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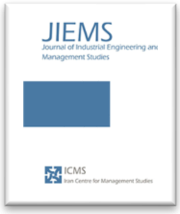

Efficiency evaluation of Iran's railway stations using data envelopment analysis

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Abstract

Railways are an efficient transport system that provides the possibility of transportation through a rail network. Railway stations are the significant part of the rail transport system and evaluating its performance is of particular importance since various activities such as passenger transport, and welfare and commercial services are provided in this part of the system. In this research, the efficiency of Iranian railway passenger stations in 19 zones as the case of study is measured by data envelopment analysis (DEA). The efficient centers and reference units for inefficient centers are identified by analyzing the efficiency of stations. Railway stations are analyzed using an output-oriented slack-based measure (SBM) model with the constant returns to scale assumption. The performance of the station is evaluated by the inputs of the total station area, the number of platforms, the number of staff, the number of available seats, the total cost of the station, and the outputs of the number of passengers transported, the number of trains stopped, and the total revenue of the station. The ranking results showed that six stations of Tehran, Mashhad, Shahroud, Zanjan, Qom, and Kerman were efficient with the score of one, and 13 stations were inefficient, which Dorud, with an efficiency of 0.283, had the lowest efficiency. Finally, for inefficient stations, the surplus values of inputs and slack values of outputs were provided to improve the efficiency. Given that the case study is one of the few studies in evaluating the efficiency of railway stations by slack-based measure model, the research provides managerial insights to improve the performance of stations. This can be considered as the main contribution of the study.

Keywords: railway station; efficiency; data envelopment analysis SBM model.

Paper Type: Original Research

1. Introduction

The transportation industry as a prerequisite for economic growth includes those activities that provide the possibility of transportation through connected networks. Transportation is particularly important in the economic growth and development of any country. Given the impact of transportation on developing interconnected networks as well as production and investment indices, it is important to measure transportation productivity in economic growth. Therefore, improving this industry increases economic productivity, leading to increased economic productivity at the macro level. Transportation management in order to optimize transport systems is one of the important issues that have affected the economic development process. In this industry, rail transportation is one of the infrastructure sectors of the economy. The most important features of rail transportation are low cost, high safety, low energy consumption, and high transportation potential. The high economic efficiency of rail transportation necessitates this sector’s development (Movahedi and Hosseini, 2010).

On the other hand, the economic growth and development of any country depend on improving the productivity of all production and service factors; thus, it is important to measure productivity. Increasing productivity in an organization can result in progress in the competitive market, improved performance of various sectors, reduced costs, increased revenue, and improved quality of products or services; examining the productivity changes trend, results in acquiring knowledge from the state of efficiency, technology, and technical knowledge in an organization. Thus, managers can have access to appropriate and comprehensive information on the performance of their organization, and make right and timely decisions for its continuous improvement based on the existing changes. Hence, optimally using the available facilities and resources helps improve productivity and efficiency (Seifnia¬¬ and Ojaghi, 2014).

Therefore, to develop the country's railway network and improve railway stations, the necessary infrastructure and facilities must be provided and the country's railway network should be evaluated to enhance the efficiency of the country's rail transport system.

Due to the importance of performance evaluation in the transportation industry, the efficiency of Iranian railway stations in the rail transport system is measured with an emphasis on productivity and optimal allocation of resources.

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This research aims to evaluate the efficiency of Iranian railway passenger stations centers in 19 zones to rank the stations by data envelopment analysis (DEA). The novelties of the paper can be mentioned as:

- In the case study, real data was extracted from reliable sources and the practical implications are developed.
- The novelty is not only in the case study but also in the model are used the slack-based models to evaluate the efficiency of railway stations.
- In this paper, first, a literature review is presented. Then, in the theoretical foundations of the research, the main models of DEA and the SBM used in this research are introduced. In the fourth section, evaluating the efficiency of railway stations is described by DEA and input and output indices. In the fifth section, results of efficiency measurement are examined. The sixth section contains the conclusion.

2. Literature review

There are few studies on efficiency measurement by DEA in rail transportation, some of which are domestic and some are related to other countries. The literature is presented in Table 1, which contains a brief description of the purpose of the study, efficiency evaluation method, and input and output indices.

