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Performance Evaluation of Tehran Subway Stations

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Efficiency evaluation is one of the major issues in urban transportation. Since the efficiency of the systems is affected by its data and output, what makes the results of the performance evaluation valid and applicable, is selecting the appropriate data and outputs of the system. In this study, the efficiency of the subway stations in Tehran in case of return, compared to the fixed scale, is measured and ranked in a three-year period (2010-2012), by using data envelopment analysis (DEA); that is a non-parametric method for assessing the performance of the units (DMUs). Also in this study, by the analysis of the sensitivity of the model, compared to the inputs, their impact on the performance of the stations is examined. The results suggest that, stations such as Sadeghiyeh, Shar-e-Rey and Panzdah-e-Khordad, have the highest level of performance and can be used as a proper model for inefficient stations.

1. Introduction

Scarcity and optimized resource allocation, are one of the challenges facing human societies. These limitations are more sensible, especially in the cases such as the production agents and consequently services and goods. So providing the model for efficiency evaluation is an efficient way in better use of available facilities to offer more and with better quality. Given the importance of the transportation industry, the high efficiency of this sector of the economy, is so important. Among the various options, rail transport is important, because on one hand there is a great investment involved, and on the other hand, due to lower fuel costs and environmental pollution and high safety, in recent years, authorities have considered it [1]. With regard to the spread of the metropolis, urban rail transportation system has been considered as a subset of rail transportation. The subway system by being capable of handling lots of passengers, and not intersecting with the surface traffic, is the best option to improve the traffic and the pollution problems in Tehran.

1.1. Performance

In the economic literature, performance and productivity are inseparable concepts from each other. The simplest definition of performance, is determined by the proportion of the output to the data, compared to a certain criterion. This specified standard can be the maximum possible production of available output, according to the production function. In this case it is necessary to define the production function, but often the units have lots of outputs and data, that in this case performance is defined as the proportion of total weight of the output to the total weight of the data. In this case using different weights, multiple data and outputs, has become a figurative data and a figurative output, or are somehow aligned [2,3]. Generally for measuring performance parametric and non-parametric methods are used.

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1.1.1. Parametric methods

Essentially in the parametric methods, by using different assumptions, a border function distribution, is estimated in a specified manner (e.g., Cobb Douglas, Translog, etc.) with a combination of errors, so that the inefficiency of the units, classified in two groups of random factors and inefficient factors. These methods are called Parametric, since in these methods, the parameter or parameters are estimated from the function [1]. The most important objection of the parametric method, are the different assumptions that are considered for the functions and inefficiency component. Therefore, given the different assumptions, different results will be obtained that makes the practical comparison among the units so difficult [4].

1.1.2. Non-parametric methods

In these methods there is no need to estimate the function production, and units' performance, will be reviewed relatively and compared to other units in the system in real situation, by using mathematical programming. Another benefit of this method is the possibility of considering multiple inputs and outputs for measuring. Data envelopment analysis is a nonparametric method based on linear programming, to estimate the technical efficiency and inefficiency evaluation of the units [5]. In this way, without having any default of the production function, the efficiency of the units is assessed by solving the mathematical model for a group of decision making units, based on the information about their input and output.

2. Background of the study

So far several studies have been conducted to assess the efficiency of transportation systems. Most studies that have been done on the rail transportation industry, were in the field of intercity freight transportation. A selection of these studies are as follows.

