Int. J. Contemp. Math. Sciences, Vol. 2, 2007, no. 32, 1569 - 1579

Iranian Railway Efficiency (1971-2004): An Application of DEA

M. M. Movahedi

Department of Management, Firouzkooh Branch
Islamic Azad University, Firouzkooh, Iran
mmmovahedi@gmail.com

S. Saati

Department of Mathematics, Tehran-North Branch
Islamic Azad University, Tehran, Iran
ssaatim@yahoo.com

A. R. Vahidi [1]

Department of Mathematics, Shahr-e-Ray Branch
Islamic Azad University, Tehran, Iran
alrevahidi@yahoo.com

Abstract

In this paper, the efficiency of Iranian Railway is evaluated using Data Envelopment Analysis (DEA) method. In this way, the railway activities from 1971 to 2004 are considered and the efficiency of each year is calculated and compared to the other years. Also, the results of ten years are shown efficient. The railway efficiency in the years after 1995 are shown as efficient years, except the year 2000 which is considerable from the view of management and decision making.

Keywords: Data Envelopment Analysis (DEA); Efficiency; Railway

1 Introduction

Purposing, planning, equipping the powers and resources, monitoring, leading and management of big organizations like banks, hospitals, power plants,

[1]Corresponding author

transportation systems and similar organizations are required the proper tools for decision making. Apart from the power, motivation and good intention which managers rely on, the decision making tools can be effective for increasing the accuracy and quality of decisions. By knowing the performance of every related section, a manager can plan for the future policies. With clearing the performance of related sections, it is possible to measure the progress and decline in order to present the efficient proposes for achieving the goals. In this reason, the comparing of optimized utilization of resources can be proposed to the other managers as a solution.

Undoubtedly, the railway has a great role in freight and passenger transportation in every country. During the resent years, the Iranian authorities have paid attention to the railway and network development which is very useful for transportation development and growth. Respecting the limitation of facilities and resources in railway, the increasing of quality of services for freight and passenger transportation will depend on the investigation of strength and weakness and also the optimization of current resources. It can be achieved by comparing different divisions of similar organization or the same departments of an organization from the view of facilities, abilities and services presented by them. This comparison cam be given a criteria which measure the efficiency of every division. By using the efficiency value of each division, it is possible to recognize the defects to solve them.

Furthermore, efficiency can be used as a criterion for analyzing the performance of special division in different times. Of course, it can be applied when the resources of an organization are constant and led by different managers. Through this method, it is possible to recognize the manager's efficiency as well as the effect of some environmental variables which are out of organization control. By using such analyzing method, the efficiency of special department in a certain period of time can be determined, so the managers are informed of the progress and decline in their department which in turn they can make proper decisions for upgrading the efficiency.

There are fewer studies about analyzing and estimating productivity and efficiency in rail-ways. It has been tested by Oum and Yu [14], which only uses a single item as an output [14]. Also Oum et al. [15], published a complete overview of productivity and efficiency in rail transport in which it is clear that the results of these estimates are very sensitive to outputs specification. Cantos et al. [2] obtained efficiency indicators using non-parametric approaches, Cowie and Riddington [6], used alternative methodologies. Regarding to the latest studies, it is not possible to evaluate efficiency precisely, so we can only use it for defining good or bad operations.

Cantos et al. [3] compared European railway companies by DEA non-parametric approach. In this study, passenger/km, ton/km, passenger trains/km and freight trains/km were considered as outputs. They considered 1) number of staff, 2) fuel consumption, 3) number of locomotives, 4) number of passenger trains, 5) number of freight trains, and 6) length of main routes/km as inputs. By using Pierson Coefficient and Spearman Ranking Coefficient, it was defined that statistically there is no significant difference between the efficiencies obtained through estimating each outputs. It has been studied for calculating and analyzing railway efficiency which will be presented in this paper. Six indices of railway productivity were studied by Agdasi and Qolami [11]. These indices contain locomotive, fuel, manpower, passenger cars, wagons and track which was performed during 1971-2001. In this study, the insignificant indices of productivity have been considered. The productivity insignificant indices were examined by correlation test whose results were also analyzed. The existing surplus resources of the railway, its attention to the freight transportation rather than passenger one, the efficiency increase as well as the effects of the imposed war between Iran and Iraq, with the impacts of Islamic revolution on railway performance are the result of this research. While some indices are ascending the others are descending. Therefore, the determination of this performance through this method is doubtful to some extent.