Also, in other studies conducted on industry Arab Momeni, Ebrahimi Arjestan and Yaghoubi (2018), the efficiency of ERP systems was evaluated with a two-stage DEA. In this model, the operational efficiency and customization efficiency of ERP packages are measured in the first and second stages. Hence, owing to the time and costs of ERP development, the operational aspects of efficiency were considered. The efficiency was also measured in terms of software features, including the number of codes and functions and the customization stage, which indicated the degree of ERP compliance with organizational processes of buyers. This paper demonstrated that ERP providers with higher operational efficiency and customization capability of ERP packages had better performance than other providers.

Hassanpour (2019) conducted a study to technical and hierarchical evaluation of Iranian electronic products manufacturing industries (IEPMI). In this paper, the unsupervised model, additive ratio assessment (ARAS), simple additive weighting (SAW), and DEA models are used to classify and analyze IEPMI. According to the results in the unsupervised model, the hierarchical cluster classification for industries was obtained based on five main criteria. In ARAS and SAW-based ranking systems, the same results were presented for IEPMI. In the DEA model, according to the inventory of input and output values, IEPMI was also classified in terms of efficiency.

In this study, the efficiency of Iranian railway passenger station centers is evaluated using the SBM model in data envelopment analysis which, according to the literature review, has been done few studies in this field.

Table 1: A literature review on the rail transportation industry

Author/ Year	The goal of study/ DMUs	Method	Country of Study	Inputs	Outputs
Movahedi, Saati, and Vahidi (2007)	Evaluating railway efficiency from 1971 to 2004	DEA (CCR)	Iran	Average of passenger wagons number, the average of freight wagons number, the average of locomotives in service, total lines in a kilometer, personnel number in thousand, total expenses, and construction budget in rial	Transported freight in ton-kilometer, the transported passenger in passenger-kilometer, total income in billion rials
George and Rangaraj (2008)	Measuring operational performance in 9 railway zones in 1998 and 1999 and 16 railway zones in 2004 and 2005	DEA (CCR, Super-efficiency) and Cross-efficiency	India	Operating expenses, tractive effort, equated track kilometers, number of employees	Passenger kilometers, ton (freight) kilometers
Yu (2008)	Evaluating technical efficiency, service effectiveness, and technical effectiveness for 40 railways in different countries in 2002	TDEA, NDEA	World	Inputs of the production process: the length of railway lines, the number of passenger cars, and the number of freight cars Shared input of the production and consumption processes: labor	Intermediate outputs of the production process: passenger–train–kilometers, and freight–train–kilometers Outputs of the consumption process: passenger-kilometers, and ton-kilometers
Yu and Lin (2008)	Evaluating technical efficiency, service effectiveness, and technical effectiveness of passenger and freight for 20 railway companies in 2002	MNDEA	World	The input of the passenger sub-production process: the number of passenger cars The input of the freight sub-production process: the number of freight cars Shared inputs of the passenger and freight sub-production processes: length of lines, and the number of employees	The intermediate output of the passenger sub-production process: passenger–train–kilometers The intermediate output of the freight sub-production process: freight–train–kilometers Outputs of the consumption process: passenger-kilometers, and ton-kilometers
Hilmola (2010)	Evaluating revenue and technical efficiency in the railway sector and examining the performance of railways at the world scale in 2004	DEA (CCR)	World	Passenger coaches/ freight wagons, total route (km), total locomotives, staff	Passenger kms /freight ton-kms, passengers / freight tons, passenger revenue /freight revenue
Hilmola (2010)	Evaluating two-stage DEA hierarchy for the rail passenger transportation and the relationship between its three models, namely the direct model of operational inputs, intermediate model, and financial model during 1980-2004	Two-stage DEA Hierarch	World	Inputs of the transportation process: passenger coaches, total route (km), total locomotives, staff	Intermediate outputs of the transportation process: passengers, and passenger-kilometers The output of the management process: passengers' revenue
Jitsuzumi and Nakamura (2010)	Investigating causes of inefficiency of 53 railway companies and allocation of optimal subsidies in 2003	DEA (NCN, BCC) and SFA	Japan	Fixed assets, staff, operating expenditures	Passenger-km, externalities on surrounding communities
Mohajeri and Amin (2010)	Finding the optimal location for the Mashhad railway station site	DEA and AHP	Iran	Main criteria include rail-related, passenger services, architecture, and urbanism, economics	Weights of criteria AHP
Markovits - Somogyi (2011)	Evaluating efficiency in the transport sector with a special emphasis on selected inputs and outputs in DEA models in various fields	DEA (BCC, CCR)	World	Selected railway inputs from the areas of labor, capital, and facilities	Desired railway outputs of the operational, and fiscal characteristics