Karlafits in his research about the DEA and the production function, has evaluated two important issues in transportation operations, the relationship between the two main aspects, namely the efficiency and effectiveness, and the relationship between performance and economy on scale, by using 256 data of transportation system in America during a period of 5 years. The results indicate a positive relationship between efficiency and effectiveness with each other [6]. Cantos et al, have investigated European railway companies by using non-parametric technique of data envelopment analysis. [7]. Lin and Yu in their research have evaluated the technical efficiency, effectiveness of service and technical efficiency of passenger and load, for the selected 20 Railways in the world in 2002 [8]. Norouzzadeh assessed the efficiency of Asian countries' railways which are the member of UIC. He, along with analyzing the data by using current models of DEA, has presented a new model and then analyzed the data, and compared the results [9]. By evaluating Metro in Taiwan, commercial spaces and parking areas were also considered as input. In this study, the sensitivity analysis indicated that in case of the removal of the commercial spaces, stations efficiency would greatly reduce. [10]. Sangtarash et al, in their study, by the combination of the two balanced scorecard and DEA, had a fresh look at this area, and have evaluated the performance of the 64 metro stations and their ranking in Tehran in a 6-month period [11]. Eullinane and Jane in their article, have evaluated various models of URTS management in different cities of the world. They have compared their technical efficiency under CRS and VRS. Their findings suggest that URTS based on private property, have a higher performance compared to the URTS with the public or combined property [12].

3. The method of data envelopment analysis

DEA thesis discussion began by Edward Rhodes booklet that evaluated academic achievement of students at the American schools in 1978. The results of these studies were released in collaboration with Charnes and Cooper, in the article that was known as CCR. CCR by converting multiple inputs and outputs into one input and one output, used mathematical programming optimization method To extend the functionality of a fuzzy input and output to multiple input and output modes.

The basic model of DEA is a linear fractional program that to solve the problem it must first be converted to a linear model, in order to use linear programming solving techniques for it. If the numerator increases compared to the denominator, the obtained model known as CCR will be as follows [9].

$$\theta_p^* = Max \sum_r u_{rp} y_{rp}$$
$$St:$$
$$\sum_i v_{ip} x_{ip} = 1$$
$$\sum_r u_{rp} y_{rj} - \sum_i v_{ip} x_{ij} \leq 0,\ j = 1, 2, \ldots, n$$
$$u_{rp}, v_{ip} \geq 0 \qquad (1)$$

Output Weight r,: u_r

Output value R of unit j, : y_{rj}

Input weight I,: v_i

Input value i of unit j: x_{ij}

Limit (1) is the denominator in the main objective function, and as the above description is considered as an arbitrary fixed number (usually 1). Limits (2) are the modified limitations of the original model, which according to the usual mathematical method has been out of fraction form. Given that in the above model, well-proportioned total of the data for the target unit is equal to 1, this model, is called the output oriented, but if the well-proportioned total of the outputs is set to 1, the model will become data Oriented.

By using DEA, a border or basis for comparison of decision making units is made, that has the best performance. Then the performance of the units, is measured according to that border. Units that are located on the border, produced the maximum output from the available data, or to produce a given output consume less data. Units that are placed under the boundary, are ineffective. They may have their production with less data, or produce more output with the same data.

In comparative evaluation, the first issue of methodology that must be addressed, is the return to the scale. If by the rise of a data unit, an output unit increases, and performance won't change, constant return to the scale, is called (CRS [1]). Otherwise, variable return to scale (VRS[2]) will happen. The assumption of being constant return to scale, only is appropriate when all the subjects in the study on the scale, are optimized to work. In the CCR model, return to scale, has been considered fixed. With the assumption of return, being variable to scale, scale efficiency can be achieved for each unit. This model is practical by solving DEA model and assuming CRS and the VRS. Thus, the technical efficiency scale, obtained from the DEA, in the case of CRS, is divided into two components, one the efficiency scale and the other, pure technical efficiency. If between the calculated technical efficiency by assuming CRS and VRS for a unit, differences exists, it means that this unit has an inefficiency scale. The inefficiency scale can be achieved by the technical efficiency difference between CRS and VRS [13].

4. The efficiency evaluation of Tehran metro

The first line of Tehran Metro was opened in 1999, and the cities of Tehran and Karaj were connected. Then gradually until 2012, 62 active station were established in this line. Currently, the construction of line 3 of the metro for connecting the North East to the South West of Tehran is going on, and some of the stations are in their final stages of construction. Currently the exploited distance of metro lines, is 158 km, and the number of the active wagons in Tehran subway is more than 1000. More than 3 million passengers are moved daily through this rail line.

