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An empirical study to measure the relative efficiencies of training organizations using data envelopment analysis

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ABSTRACT

This paper presents an empirical study on measuring relative efficiencies of test drive educational organizations using data envelopment analysis. The study uses a Delphi method to determine the most important input/output factors and then gathers the actual data for all units located in an Iranian province called Zanjan. The results of the implementation of the DEA method are compared for different periods of the recent year and they are analyzed. We perform the DEA implementation for two separate regions, one for the units located inside the city and the other for the units located in the rural area. The output results of both methods are compared and the results are discussed in details.

1. Introduction

During the past two decades, there have been tremendous studies on measuring relative efficiency for non-financial organizations using data envelopment analysis (DEA) (Charnes et al., 1978). DEA is popular among mathematicians and practitioners from different perspectives. Mathematicians mostly consider the method as a good area of research and practitioners look at it as a simple tool for performance measurement (Charnes et al., 1994). The method simply uses some input/output parameters to calculate the relative efficiencies of various units through the adaptation of a linear programming toolbox such as Lingo where even the necessary DEA toolbox is also available. The other advantage of the implementation of DEA is the availability of sensitivity analysis on the use of Simplex method. Therefore, there is no need to resolve a method whenever there are some changes on the input/output parameters. The other advantage of DEA is the capability of using no-financial terms influencing the performance of the organizations. For the past two decades, there have been many evidences to confirm that intangible assets play important role on the success of the firms

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(Kaplan & Norton, 1992). Human resources are the most important part of many high-tech organizations (Kaplan & Norton, 2004). On the other hand, a firm with shortage on fixed assets and money could also face with some challenges. Therefore, there must a good combination of tangible and intangible assets to provide a meaningful efficiency measurement (Najafi et al., 2011). Deller and Rudnicki (1993) studied the efficiency of Maine elementary schools in an attempt to maximize student achievement, given certain student and community specifications and reported a strong relationship between school expenditures and student performance.

Educational systems are good examples of the firms where non-financial factors play important roles on performance measurement. The first experience of DEA implementation belongs to elementary schools in an urban school district (Bessent & Bessent, 1980). The approach determines the identification of efficient and inefficient schools and provides management information relative to input and output measures. Bessent et al. (1982) implemented DEA to Houston independent school district. Measuring the efficiency of public schools has been a concern over the past several decades for many reasons (Hanushek, 1986). The public schools must run on an economic scale to reduce the unnecessary expenditures. The educational systems normally require significant amount of governments' budget to run and a small decrease on the budget in this part could help other governmental agencies (Ray, 1991, Walberg & Fowler, 1987). Chakraborty et al. (2001) presented an emperical analysis for measuring the relative efficiency of public schools using stochastic method. Borge and Naper (2006) performed an empirical analysis on measuring efficiency potential and efficiency variation in Norwegian Lower Secondary Schools based on the implementation of DEA approach. Naper (2010) analyzed the relationship between teacher hiring practices and educational efficiency in Norwegian school districts. These evidences clearly show that there is a major concern in different countries for constantly measuring the relative efficiency of educational systems. In this paper, we present a practical approach to measure the relative efficiency of driving test organizations in a major province of Iran. The implementation uses DEA method and using various input/output financial and non-financial data, we study the performance of all units. This paper is organized as follows. We first present the problem statement of the proposed DEA method in section 2. Section 3 explains the details of the implementation of our DEA approach and finally concluding remarks are given at the end to summarize the contribution of the paper.

2. Problem Statement

In this section, we present the problem statement of the proposed DEA method used in this paper. In a DEA method, there are normally some inputs and outputs associated with all decision-making units. Let x_{ij} be the inputs for one of decision-making unit with $i=1,\ldots,m$ and y_{rj} be the outputs of the same units with $r=1,\ldots,s$ and $j=1,\ldots,n$ and suppose u_i and v_j are the dual variables associated with x_i and y_j, respectively. The constant return to scale DEA modeling formulation is as follows,

$$\begin{aligned} \max \quad & z = \frac{\sum_{r=1}^{s} u_r y_{r.}}{\sum_{i=1}^{m} v_i x_{i.}} \\ \text{subject to} \quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \\ & x_{ij}, y_{ij \ge 0} \end{aligned} \tag{1}$$