By using DEA model, the efficiency of Iranian railway divisions were analyzed by Alian-nejadi [12]. Because of the current limitations, the researcher chose three variables of manpower, track length and equipments as the inputs, and the three variables of loaded freight, transported passenger and net income as the outputs. Also, Movahedi et al. [13] compared the Iranian railway performance with 70 countries. This research has considered the main tracks, number of locomotives in service, passenger cars, wagons and staff, as inputs and the passenger-kilometer and freight ton- kilometer as output variables. In this research, the Iranian railway efficiency is 0.682 and the results of it show that the Iranian railway rank is thirteen.

For calculating and comparing the railway efficiency in different years, the railway facilities, resources, products and services in each year were considered as an independent unit. Then the efficiency and performance of railway in different years will be compared using DEA method for efficiency estimation. After identifying the efficient years, the Andersen- Petersen method [1] is used for ranking.

2 Data Envelopment Analysis

In the real world, each Decision Making Unit (DMU) uses several inputs to produce several outputs. Here, the efficiency is determined by the ratio of weighted sum of outputs on weighted sum of inputs. DEA was proposed to determine the above mentioned weights. The first model in DEA is developed by Charnes et al. [4] which is known as CCR model. Considering n as number of DMUs, m as number of non negative inputs x_{ij} $(i = 1, \ldots, m,\ j = 1, \ldots, n)$

and s as number of non negative output y_{rj} $(r = 1, \ldots, s,\ j = 1, \ldots, n)$, CCR model for evaluating the pth DMU with inputs x_{ip} $(i = 1, \ldots, m)$ and outputs y_{rp} $(r = 1, \ldots, s)$ is as follows:

$$\max W = \sum_{r=1}^{s} u_r y_{rp} \tag{1}$$

$$\text{s.t} : \sum_{i=1}^{m} v_i x_{ip} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \quad j = 1, ..., n,$$

$$u_r,\ v_i \geq \epsilon, \quad r = 1, ..., s,\ i = 1, ..., m.$$

In (1), ϵ is a non-Archimedes infinitesimal number and v_i $(i = 1, \ldots, m)$ and u_r $(r = 1, \ldots, s)$ are inputs and outputs weights, respectively. W is the optimal value which shows the efficiency of pth unit. If $W = 1$ then the evaluated unit is efficient; otherwise, it is inefficient. The dual of (1) is as follows:

$$\min Z = \theta - \epsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+) \tag{2}$$

$$\text{s.t} : \sum_{j=1}^{n} \lambda_j x_{ij} - \theta x_{ip} + s_i^- = 0, \quad i = 1, ..., m,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rp}, \quad r = 1, ..., s,$$

$$\lambda_j,\ s_r^+,\ s_i^- \geq 0, \quad j = 1, ..., n,\ r = 1, ..., s,\ i = 1, ..., m.$$

In evaluation DMUs by DEA, the efficiency value is "1" for the efficient units. Therefore, it is possible to rank the inefficient unit based on their inefficiency, while the efficient units fail to be ranked. For ranking the efficient units, a model developed by Anderson and Petersen [1]. This model is as follows:

$$\min Z = \theta \tag{3}$$

$$\text{s.t} : \theta x_{ip} - \sum_{\substack{j=1 \\ j \neq p}}^{n} \lambda_j x_{ij} \geq 0, \quad i = 1, ..., m,$$

$$\sum_{\substack{j=1 \\ j \neq p}}^{n} \lambda_j y_{rj} \geq y_{rp}, \quad r = 1, ..., s,$$

$$\lambda_j \geq 0, \quad j = 1, ..., n.$$

3 Data Envelopment Analysis in Iranian Railway

The purpose of this research is the analysis and calculation of annual performance and efficiency in years 1971-2004. So, the railway efficiency in each year was calculated. The annual performance and activity of railway was considered as an independent DMU.

