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Efficiency Evaluation of 12 Regions of RAI[1] (Iranian Railway) Using Data Envelopment Analysis (DEA)[2]

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Abstract

Safe, fast, efficient and effective railway is a main factor of economic development level of every country. This paper uses the DEA method to evaluate and compare the efficiency of 12 Regions of RAI. In addition, we introduce the reference(s) unit(s) for every inefficient region, and determine the amount of input decrease and/or output increase need to become them efficient. Findings indicate that in 2006, 4 regions of 12 are in Constant Return to Scale (CRS) status and 7 of them in Variable Return to Scale (VRS), and the average efficiency is 0.730 and 0.888, respectively. In other words, RAI works 27 percent under its capacity. More over results indicate that Hormozgan, Khorasan, Tehran and Isfahan Regions have the most efficiency respectively. The results show that the 8 regions, have been working in Increaser Return to Scale and 4 reminder Regions in Decrease Return to Scale. According to this results, we submit the suitable suggestion for improve the efficiency of the inefficient regions.

Keywords : *efficiency evaluation, data envelopment analysis, railway*

1. Introduction

Man, throughout his life has always faced with the limitation in production, products and services. In order to deal with this problem one has to make the best use of the available potentials to reach the highest production rate and quality. In one word, the answer to these needs is the concept of "efficiency".

Since the transportation is one of the basic fields of development, the actions such as manpower adjustment, regulating, policy-making and other measures are to be done in the best manner. Considering the potentials without making them most advantageous, would cause serious losses that will irreversibly affect on development.

According to the above discussion, transportation can be divided into four groups: air, railway, land and sea among which the railway transportation concerning the energy consumption, environmental effects, safety, expenses and other factors has more importance than other modes. The high economical advantages of the railway make it essential to study.

Now there are some questions according to above: are the resources properly assigned for this field? Is the efficiency of resources in such a way not to cause the future assignments to be useless? These questions fail to be answered unless the efficiency of different railway districts are investigated and evaluated. So, it is important and vital to evaluate the different railway districts system in Iran.

2. Research

Nowadays, the evaluation and investigation of different economical areas has attracted the researchers' attention. Issues like decentralization and increase in managers' responsibilities as well as optimization of current resources have made different organizations to investigate their units. The Islamic republic IRA is not an exception from this rule, so analyzing the efficiency and making some comparisons in different districts is a good way of achieving this goal.

One of the factors showing the efficiency of a system is

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the ratio of outputs to inputs. There are two ways of analyzing the efficiency: 1- parametric methods 2- non-parametric methods.

In this paper the latter method has been used. The main benefit of the DEA method is reflected in the systems that have the multiple inputs and outputs. After the efficiency evaluation, one can help managers to make decisions and plan in such a way to make the best use of available resources. Therefore, this research has been focused on the "Evaluation of the efficiency in different districts of the RAI using Data Envelopment Analysis.

3. The Importance and Aim of This Research

Transportation is one of the main elements of development in a society in which the high efficiency is of a great importance in this field of economy. Among different modes the railway is very important due to the huge investment assigned from one hand, and low prices of fuel, environmentally friend, and safe from another which makes it distinct. Because the resources are limited, the high efficiency is of a great importance. Ever increasing of challenge in different fields has made organizations to evaluate their affiliated units from different aspects. RIA like other organizations attempts to evaluate its units in order to compete. Being optimized is not possible unless through the evaluation of different areas on a scientific basis to find the best strategies.

Our main objective in this research is to evaluate the efficiency of different districts of the IRA. Finding of the factors that affect the efficiency are vital. Detection of non efficient districts in order to improve the efficiency of other ones is other e aim of this research. This research will try to answer the following questions:

1- Has the efficiency of IRA districts been optimum in 2006?
2- Are the IRA districts capable of increasing the freight tonnage and number of passengers with the existing possibilities?
3- Is each districts, concerning its inputs and outputs considered as a unit?
4- What are the sample units or units for increasing the efficiency of non-efficient ones?