Model (1) is the basic DEA, which can be solved *j* times to determine the relative efficiencies of various units. However, since model (1) is nonlinear in structure, Charles et al. (1978) proposed a simple modification of the objective function to convert model (1) into a simple linear programming problem as follows,

$$\begin{aligned} \max \quad & z = \sum_{r=1}^{s} u_r y_{r.} \\ \text{subject to} \quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \\ & \sum_{i=1}^{m} v_i x_{i.} = 1 \\ & u_r, v_i \ge 0, \qquad j = 1,...,n \end{aligned} \tag{2}$$

Problem (2) has been widely used for the past three decades and the results are commonly accepted as a tool for measuring the relative efficiencies of various units. There are literally different versions of DEA methods such as input or output oriented models and they are used depending on whether we have control on the output or the input parameters. DEA models have been extended when there are uncertainties associated with inputs/outputs called robust DEA. In robust DEA we consider an acceptable perturbation on each parameters and final solution will not change as long as these parameters change in the interval of uncertainties (Roghanian & Foroughi, 2010).

3. Empirical Analysis

During the past few decades, there has been growing interest on privatization to reduce the cost of running the governments. The governmental agencies try to reduce their direct duties by outsourcing their responsibilities. One of the major responsibilities of governmental agencies is to issue driving license for individual applicants. The entire process of getting driver license includes training, written and driving examinations. The primary concern is to maintain a good quality service to reduce the number of accidents. In fact, one of the major causes of accidents is that drivers are not fully familiar with traffic, driving rules and regulations. Over the past two decades, all parts of the written and driving tests have been handed to private sector. Therefore, there are some organization agencies where applicants can register to training classes. The government is responsible to give the necessary exams and the certificates are granted once applicants pass the required written and practical tests. Once an exam is held, an agent from government must participate in the exam to make sure that no rule is violated. Therefore, a private organization with higher rate of success on exams is not only ideal for the owners but also it is ideal for government. The proposed DEA model of this paper uses four inputs and one output to measure the relative efficiencies of different decision-making units. Fig. 1 shows the input/output parameters of the model.

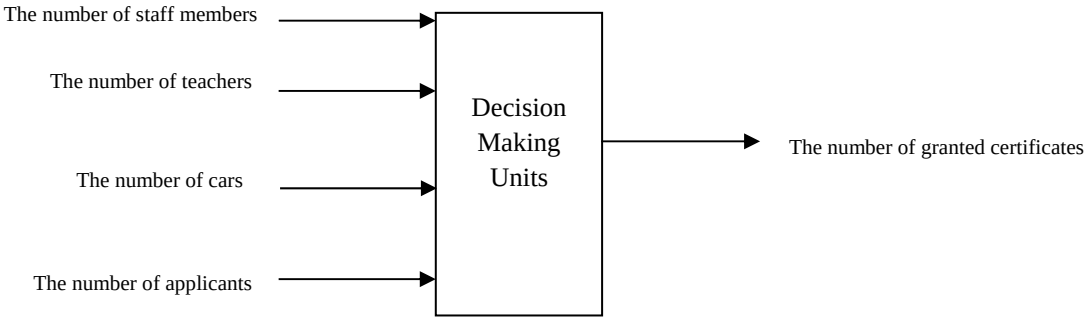

Fig. 1. The input and the output of DEA model

The study of this paper focused on nine major units located in one of the Iranian cities called Zanjan. Table 1 summarizes the number of staff members, the number of teachers and the number of cars used for training and examination.

Table 1
The number of input values for the first three inputs for the city of Zanjan

Unit	1	2	3	4	5	6	7	8	9
Staff	4	4	4	4	4	4	4	4	4
Teacher	30	24	17	18	27	8	20	12	13
Car	30	21	17	18	26	8	20	11	13

Table 2 demonstrates the number of applicants who registered to get the necessary certificates.

Table 2
The number of applicants who registered for exams for the units located in Zanjan

Unit	Months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	160	179	129	292	260	136	187	162	100	114	133	90	162	61
2	180	210	170	300	300	300	300	200	180	190	240	150	227	58
3	70	110	88	120	120	142	122	95	117	150	149	100	115	25
4	109	113	120	165	163	180	147	170	158	129	199	146	150	28
5	188	207	162	198	259	203	286	211	256	210	139	160	207	43
6	59	62	50	64	100	77	70	74	52	28	100	67	67	20
7	92	89	48	126	174	140	65	82	41	83	77	58	90	39
8	56	45	41	59	122	78	49	51	50	78	57	14	58	26
9	63	88	71	143	119	119	85	89	73	67	101	54	89	27

Finally Table 3 summarizes the number of customers who have successfully passed the exams and received certificates.