The first step in clearing the model is identifying the organization inputs and outputs. The activity and performance of railway in each year is considered as a DMU in which the opinions of experts and advisors have been derived to define six inputs and three outputs for each one. Some inputs are similar in nature which are merged based on their importance and nature. The most important factor for merging these inputs is that in the literature of DEA some limitations such as $n \geq 3(m+s)$ [3] and or $n \geq 2(m+s)$ [5] are applied. In this research for decreasing the number of inputs the total expenses and development budget which are similar in nature, have been merged.

Each factor which has a cost nature is considered as an input and every factor with a benefit nature is considered as an output. For instance, the number of freight and passenger wagons, locomotives in service, personnel and so on are considered as annual inputs and the total income, passenger - kilometer and freight ton - kilometer are considered as outputs.

The input and output data in each year for the railway were derived from the information group and statistics unit [8] and the information related to Consumer Price Index (CPI) are gathered based on the annual statistics of different years [10]. The used input and output were selected based on the research limitations and type and quality of exiting information which are as follows:

(a) input variables

I1: Average of freight wagons number,

I2: Average of freight wagons number,

I3: Average of locomotives in service,

I4: Lines consisting of main, siding and industrial lines in kilometer,

I5: Personnel number in thousand,

I6: Total expenses and construction budget in Rial.

(b) Output variables

O1: Transported freight in ton-kilometer,

O2: Transported passenger in passenger-kilometer,

O3: Total income in billion Rials.

4 Results

Input and output data related to railway in 1971-2004 are shown in table 1. The total expenses, construction budget and total income are based on current prices. Hence, considering the PCI with constant prices of the year 1990 [9], these values change to constant prices and then are used. Considering the table 1 and by using CCR model, the efficiency of each year has been estimated based on input nature. The results of this evaluation with their respective references are shown in table 2.

year	I1	I2	I3	I4	I5	I6	O1	O2	O3
1971	6757	428	233	4509	29693	0.86	3	1.7	1.03
1972	6757	428	227	4509	30789	0.81	3.6	2	0.97
1973	7998	429	203	4519	30789	0.72	4.3	2.1	1.01
1974	7998	429	242	4525	32449	0.75	4.9	2.2	1
1975	7998	445	251	4525	32964	0.91	4.9	2.8	1.02
1976	13556	596	315	4525	33757	0.98	4.8	3.5	1.08
1977	13450	602	306	4567	36623	0.7	5	3.6	0.86
1978	13450	570	227	4567	33284	1.01	4	2.9	0.65
1979	12265	570	128	4567	34587	0.9	3.1	3.2	0.58
1980	12150	760	102	4567	33617	0.83	3.4	2.7	0.52
1981	12422	985	120	4567	36779	1.43	3.8	2.5	0.51
1982	12422	1003	166	4567	36992	1.66	5.5	4.7	0.6
1983	12247	1000	169	4567	38768	1.72	6.7	5.7	0.74
1984	11746	955	242	4567	41294	1.64	7.5	6.1	0.7
1985	11746	916	247	4567	40797	1.56	6.8	5.6	0.63
1986	12205	916	239	4567	38964	1.03	7.3	4.6	0.53
1987	13074	911	227	4568	38481	0.87	8.6	3.6	0.51
1988	13074	889	148	4568	37178	0.83	8	4.6	0.41
1989	12433	834	169	4569	36943	0.76	7.9	4.7	0.37
1990	12224	945	176	4847	57793	1.24	7.6	4.5	0.49
1991	12629	896	150	4847	35866	1.33	7.7	4.5	0.67
1992	13322	934	163	4847	35440	1.51	8	5.2	1.09
1993	13451	962	156	5022	34448	1.58	9.1	6.4	0.82
1994	14785	930	177	5226	33870	1.6	10	6.4	0.82
1995	14995	892	167	5332	32259	1.38	11.9	7.2	1.04
1996	15240	862	168	5612	30182	1.73	13.6	7	1.29
1997	15315	732	177	5995	28756	2.28	14.4	6.1	1.67
1998	16034	650	172	6264	28407	0.53	12.6	5.6	1.41
1999	12165	858	170	6398	27812	2.13	14.1	6.5	1.63
2000	14017	885	185	6688	28061	3.22	14.2	7.1	1.57
2001	12363	872	193	7156	26673	3.25	14.6	8	1.45
2002	14754	942	207	7268	15264	3.11	15.8	8.6	1.28
2003	15206	1012	224	7268	14305	4.07	18	9.3	1.29
2004	16328	1066	231	7584	13748	3.87	18.2	10	1.31