4. Background and Theoretical Basics of the Research

The importance of productivity and efficiency in the process of production in addition to the economical activities has got a long background in economics literatures. Improvement in human know-how in different areas especially in economics has culminated the concept of above terms while at the same time made their measurement easier. In new concept, efficiency means not to waste the resources which are the ratio of the outputs to the total inputs. Productivity means comparing the efficiency of an organization in two different time intervals or comparing the efficiency of two different organizations at the same period of time. There are also other descriptions among which the above-mentioned ones are more common [Imami Meibodi, 2000].

In the simplest manner, an organization has an input and output unit whose efficiency is defined as a ratio of output to input compared to the specific standard regarded as a function of production. In this case it is necessary to have a function of production. Usually the units have several inputs and outputs to which the efficiency is described as the ratio of outputs total weight to inputs. Actually in this case multiple inputs and outputs are changed into a virtual output or synchronized somehow [Jahanshahlou, Alirezaei, 1995].

According to the above description, the efficiency measurement should be compared with an accepted appropriate standard which can be determined through different ways such as the ratio analysis and border analysis methods. In border analysis approach the concept of efficiency that is in close relation with the operation evaluation is used. There will be a border that is called the efficiency border. The branches working on this border are considered as efficient with best operation and the units working below this line are considered as not efficient [Rezvani, 2001].

In economical theories there are two different methods for evaluating the efficiency called as parametric and non-parametric methods. In parametric approach there are different methods such as **Stochastic Frontier Approach** (SFA), **Tick Frontier Approach** TFA and **Distribution Free Approach** DFA for determining the border. In all of these parametric approaches it is tried to estimate a linear production function in a specific manner (like translog, Cabdoglas, etc) through using different assumptions with a combined error term. So in this way the non efficiency of different units is attributed to the stochastic factors and non efficiency factors [Bauer et al., 1998].

The most important problem of the parametric approach refers to the different assumptions considered for the functions. With different assumptions, different estimations are generated that makes it difficult to compare different units in practice.

In non-parametric approach, there are different methods for evaluating the non-efficiency whose most important

ones are the stepped frontier and linear programming [Vadoodi Mofid, 2006].

5. Measuring Efficiency Using DEA

DEA (Data Envelopment Analysis) was first used by Edward Rohodos in his PhD thesis guided by Cooper in which he analyzed the educational improvement of the students in the United States schools. The results were published in a paper known as CCR. The CCR through converting the multiple inputs and outputs into the single input and output could use the optimized mathematical methods for generalizing the efficiency of a single phase input and output into the multiple ones [Charnes, Cooper, 1978].

Then, in 1984, Benker, Charls and Cooper published a paper in which a model called BCC was represented. BCC stands for the abbreviation of their names. In this model the issue of efficiency to scale was added to the CCR [Banker, 1984].

This method globally known as efficiency measuring method, attempts to measure the efficiency while providing the type of efficiency to the production scale for different enterprises. By improving the DEA method it has become one of the active domains of efficiency measurement greatly welcomed by the world researchers. It has got a significant application in evaluating the operation of the public and non-profitable organizations whose price data are not usually available or reliable. In this method the term DMU (Decision Maker Units) is used instead of term producer for generalization. This method that uses linear programming is a non-parametric method that estimates the equal production functions [Imami Meibodi, 2000].

In primary stage, the DEA method expresses the following pattern to measure the partial efficiency:

$$\text{MAX} \quad \frac{\sum_{r=1}^{S} U_{ro} y_{ro}}{\sum_{i=1}^{n} V_{io} X_{io}}$$

$$\text{ST} \quad \frac{\sum_{r=1}^{S} U_{ro} y_{rj}}{\sum_{i=1}^{n} V_{io} X_{ij}} \le 1, \; i = 1,2,\ldots, n; r = 1,2,\ldots,s$$

$$U_{ro}, V_{io} \le 0 \qquad j = 1,2,\ldots,m$$

In other words in DEA the weighted ratio of inputs and outputs are maximized provided that the same coefficients in other enterprises don't make them more than one unit.