4.1. Inputs and outputs

In this study, the station costs (cost of electricity), number of the personnel, costs of staffs' salary, space of the station, facilities access (including the number of elevators, escalators and terminal access by taxi and bus station), are considered as input and the number of the passengers and the earnings per station, as outputs.

After determining the inputs and outputs, data for the years 2010-2012 for all of the subway stations of Tehran (62 stations) were collected. Also to resolve the DEA model, Lingo software was used. It should be noted that some stations, were not at the startup of Tehran's metro, and gradually added to the Tehran subway network (Table 1).

[1] constant returns to scale

[2] variable returns to scale

The results of the above table show that during the period under review, stations such as Sadeghiyeh, 15 Khordad, and Shahre Rey had the highest level of performance, and on the other hand, stations including Baqershahr and Shahid Hemmat had the lowest level of performance.

4.2 Sensitivity analysis

To analyze the sensitivity of the performance of the studied stations, the parameter of access to the station and its effect on the number of passengers and consequently the efficiency of the station, have been evaluated. In this study, after making the above changes, the performance of all the stations have been recalculated, and stations' ranks of the first three and the last three are shown in terms of efficiency level, in Table 2 and Table 3. The results show that the efficiency of each of the stations have been changed considerably, and thus stations' rank faced less modifications.

Table 1. Results of data processing in the years 2010-2012

Station	2010		2011		2012	
	D.E.A. Score	Rank	D.E.A. Score	Rank	D.E.A. Score	Rank
Kahrizak	-	-	-	-	0.031	58
Tajrish	-	-	-	-	0.055	55
Gheitarieh	0.065	43	0.422	29	0.516	26
Shahid Sadr	-	-	0.104	47	0.189	50
Gholhak	0.284	31	0.412	30	0.485	30
Dr. Shariati	0.123	41	0.215	42	0.283	43
Mirdamad	0.235	35	0.308	35	0.400	36
Shahid Haghani	0.815	4	0.560	16	0.397	37
Shahid Hemmat	0.041	44	0.039	49	0.037	57
Mosalla	0.544	16	0.525	21	0.517	25
Shahid Beheshti	0.536	17	0.537	20	0.562	20
Shahid Mofatteh	0.600	12	0.609	13	0.631	14
Haft-e-Tir	1	1	1	1	0.926	2
Taleghani	0.460	22	0.432	28	0.431	34
Darvazeh Dolat	0.752	7	0.731	7	0.711	9
Saadi	0.774	6	0.813	4	0.858	4

Table 1. Continued

Panzdah-e-Khordad	1	1	1	1	1	1
Khayyam	0.497	20	0.451	26	0.439	32
Molavi	0.604	11	0.638	10	0.635	13
Shoush	0.332	26	0.329	33	0.329	42
Terminal-e-Jonoub	0.596	14	0.643	9	0.724	8
Khazaneh	0.189	40	0.183	43	0.187	51
Ali Abad	0.597	13	0.513	23	0.538	23
Javanmard-e-Ghassab	0.512	19	0.542	18	0.580	19
Shahr-e-Rey	1	1	1	1	1	1
Bagher shahr	0.021	45	0.018	50	0.019	60
Shahed	0.208	37	0.289	37	0.330	41
Haram-e-Motahhar	0.304	28	0.368	32	0.392	38
Sadeghieh	1	1	1	1	1	1
Tarasht	0.298	29	0.267	38	0.252	46
Daneshgah-e-Sharif	0.627	9	0.622	12	0.590	18
Azadi	0.825	3	0.780	6	0.672	10
Navvab	0.792	5	0.830	3	0.864	3
Meydan-e-Horr	0.317	27	0.292	36	0.270	45
Daneshgah-e-Imam Ali	0.251	33	0.243	40	0.248	47
Hasan Abad	0.523	18	0.541	19	0.545	21
Imam Khomeini	0.725	8	0.724	8	0.754	7
Mellat	0.449	23	0.447	27	0.411	35
Baharestan	1	1	0.920	2	0.823	5
Darvazeh Shemiran	0.225	36	0.251	39	0.275	44
Imam Hosein	0.627	10	0.562	15	0.511	27
Shahid Madani	0.207	38	0.218	41	0.218	49