Table 1: Data of inputs and outputs

year	efficiency	Reference set
1972	0.983	1971=0.78, 1998=0.06, 1999=0.06
1973	0.984	1971=0.73, 1998=0.18
1974	0.966	1971=0.65, 1997=0.04, 1998=0.19, 1999=0.00
1975	0.969	1971=0.50, 1997=0.10, 1998=0.13, 1999=0.10
1976	0.887	1997=0.32, 1998=0.38
1977	0.754	1996=0.12, 1997=0.06, 1998=0.43
1978	0.568	1996=0.17, 1997=0.08, 1998=0.21, 2004=0.01
1979	0.608	1995=0.18, 1998=0.24, 2004=0.06
1980	0.604	1995=0.06, 1996=0.24, 1998=0.10
1981	0.466	1996=0.18, 1999=0.15, 2004=0.03
1982	0.698	1995=0.38, 2004=0.19
1983	0.835	1995=0.43, 2004=0.26
1984	0.890	1995=0.51, 2004=0.24
1985	0.828	1995=0.52, 2004=0.19
1986	0.758	1995=0.58, 1998=0.08
1987	0.779	1996=0.33, 1998=0.33
1988	0.817	1995=0.42, 1998=0.28
1989	0.866	1995=0.37, 1998=0.36
1990	0.714	1995=0.54, 1998=0.03, 2004=0.05
1991	0.691	1995=0.49, 1998=0.04, 2001=0.03, 2004=0.04
1992	0.874	1996=0.52, 1997=0.20, 1998=0.05
1993	0.907	1995=0.69, 2004=0.14
1994	0.878	1995=0.72, 2004=0.12
2000	0.972	1997=0.14, 1999=0.61, 2001=0.10, 2004=0.15

Table 2: The reference sets of inefficient years

The railway efficiency was analyzed during 34 years. For example, the year 2003 is an efficient year which means that the railway has used its resources better than the other years. Contrary, the year 1994 is an inefficient year in which its efficiency value equals 0.878. It means that the railway just uses % 87.8 of its resources for achieving its goals and % 12.2 of them was wasted.

Within the years 1971-2004, only 10 years (1971, 1995, 1996, 1997, 1998, 1999, 2001, 2002, 2003 and 2004) were evaluated as efficient years. For a better comparison, the evaluation results are shown in table 2.

In table 2, the values of reference column show that each inefficient year have been compared to which one of the efficient year. For example, 1994 was compared to the efficient years 1995 and 2004. On the other hand, the contribution of efficient years 1995 and 2004 on inefficiency of 1994 are % 72 and % 12, respectively. Also for the other inefficient years we can get similar results. Although within the above 10 years the railway efficiency has been equal to "1" of course it doesn't mean that it is perfect "% 100", and only shows that the railway efficiency in these years is higher than the other ones. For example, the efficient values for the years 1993 and 1975 are 0.907 and 0.969 respectively which is evaluated as inefficient years. The year 1995 has got a better efficiency than 1994, because its efficient value is near to "1".