Banker, Charnes and Cooper (1978) expanded the CCR model so that the variable efficiency accommodates the relative to scale.

This is possible by formulating the binary problems in linear programming with the assumption of the constant efficiency relative to the scale by adding the convexity limitation to this model. In this case the calculation is done with the assumption of variable efficiency relative to the scale.

So that:

$$\text{Min } \theta$$

$$S.T - \sum_{r=1}^{S} U_r Y_{ro} + \sum_{r=1}^{S} \lambda_j y_{ij} \ge 0, \; j = 1,2,\ldots,n$$

$$\theta \sum_{i=1}^{m} V_i X_{io} - \sum_{i=1}^{m} \lambda_j X_{ij} \ge 0$$

$$\lambda > 0$$

$$NI'\lambda = 1$$

The above model with the above-mentioned limitation does not determine whether an enterprise is working in ascending or descending efficiency area. In practice, this happens by comparing the ascending efficiency limitation with the scale of ($NI'\lambda \le 1$)

So that:

$$\text{Min } \theta$$

$$S.T - \sum_{r=1}^{S} U_r Y_{ro} + \sum_{r=1}^{S} \lambda_j y_{ij} \ge 0, \; j = 1,2,\ldots,n$$

$$\lambda > 0$$

$$\theta \sum_{i=1}^{m} V_i X_{io} - \sum_{i=1}^{m} \lambda_j X_{ij} \ge 0$$

$$NI'\lambda \le 1$$

In other words, the nature of efficiency in non-efficiency scale for a given enterprise is defined through comparing the technical efficiency in the non-ascending efficiency status relative to scale with the degree of technical efficiency variable relative to scale. It is performed in such a way that if these two efficiencies are equal, then the given enterprise would face with the ascending efficiency relative to scale; otherwise the condition of ascending efficiency relative to the scale is fulfilled.

This model is called BCC with the assumption of variable efficiency relative to scale. According to this model, the calculated efficiency in CCR is divided into managing efficiency and efficiency of scale.

6. Scale Efficiency

Based on the CCR and BCC scores, we can define scale efficiency as follows:

Definition (Scale Efficiency) Let the CCR and BCC scores of a DMU be θ^*_{CCR} and θ^*_{BCC}, respectively. The scale efficiency is defined by

$$SE = \frac{\theta^*_{CCR}}{\theta^*_{BCC}}$$

SE is not greater than one. For a BCC-efficient DMU with CRS characteristics, i.e., in the most productive scale size, its scale efficiency is one. The CCR score is called the (global) technical efficiency (TE), since it takes no account of scale effect as distinguished from Pure Technical Efficiency (PTE). On the other hand, BCC expresses the (local) pure technical efficiency (PTE) under variable returns-to-scale circumstances. Using these concepts, the above relationship demonstrates a decomposition of efficiency as [Cooper, Lawrence, and Kouru, 2006]:

$$TE = SE \times PTE$$

7. Background of the Study

About the DEA model, several studies have been done and papers have been published. At the same time for calculating and analyzing the efficiency in railways, a little work has been done such as: national studies about the efficiency of railway in Iran by Movahedi in which the efficiency was calculated during 1971 to 2003 using DEA and the efficient units were introduced. In this research the railway was defined as a unit for decision making for each year. The inputs for this research include the number of equivalent locomotives in service, the freight cars passenger's coaches, length of the rail network, number of staff plus the operational and construction expenses. The other outputs include ton-kilometers, passengers-kilometers and revenue. The results show that from 1350 to 1382 only 6 years were efficient.

Another domestic research performed for the evaluation of efficiency in IRA includes Movahedi's (2006) in which the efficiency of railways in Iran is compared with the railways in other countries. The information is gathered from UIC countries in 2002. In this research two inputs including ton-kilometers and passengers-kilometers are considered. On the other hand, inputs include the number of equivalent locomotives in service, the freight cars, passenger's coaches, length of the rail network, the number of staff. Because the total productivity has been the main objective, the DEA is used.

