8, 10.42 and 9.3, respectively. Similarly, we can compute the efficient numbers for other units and Table 2 summarizes the results of our survey.

Table 2
The summary of efficient resources

		EFFICENCY		Input-excess						Output-shortfall
		z	s(i1)	s(i2)	s(i3)	t(o1)	t(02)	T(03)	T(04)	
DMU	1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Lambda(dmu1)=1.00
DMU	3	0.84	0.07	0.04	0.00	0.01	0.01	0.00	0.00	Lambda(dmu1)=0.25lambada(dmu4)=0.58
DMU	6	0.93	0.00	0.11	0.00	0.02	0.03	0.00	0.00	Lambda(dmu1)=0.30 lambda(dmu4)=0.55 lambda
DMU	7	0.93	0.41	0.02	0.00	0.04	0.03	0.00	0.00	Lambda(dmu4)=0.36 lambda(dmu15)=0.56
DMU	8	0.89	0.02	0.00	0.08	0.04	0.03	0.00	0.00	Lambda(dmu1)=0.28 lambda(dmu4)=0.59
DMU	9	0.92	0.24	0.00	0.17	0.02	0.03	0.00	0.83	Lambda(dmu15)=0.88
DMU	10	0.81	0.18	0.12	0.00	0.03	0.01	0.00	1.71	Lambda(dmu15)=0.79
DMU	11	0.97	0.00	0.00	0.58	0.03	0.01	0.00	0.00	Lambda(dmu1)=0.65 lambda(dmu4)=0.21 lambda
DMU	12	0.90	0.01	0.00	0.52	0.02	0.00	0.00	0.00	Lambda(dmu1)=0.71 lambda(dmu4)=0.13
DMU	14	0.63	0.00	0.20	0.51	0.01	0.00	1.17	0.00	Lambda(dmu1)=0.34 lambda(dmu5)=0.22
DMU	16	0.93	0.00	0.35	0.00	0.01	0.02	0.00	0.00	Lambda(dmu1)=0.21 lambda(dmu4)=0.03 lambda
DMU	17	0.89	0.00	0.00	0.60	0.04	0.02	0.00	0.00	Lambda(dmu1)=0.32 lambda(dmu4)=0.41 lambda
DMU	18	0.94	0.00	0.21	0.58	0.00	0.01	0.00	0.00	Lambda(dmu1)=0.56 lambda(dmu15)=0.33
DMU	20	0.97	0.00	0.10	0.21	0.00	0.00	0.00	0.00	Lambda(dmu1)=0.25lambda(dmu4)=0.04lambda

Next, we present details of our findings on present and optimal values of inefficient units in Table 3 as follows,

Table 3
The summary of efficient weights of input projection points

	Initial			Final		
	x_1	x_2	x_3	x_1	x_2	x_3
DMU1	13.45	13.10	11.27	13.45	13.10	11.27
DMU2	13.05	12.87	11.21	13.05	12.87	11.20
DMU3	12.94	12.46	11.04	10.84	10.47	9.30
DMU4	12.88	12.40	11.18	12.88	12.40	11.18
DMU5	13.01	12.77	11.13	13.01	12.77	11.13
DMU6	12.77	12.52	11.02	11.90	11.56	10.26
DMU7	12.57	12.21	11.02	11.24	11.30	10.22
DMU8	12.71	12.25	10.96	11.29	10.90	9.68
DMU9	11.72	11.88	10.94	10.52	10.89	9.86
DMU10	11.89	12.24	10.94	9.43	9.77	8.85
DMU11	12.22	11.90	10.97	11.91	11.60	10.10
DMU12	12.49	12.14	11.10	11.20	10.89	9.43
DMU13	11.92	11.99	11.04	11.93	11.99	11.04
DMU14	12.06	12.10	11.00	7.54	7.37	6.37
DMU15	11.90	12.32	11.16	11.90	12.32	11.16
DMU16	11.98	12.56	10.90	11.17	11.37	10.17
DMU17	11.95	11.65	10.98	10.69	10.42	9.22
DMU18	12.04	12.20	11.11	11.37	11.31	9.91
DMU19	11.72	12.29	10.90	11.68	11.88	10.75
DMU20	12.05	12.30	11.08	11.65	11.80	10.51
DMU21	12.12	11.91	10.89	12.12	11.91	10.89
DMU22	12.66	12.73	11.04	12.66	12.73	11.04

Finally, we use Anderson-Peterson method (Andersen & Petersen, 1993) to provide performance measurement among 9 efficient units and Table 4 shows details of our findings.

Table 4
The summary of ranking efficient units based on Anderson-Peterson method

		EFFICENCY	Input-excess			Output-shortfall			
	Unit	z	V1	V2	V3	U1	U2	U3	U4
DMU	1	1.10	0.000	0.000	0.089	0.000	0.000	0.005	0.020
DMU	2	1.07	0.000	0.000	0.089	0.000	5.096	0.023	0.000
DMU	4	1.08	0.000	0.081	0.000	3.177	1.652	0.028	0.000
DMU	5	1.05	0.000	0.066	0.015	0.000	2.083	0.000	0.019
DMU	13	1.02	0.071	0.013	0.000	2.339	0.000	0.021	0.009
DMU	15	1.14	0.084	0.000	0.000	0.000	0.000	0.042	0.000
DMU	19	1.00	0.085	0.000	0.000	1.554	0.000	0.016	0.014
DMU	21	1.02	0.000	0.084	0.000	4.489	1.000	0.025	0.000
DMU	22	1.35	0.000	0.000	0.091	9.486	0.000	0.000	0.000

4. Discussion and conclusion

In this paper, we have presented an empirical investigation to measure the relative performance of 22 municipality units located in city of Tehran, Iran. The study has considered three inputs and four outputs for performance measurement and using constant return to scale data envelopment method, the study has determined the relative efficiency of all units. Based on the results of our survey, we can conclude that most units where either efficient or close to their efficient utilization of their resources. In other words, the inefficient units were only 7% off from the efficient ones and we have provided some suggestions to convert the inefficient units into efficient ones by reducing their inputs. The proposed study of this paper has also performed supper efficiency among 9 efficient units and provided appropriate ranking for these units.

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