Table 3
The number of customers who received certificates for the units located in Zanjan

Unit	Months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	32	92	163	100	126	145	167	150	149	166	115	162	131	40
2	174	191	199	108	227	193	206	157	212	198	223	182	189	32
3	63	85	92	110	90	93	93	79	87	135	94	103	94	17
4	24	153	111	129	116	139	124	80	76	107	117	106	107	34
5	71	76	217	155	178	190	140	149	113	208	158	151	151	46
6	51	71	68	44	66	49	94	55	66	67	45	56	61	14
7	74	63	78	67	74	121	91	96	81	77	46	26	75	24
8	0	44	33	37	53	28	60	49	33	44	46	57	40	16
9	60	71	81	38	76	78	102	80	55	89	55	86	73	18

The DEA model (1) was run for 12 different monthly periods of year 2009 and the results are summarized in Table 4.

Table 4
The summary of measuring the relative efficiencies of the units located in Zanjan

Unit	The relative efficiencies of different units for various months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	0.21	0.51	0.92	0.65	0.64	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.76	**1.00**	0.81	0.26
2	**1.00**	**1.00**	**1.00**	0.78	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	0.98	0.06
3	0.93	0.59	0.76	**1.00**	0.99	0.75	0.74	0.85	0.61	0.96	0.66	0.98	0.82	0.15
4	0.22	**1.00**	0.75	**1.00**	0.94	**1.00**	0.91	0.67	0.48	0.72	0.70	0.97	0.78	0.24
5	0.41	0.40	**1.00**	**1.00**	0.90	**1.00**	0.69	0.95	0.53	**1.00**	**1.00**	**1.00**	0.82	0.25
6	0.89	**1.00**	**1.00**	0.81	0.87	0.80	**1.00**	**1.00**	**1.00**	**1.00**	0.61	**1.00**	0.92	0.12
7	0.83	0.52	**1.00**	0.60	0.56	0.91	**1.00**	**1.00**	**1.00**	0.61	0.53	0.24	0.73	0.26
8	0.00	0.72	0.55	0.68	0.57	0.37	0.89	0.88	0.47	0.44	0.71	**1.00**	0.61	0.27
9	0.98	0.63	0.83	0.41	0.84	0.80	0.99	**1.00**	0.58	0.88	0.55	**1.00**	0.79	0.20

As we can observe from Table 4, various units performed differently during the study in terms of their efficiencies. Unit 2 represents the best performer since it was efficient in 11 months. Units 8 represents the worst performer since it was efficient only once during the year. The mean and the standard deviation of efficiencies for various units are presented in the last two columns of Table 4. According to the numbers, while unit 3 was efficient only once but it could manage to maintain an average of 0.82 with relatively low standard deviation, 0.15, which is far better than the average efficiencies of units 4 and 7 despite the fact that they were efficient more than once.

We repeat the study for the units located in the rural area of the province of Zanjan. Table 5 and Table 6 show the information of the number of staff members, the number of teachers, the number of cars used and the number of applicants who registered to take the necessary exams in rural area.

Table 5
The number of input values for the first three inputs for the rural area

Unit	1	2	3	4	5	6	7	8	9	10
Staff	4	4	4	4	4	4	4	4	4	4
Teacher	8	13	10	14	13	14	11	15	8	6
Car	8	13	10	14	12	14	11	14	8	6

Table 6
The summary of the number of applicants who registered for the exams in rural area

Unit	Months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	45	71	68	120	100	115	75	84	94	58	88	57	82	23
2	14	42	48	94	100	90	67	80	116	81	81	45	72	29
3	84	72	77	134	76	108	78	94	139	174	136	55	102	35
4	95	76	60	122	102	90	86	74	88	100	90	66	87	17
5	93	82	86	160	149	158	116	137	147	162	152	63	125	36
6	100	100	77	168	139	145	97	145	193	197	136	102	133	39
7	52	73	55	73	72	92	60	48	70	72	85	77	69	13
8	73	69	64	86	93	79	76	80	53	95	83	64	76	12
9	30	32	26	43	34	53	21	31	34	87	59	40	41	18
10	21	30	27	40	39	40	46	28	43	57	54	39	39	11

The numbers of applicants who were granted the required driving certificates as the necessary output of the proposed model are given in Table 7.