Another research in this area can be the M.S. thesis of Mr. Javad Rezaee (2002) in which the efficiency of different railway districts has been measured in 2002. The inputs and outputs include the main routes, staff, passenger coaches, freight cars, consumed energy, tons of carried freight and number of people transported.

Among the most important foreign researches done on evaluating the operation in railway transportation is the Oum and Yu (1994) in which one element was considered as the output. Also Oum et al. (1999) did a thorough review on evaluating the productivity and efficiency in railway transportation. The results of this research show high sensitivity to the outputs attributes. Cantos et al. (1999) found the factors of efficiency by using non-parametric approaches while Cowie, and Riddington, (1996) used the selective methodology. According to the latest research, the precise measuring of the efficiency is not possible and can only be used to make clear whether the operation is good or bad. In most studies some given companies are considered very efficient while in other studies are non-efficient.

Pedro Cantos et al. (1999) evaluated the European railways using non- parametric DEA. In this study the outputs were the passengers, ton- kilometer carried and the number of freight cars.

The variables used as inputs were:

1. Number of staff, 2. Energy consumption and raw materials, 3. Number of locomotives, 4. Number of passenger coaches, 5. Number of freight cars 6. Main lines in kilometers. By using the Pierson coefficient tests and spearman ranking test it was clear that measuring the efficiency has the same result in both said outputs from statistical view. In this research done in Spain the efficiency of 16 European countries was evaluated using DEA. According to the results, the railways of Sweden, Finland, Switzerland and Netherlands had the highest efficiency while Norway, Denmark, Ireland and Greece were in the lowest rank.

8. Methodology

In order to find a suitable method of research it is necessary to investigate the issue. Our main objective in this study is to measure the efficiency in different railway districts in Iran. In order to determine this parameter it is important to distinguish the affecting factors in each district. They are considered as an analyzing unit consisting of an input and output. It is important to determine the inputs and outputs that show the efficiency of districts in the best manner. In order to achieve the above-mentioned objective interviewing with the chief managers was on the

top of the tasks.

The researcher's method is as follows and describes the desirable characteristics of the measuring system for efficiency:

1. The evaluation period is determined based on the availability of information and management goals of efficiency evaluation.
2. Interviewing with the top managers and employees working in the Islamic Republic of IRA as well as the viewpoints of the experts of railway research center.
3. Determining the inputs and outputs that show the efficiency of the different districts in the best manner.
4. Gathering of information to rationalize the observations.
5. Measuring the efficiency of the different districts using DEA method.

9. Measuring Efficiency, Determining the Inputs and Outputs in DEA Model Used in This Research

As mentioned before, each unit is considered as a single DMU which consists of different inputs and outputs. In fact, each railway district uses the inputs to produce its outputs. As a theoretical basis of DEA, the efficiency is the ratio of the total weight outputs to the total inputs. Therefore, the proper determination of inputs and outputs that show the efficiency is of a great importance.

According to the background of the present research and interviews with the managers of different railway districts, the inputs include: 1. total length of the main lines 2. Human resources 3. Number freight wagons 4. Number of passenger coaches. The outputs include passenger-kilometer and tones-kilometer.

10. Inputs

The input in DEA is a factor if it is added to the system, provided the conditions are constant, the efficiency decreases. The inputs in appendix 1 are as follow:

11. The Main Line of Railway

Since this activity refers to the transportation so the length of the line acts as a main factor. It seems that the more efficient district is a one that makes the best use of its line capacity.

12. Human Resources

There is no doubt that each district is managed by the staff working in different units who based on their experience and skill would play an important role within their area of activity.

It is clear that improper job allocation among staff in addition to the low productivity of personnel with a little knowledge about the condition would impose a negative effect on efficiency. Therefore, the most efficient unit is one that uses enough number of personnel through logical distribution. It can be concluded that paying low attention to each of the above factors would make the efficiency impeder.