year	I1	I2	I3	I4	I5	I6	O1	O2	O3
1972	1.66	5.23	14.57	9.29	17.59	1.66	6.4	0	0
1973	3.74	1.62	2.97	3.98	14.97	1.62	4.76	8.06	0
1974	3.4	3.4	24.85	7.57	24.21	3.4	0	9.25	0
1975	3.12	3.12	36.01	10.39	31.87	3.12	20.44	0	0
1976	25.34	25.69	68.09	11.31	47.4	11.31	97.54	17.64	0
1977	34.52	35.42	71.89	24.61	55.17	24.61	57.86	0	0
1978	50.31	43.25	68.87	43.25	63.95	43.25	54.39	0	0
1979	44.2	39.15	39.15	41.71	66.47	39.15	99.94	0	3.56
1980	55.28	63.35	39.6	55.75	70.45	39.6	55.96	0	0
1981	64.76	73.27	53.38	57.41	76.46	53.38	32.68	0	0
1982	35.33	52.42	41.58	30.18	66.41	30.18	47.1	0	8.83
1983	27.73	43.91	31.89	16.51	65.22	16.51	47.19	0	6.47
1984	11.92	36.11	52.53	11.05	62.75	11.05	39.77	0	21.27
1985	17.15	37.07	56.79	17.77	62	17.15	40.7	0	24.42
1986	24.25	43.78	59.56	27.31	52.04	24.25	7.82	0	34.47
1987	28.92	52.94	58.27	22.1	57.45	22.1	0	14.9	73.76
1988	23.23	43.26	25.82	18.27	48.01	18.27	6.87	0	103.56
1989	14.87	38.3	32.77	13.4	46.01	13.4	13.55	0	141.88
1990	28.57	46.39	44.53	34.39	51.9	28.57	0	0	34.45
1991	30.91	43.43	33.28	32.83	53.5	30.91	0	0	0
1992	15.53	37.24	23.54	12.55	39.84	12.55	33.94	0	0
1993	9.98	24.47	9.28	9.48	33.83	9.28	18.83	0	10.43
1994	16.75	20.25	19.5	12.21	29.48	12.21	7.75	0	10.8
2000	6.73	2.77	2.77	2.77	9.47	23.09	4.13	0	0

Table 3: Rate of changes in inputs and outputs

Table 3 shows the percentage of necessary changes in inputs to make the non-efficient years as an efficient one. For example, in 1994 the total expenses and construction budget which are not used are % 12.21 for freight wagons, % 29.48 for passenger coaches, % 12.21 for locomotive, % 19.5 for main routes, % 20.25 for staff and % 16.75 for total expenses and construction budget. Also, the railway could have gained % 7.75 more in ton-kilometer for carried freight and % 10.8 of income more than current situation to achieve efficiency boundary. The zero in the column of passenger-kilometer shows that the railway has no extra capacity for passenger handling in 1994. Also, the similar results can be achieved for the other non-efficient years.

For comparing the ten efficient years to select the best one, the Andersen and Petersen ranking model is used. Based on the results, the efficiency value of 1998 is 2.532 as a first rank and the years 1999, 1995, 1997, 2004, 1971, 2001, 2003, 1996 and 2002 are ranked respectively. In table 4, the efficient years were ranking according to their efficiency.

Year	1998	1999	1995	1997	2004	1971	2001	2003	1996	2002
Rank	1	2	3	4	5	6	7	8	9	10
Efficiency	2.532	1.176	1.124	1.119	1.110	1.070	1.065	1.053	1.035	1.023

Table 4: Ranks of efficient years

5 Conclusion

The figure 1 shows the results of efficiency and performance of railway in 1971-2004 in which ten years are selected in order to calculate the efficient years.

The year 1981 has the minimum efficiency of 0.466 and 1998 has the maximum efficiency of 2.532. From 1971 to 1995 we find no efficient years whose reason refers to the Islamic revolution and imposed war. During imposed war, the efficiency of 1983, 1984, 1985 is higher than 0.8 but not equal to '1". The carried freight ton-kilometer of these three years is higher than the other years of the imposed war which proves their high efficiency. After 1984 from 1995 up to the end of 2004 except year 2000 we see that the railway is efficient. This improvement can be caused by upgrading the managing methods and strategic decisions such as privatization of passenger division and transportation of transit freight which is very effective because of high revenue. Although, the railway performance in 1971-2004 shows ascending growth, but when the railway efficiency is "1" it does not imply that the railway has used its whole facilities.