Table 7

The summary of the number of applicants who registered for the exams in rural area

Unit	Months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	19	73	71	63	69	66	48	40	81	61	44	70	59	18
2	0	46	82	62	53	27	81	95	44	32	60	4	49	30
3	73	139	123	61	72	138	88	87	75	114	56	96	94	29
4	51	85	139	99	95	115	43	149	57	28	70	175	92	46
5	65	68	82	51	46	101	98	132	115	77	82	104	85	26
6	136	104	88	90	102	136	115	102	134	104	111	101	110	17
7	0	53	72	156	75	86	52	74	78	61	44	82	69	36
8	117	37	69	147	57	3	161	65	56	44	80	59	75	46
9	0	57	36	3	20	51	30	57	29	39	28	54	34	19
10	34	56	24	18	41	4	0	63	32	36	41	30	32	19

The results of the implementation of the proposed DEA model of this paper for the units located in the rural areas of the city of Zanjan are summarizes in Table 8.

Table 8

The summary of measuring the relative efficiencies of the units located in rural area

Unit	The relative efficiencies of different units for various months												Statistics	
No.	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Std
1	0.28	0.66	0.72	0.56	**1.00**	0.60	0.56	0.47	**1.00**	**1.00**	0.69	0.70	0.69	0.22
2	0.00	0.56	0.74	0.40	0.59	0.23	0.58	0.69	0.44	0.45	0.80	0.04	0.46	0.26
3	0.75	**1.00**	**1.00**	0.43	**1.00**	**1.00**	0.82	0.82	0.76	**1.00**	0.71	0.77	0.84	0.17
4	0.39	0.61	**1.00**	0.63	**1.00**	**1.00**	0.28	**1.00**	0.66	0.35	0.84	**1.00**	0.73	0.28
5	0.56	0.49	0.62	0.33	0.51	0.73	0.71	**1.00**	**1.00**	0.71	0.86	0.69	0.68	0.20
6	**1.00**	0.75	0.63	0.58	**1.00**	0.99	0.77	0.68	**1.00**	0.91	**1.00**	0.58	0.82	0.18
7	0.00	0.38	0.63	**1.00**	**1.00**	0.73	0.44	0.73	**1.00**	0.90	0.60	0.60	0.67	0.30
8	**1.00**	0.28	0.50	0.94	0.64	0.03	**1.00**	0.44	0.95	0.56	**1.00**	0.35	0.64	0.33
9	0.00	0.92	0.60	0.03	0.56	0.75	0.67	0.83	0.77	0.54	0.54	0.54	0.56	0.28
10	**1.00**	0.97	0.40	0.21	**1.00**	0.78	0.00	**1.00**	0.71	0.71	0.91	0.53	0.69	0.34

As we can see from Table 2, unit 3 represents the best performer among all other units. It was efficient five times with the mean and standard deviation of 0.84 and 0.17, respectively. Unit 6 is the second best performer with an average efficiency of 0.82 and standard deviation of 0.18, respectively. Unit 2 was the worst performer since it was not considered to be efficient and maintained a low average efficiency of 0.46. Unit 4 was efficient five times but it represented a low performance in other periods and consequently ended up having low average on efficiency. The other units provided an average of above 50 percent, which means that they could possibly increase their efficiencies by reducing their inputs and increasing their output.

One important observation from comparing the results of Table 4 and Table 8 is that the average efficiencies of nine units located inside the city is 80 percent while the average efficiencies of ten units located outside the city is about 68 percent. A brief study on the customer backgrounds reveals that the units located inside the cities serve more people who higher level of educations. The other observation is that the units located inside the city always have some registered people who wish to take part in exams but the units located in rural area could not give examination occasionally because no applicant registered.

4. Conclusion

In this paper, we have presented an empirical study on the implementation of DEA method for private organizations responsible for training and giving the necessary written and driving tests. The proposed DEA model of this paper considered four inputs including the numbers of staff members, teachers, cars and participants. We have considered only the number of people who passed the examinations successfully as the main output criteria. The proposed model was tested on two groups of private organizations located in the city and the rural area and the results have been compared and analyzed.

The research can be extended in different ways. One of the necessary open questions is to detremine the main reasons for failure on test drive. The present study did not have any access to such data and gethering the necessary data needed a comprehensive survey with questionnare which was beyound the scope of this research. A good work could normally focus to detremine the common reasons for failure on test drive exams and provide necessary steps to prevent them. We leave this as future research for interested researchers.

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