13. Number of Freight Wagons

Knowing that there is no apparent statistics about the number of the freight wagons for each district in a year,

Appendix 1. Inputs Data (2006)

District	The main line of railway	No. of staffs	Number of freight wagons	Number of freight wagons
South	384	681	1355.09	40.79
Lorestan	215	741	559.52	54.76
Arak	360	655	996.56	76.63
Tehran	868	965	2146.28	530.03
North	401	556	300.4	26.31
Northeast	1080	643	891.46	193.69
Khorasan	728	1081	1400.41	223.63
Northwest	485	682	507.57	87.22
Azarbayjan	467	842	541.55	45.26
Isfahan	649	784	2182.92	61.74
Southeast	1092	825	5807.52	25.41
hormozgan	812	863	3110.39	24.4

Sources: Iranian Railway Activities Statistics, Different years.

Appendix 2. Output Data

The unit of transportation (Total of ton-kilometer and passenger-Kilometer)	District	Items
2014135	South	1
1143768	Lorestan	2
1219774	Arak	3
5542372	Tehran	4
399933	North	5
1232651	Northeast	6
4332842	Khorasan	7
853614	Northwest	8
624875	Azarbayjan	9
4553334	Isfahan	10
3924634	Southeast	11
5907629	hormozgan	12

Sources: Iranian Railway Activities Statistics, Different years.

these statistics were extracted using the following equations [Rezaei 2002]:

$$p = \frac{Total\ transportation\ of\ freight\ wagons}{Total\ existing\ wagons}$$

$$= \frac{Total\ transportation\ of\ freight\ wagons\ in\ each\ District}{Number\ of\ freight\ wagons\ per\ district}$$

14. Number of Passenger Coaches

In order to extract the statistics of the number of the passenger coaches per district, knowing that there isn't any reliable statistics, the following relation has been used [Rezaei, 2002]:

$$p = \frac{Total\ transportation\ of\ passenger\ coaches}{Total\ existing\ coaches}$$

$$\frac{Total\ transportation\ of\ the\ passenger\ coaches\ per\ distr.}{Number\ of\ freight\ wagons\ per\ district}$$

15. Outputs

Output in DEA is a factor that if added to the system provided that the other conditions are constant, the efficiency increase. The outputs in appendix 2 are as follow:

16. Ton-Kilometer

One of the outputs used in the model is ton-kilometer that means carrying one ton of cargo for one kilometer.

17. Passenger-Kilometer

One of the outputs used in the model Passenger-kilometer that means carrying one Passenger for one kilometer.

In DEA the more the evaluated units are, compared with the number of inputs and outputs, the more powerful will be the model [Mehregan, 2004]. For this reason ton-kilometer and person-kilometer are added to each other and are considered as a single unit for transportation. This method is acceptable by the UIC.

item	district	Total Technical Efficiency	Pure Technical Efficiency	Scale Efficiency	Type of Return to Scale	No. of Reference Unit(s)
1	South	0.738	1.000	0.738	Increasing	1
2	Lorestan	0.824	1.000	0.824	Increasing	2
3	Arak	0.519	0.873	0.594	Increasing	2,1,5
4	Tehran	1.000	1.000	1.000	Constant	4
5	North	0.524	1.000	0.524	Increasing	5
6	Northeast	0.459	0.688	0.667	Increasing	4,5,10
7	Khorasan	1.000	1.000	1.000	Constant	7
8	Northwest	0.544	0.748	0.726	Increasing	7,5
9	Azarbayjan	0.460	0.592	0.776	Increasing	10,7,5
10	Isfahan	1.000	1.000	1.000	Constant	10
11	Southeast	0.695	0.751	0.926	Increasing	5,10,12
12	hormozgan	1.000	1.000	1.000	Constant	12
Average		0.730	0.888	0.815	---	---

Fig. 1 The results of research

18. Findings of the research:

Considering the inputs and outputs as well as analyzing the efficiency using DEA, the following resulted was attained that are illustrated in Fig. 1.

The findings of the research show that in 2006 from total number of 12 areas, four were CRS and 7 were in VRS and the average efficiency in these two cases is 0.730 and 0.888 respectively. Also 8 units were working with increasing efficiency and 4 units were working with constant efficiency.