With analyzing the input and output data and values in 1985 up to 1992 as well as comparing this data with railway efficiency in the mentioned years, it is recognized that several important inputs like length of main lines are constant. But from 1992, onward by developing the rail networks its efficiency beings ascending. So one of the suggestions for ascending efficiency is to meet railway needs. The years 1998 and 1999 are placed in second and third rank among efficient years due to decreasing of the number of personnel in these years.

In order to improve the efficiency one solution is to prepare better plans for using railway inputs. Also, the output increase is another solution which can be obtained through more freights and passengers handling. The third solution for increasing the railway efficiency is to replace the old and out of service fleet including locomotives and wagons with new ones. The other solutions such as preventive maintenance, technology upgrade and decreasing the personnel can also be taken into account.

Considering the research limitations including subsidy which Raja receives from the government, the budget allocated to the railway for fuel economization and the personnel of sub companies paid their salaries by railway, the results of the research may change and some efficient years may turn into non-efficient ones.

The railway performance in each year has been compared to the other years. If we consider the period shorter than before, some of the years after 1995 which are efficient in the results can be changed into non- efficient ones. For example, if we consider only the year's after1984, the results can be changed. Moreover, it must be mentioned that in recent years there are external factors such as the imposed war which affects the railway efficiency. For utility of these factors must be planned.

It should be mentioned that there are some other factors that can affect the railway efficiency. These factors are service quality, infrastructure installations and longer rail routes in comparison to the roads. For instance, when the railway route passes through the mountainous areas the ton-kilometer and passenger-kilometer would be longer than the road in which it seems that the railway performance is higher while the railway customers waste a lot of time. Considering the passenger numbers and the amount of freight as output variables they can be the subject of another research plan. There are several potential capabilities in the railway which must be studied too. In regard to the research limitations, the above-mentioned items can be used for the future research, provided the necessary data are found.

References

[1] Andersen, P. and NC. Petersen, (1993), A procedure for ranking efficient units in data envelopment analysis, Management Science 39, 1261-1264.

[2] Cantos, P., J.M. Pastor and L. Serrano, (1999), productivity, efficiency and technical change in the European railways, A non-parametric approach, Transportation, 26, 337-357.

[3] Cantos P., MJ. Pastor and L. Serrano, (2003), Efficiency measures and output specification: The case of European railways, Journal of Transportation and Statistics 3, .

[4] Charrnes, A., WW. Cooper and E. Rhodes, (1978), Measuring the efficiency of decision making units, European Journal of Operational Research 2, 429-444.

[5] Cooper, WW. Cooper, LM. Seiford, Tone, (2000), Data envelopment analysis, Kluwer Academic Publishers.

[6] Cowie, j. and G. Riddington, (1996), Measuring the efficiency of European railways, Applied Economics 28, 1027-1035.

[7] Dyson, RG., R. Allen, AS Comanho, V. Podinovski, CS. Sarrico and EA. Shale, (2001), Pitfalls and protocols in DEA, European Journal of Operational Research 132, 245-259.

[8] Iranian Railway Activities Statistics, Different years.

[9] Iranian Central Bank, Balance Sheet in Different years.

[10] Annual Statistics, Iranian Statistics Center, Different years.

[11] Aqdasi, M. and AR. Qolami, (2003), The study on productivity indexes and combination of productive factors in Iranian Railway, Technical Journal of Tarbiat - Modarres University, 11, 79-96.

[12] Aliyan-Nejadi, MR., (2001), Present the Data Envelopment Analysis (DEA) for evaluating the organized railway stations efficiency, Master of Science thesis, Azad University, Semnan Branch.

[13] Movahedi, MM. and Colleagues (2004), the comparison between Iranian Railway and other countries, present the suggestion for improving it, Technical Scientific Quarterly Journal, Azad University, Firoozkooh Branch.

[14] Oum, TH. and C. Yu, (1994), Economic efficiency of railways and implications for public policy, Journal of Transport Economics and Policy, 28, 121-138.

[15] Oum, TH., WG. Waters, and C. Yu, (1999), A Survey of productivity and efficiency meas-urement in Rail transport, Journal of Transport Economics and Policy, 33, 9-44.

Received: September 1, 2007