Table 1. Continued

Sabalan	0.569	15	0.599	14	0.600	16
Fadak	0.296	30	0.327	34	0.354	39
Golbarg	0.487	21	0.520	22	0.523	24
Sarsabz	0.395	24	0.456	25	0.494	29
Daneshgah-e-Elm-o-Sanaat	0.918	2	0.7904679	5	0.595	17
Shahid Bagheri	0.111	42	0.176	44	0.331	40
Tehran Pars	0.333	25	0.479	24	0.500	28
Farhangsara	-	-	0.104	48	0.439	33
Meidan-e-Azadi	-	-	0.001	52	0.778	6
Ostad Moein	-	-	-	-	0.038	56
Dr. Habibollah	-	-	-	-	0.067	54
Tohid	-	-	0.0003	53	0.166	52
Enghelab Eslami	0.243	34	0.549	17	0.626	15
Vali Asr	-	-	0.160	45	0.670	11
Ferdowsi	0.263	32	0.374	31	0.483	31
Meidan-e-Shoha	0.206	39	0.632	11	0.543	22
Sheikh-al-Raeis	-	-	-	-	0.116	53
Pirouzi	-	-	-	-	0.025	59
Nabard	-	-	0.123	46	0.652	12
Shahid Kolahdouz	-	-	0.017	51	0.236	48

5. Conclusions

Efficiency evaluation, is one of the most challenging and yet, the most critical issues of an organization and reflects the strategy and thought that is dominant on it. Metro, as the most widely used means of public transportation in Tehran, is not an exception, because it has an undeniable role in reducing traffic and air pollution, and has a direct effect on urban life and the administrative and business activities in the capital. Hence, continuous evaluation of the performance of this institution, would lead to proper planning for the future and increasing efficiency. As a result, people will use the subway more and more.

In this study, by using data envelopment analysis, efficiency of Tehran Metro has been evaluated. The results show that the average efficiency of subway stations in Tehran in the

Table 2. Stations with the highest efficiency in the years 2010-2012

Station	2010		Station	2011		Station	2012	
	D.E.A. Score	Rank		D.E.A. Score	Rank		D.E.A. Score	Rank
Panzdah Khordad\ Shahr-e-Rey\ Sadeghie\ Baharestan	1	1	Panzdah Khordad\ Shahr-e-Rey\ Sadeghie	1	1	Panzdah Khordad\ Shahr-e-Rey\ Sadeghie	1	1
Daneshgah-e-Elm-o-Sanaat	0.918	2	Baharestan	0.920	2	Navvab	0.864	2
Haft-e-Tir	0.832	3	Navvab	0.830	3	Baharestan	0.823	3

Table 3. Stations with the lowest efficiency in the years 2010-2012

Station	2010		Station	2011		Station	2012	
	D.E.A. Score	Rank		D.E.A. Score	Rank		D.E.A. Score	Rank
Gheitarieh	0.065	47	Shahid Kolahdouz	0.017	54	Kahrizad	0.031	60
Hemmat	0.041	48	Azadi	0.001	55	Pirouzi	0.025	61
Bagher Shahr	0.021	49	Tohid	0.0003	56	Baghershahr	0.019	62

years 88 to 90, were 48.56 percent, 45.91 percent and 46.62 percent, respectively.

In the present study, it is assumed that all the stations have access to the complementary public transportation system (bus, BRT, taxis, vans), and then the efficiency of the stations were re-examined. The results indicate that in the case of implementation of this policy, a significant improvement in the efficiency of this organization, will be seen. Therefore, access of all subway stations to the complementary public transportation system should be seriously considered in the future planning.

Based on the results of this study, stations including Sadeghiyeh, Panzdah khordad, and Shahr-e-Rey, during the period under study, had the highest level of performance. Therefore, for the same reason the performance of these stations can serve as a model for increasing the efficiency of the other stations.

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