The districts of Tehran, Khorasan, Isfahan and Hormozgan have unit efficiency and are placed on the frontier line. It should be noted that the efficiency of the efficient districts is showed with "1" and it doesn't mean they are working perfectly, but it means their efficiency compared with others is 1. In the present research the operation of South, Lorestan, Arak, North, North eastern, North western, Azarbayjan and South eastern are non efficient.

In DEA a set of efficient branches are introduced as controls for any of non efficient units that show the aims of the inputs or outputs with given coefficients.

For example in Azarbayjan, the districts 7, 5 and 10 are introduced as control patterns. These districts are Khorasan, North and Isfahan, respectively. Azarbayjan has to increase its output according to the outputs of this linear combination.

19. Ranking of Efficient Units

DEA divides the analyzed units into two groups of efficient and not efficient. Efficient units are those that their rank of efficiency equals 1.

The non efficient units will be ranked after they gather ranking, but the units whose ranks are 1 are not able to be ranked using the classic DEA methods. For this reason some methods have been introduced among which the Peterson-Anderson method is reliable.

The results of ranking by using the above methods for the efficient districts show that: Hormozgan, Khorasan, Tehran and Isfahan are the most efficient areas with the ranks of 2.421, 1.4183, 1.116, and 1.092 respectively.

20. Conclusions

As it was shown in Table 1, the average Scale Efficiency is 0.815 and the average of Pure Technical Efficiency for management is 0.888 which means that the railway districts from the view of scale and management have empty spaces, provided the other conditions are constant. Therefore, it should be tired to make the best use of these resources. Another important issue related to the results of the efficiency is the total efficiency of railway districts that is 0.730. In other words it can be said that the railway of Iran using the existing facilities without changing the capacity can increase its output up to 0.270.

As it was said in this research each unit of railway is considered as a single unit for decision-making. Therefore, the aim of this evaluation is to determine the efficient and non efficient districts and to give suggestions for improvement. Generally, it can be said that the reduction and increase of any input or output can affect on efficiency. Here are some examples:

1. Because the southern districts, Lorestan, Arak, North, Northeast, Northwest, Azarbayjan and southeast are facing with Increasing Efficiency relative to scale can improve their efficiency by changing their framework and moving toward optimum scale. Therefore, it is suggested that the investment in railway is given the first priority.
2. It is suggested that Arak increases its output as much as 176949 in order to reach the highest efficiency in its outputs. Control units are south, Lorestan and North. If it is possible to transport a larger amount of cargo through less number of car movement the efficiency will improve.
3. Because the northwest is located on transit routes, it must carriy freight less than people. So northwest has to increase its outputs as much as 287022 units in order to reach the highest efficiency. The most important part of this increase should be focused on strategies that attract the cargo. For this reason, providing facilities for cargo owners, marketing, speed, precision and quality in transportation are important.
4. Azarbayjan is located in a place that is considered as a terminal for importing and exporting, is the only district whose management efficiency is not equal to unit one. So it is suggested to increase its output as much as 429988 units in order to reach the highest efficiency. Also due to its geographic situation from the view of gradient, high altitude from sea level, being mountainous much number of human resources are found there. Human resource adjustment due to the arrival of new technology in different fields, infrastructure rehabilitation, in addition to the decrease in inputs, safety improvement, and increase in trains speed on the other hand are effective in attracting cargo and passenger.
5. It is suggested that Southeast district must increase its output as much as1302583 in order to reach the highest efficiency. This is possible by organizing the transportations from Chadormaloo Mine as well as reduc-

ing the movement of empty wagons in this district. Human resource adjustment and improving the working condition are of other effective suggestions. Taking the opportunities for loading the wagons in return to Chadormaloo is recommended.

6. Better planning to make better use of entrance gates in different districts using two ways loaded freight cars, continuous education of human resources, maintenance and renewal of the right of way are also recommended.
7. Providing a proper condition for private and non governmental sectors to engage in handling passenger and freight are suggested too.

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