Author/ Year	The goal of study/ DMUs	Method	Country of Study	Inputs	Outputs
Movahedi, Abtahi, and Motamedi (2011)	Evaluating Iranian railway efficiency compared to 60 countries in 2007	DEA (VRSTE, CRSTE, Scale)	Iran	Equivalent locomotives that include main and marshaling locomotives per unit, passenger coaches per unit, freight wagons that have the type of wagons per unit, the average number of staff per year per 1000 persons, the total length of main routes which contain single track, double track and the length of electrified track per kilometer	Carried passenger per million kilometers, carried freight per million-ton kilometer
Petrović, Pejčić-Tarle, and Vujičić (2012)	Evaluating technical efficiency, scale efficiency, and Super-efficiency of freight transport systems in 14 European countries during 2005-2009	DEA (CRS, VRS, Scale) and Super-efficiency	Europe	Length of lines in use (total route–km), number of wagons for goods transportation, number of employees	Freight ton–kilometers
Kabasakal, Kutlar, and Sarikaya (2013)	Evaluating technical efficiency and allocative efficiency of 31 railway companies and total factor productivity (TFP) during 2000-2009	DEA (BCC, CCR) and Panel Regression and Malmquist Index	World	Total annual costs of operation, the average annual number of employees, the total length of mainline, the total number of traction vehicles, the total number of passenger cars, the total number of cargo cars	Annual total revenues earned, the total number of passengers transported, the total number of passengers per kilometers, total cargo ton transported, total cargo ton per kilometers transported
Kutlar, Kabasakal, and Sarikaya (2013)	Evaluating technical efficiency and allocative efficiency of 31 railway companies during 2000-2009	DEA (BCC, CCR) and Tobit Regression	World	Total annual costs of operation, the average annual number of employees, the total length of the mainline, the total number of traction vehicles, the total number of passenger cars, the total number of cargo cars	Annual total revenues earned, the total number of passengers transported, the total number of passengers per kilometers, total cargo ton transported, total cargo ton per kilometers transported
Rayeni and Saljooghi (2014)	Evaluating cross efficiency to measure the performance of railway activity data from 1977 to 2010 and comparing with other data envelopment analysis models	DEA (CCR) and Cross-efficiency and Super-efficiency	Iran	Average of passenger wagons number, the average of freight wagons number, the average of locomotives in service, lines consisting of main, siding and industrial lines in a kilometer personnel number in thousands total expenses, and construction budget in rials	Transported freight in ton-kilometer, the transported passenger in passenger-kilometer, total income in billion rials
Bian, Hu, and Xu (2015)	Evaluating overall efficiency of 18 railway companies and efficiency of parallel sub-systems with shared inputs and outputs in 2010	Centralized DEA	China	The input of the passenger transportation sub-process: passenger dispatchers Inputs of the freight transportation sub-process: freight dispatchers, and freight handling machinery Shared inputs of the passenger and freight transportation sub-processes: employees	The output of the passenger transportation sub-process: person-kilometers The output of the freight transportation sub-process: ton-kilometers The shared output of the passenger and freight transportation sub-processes: revenues
Tavassoli, Faramarzi, and Saen (2015)	Measuring overall efficiency of railways, technical efficiency, service effectiveness, and technical effectiveness of passenger and freight of 13 Iranian railways in 2012	NDEA	Iran	The input of the passenger sub-production process: the number of passenger cars The input of the freight sub-production process: the number of freight cars Shared inputs of passenger and freight sub-production processes: fuel, and employees	The intermediate output of the passenger sub-production process: passenger-train-kilometers The intermediate output of the freight sub-production process: freight-train-kilometers Outputs of the consumption process: passenger-kilometers, and ton-kilometers

Author/ Year	The goal of study/ DMUs	Method	Country of Study	Inputs	Outputs
Tsai, Mulley, and Merkert (2015)	Evaluating technical, cost, and allocative efficiency of 20 international urban railway systems in Asia, Australia, Europe, and North America during 2009-2011	DEA and Tobit Regression	World	The number of employees, the number of cars, labor price, capital price	Car-km, patronage
Khadem Sameni, Preston, and Khadem Sameni (2016)	Evaluating technical efficiency and service effectiveness of 96 railway stations in 2007	DEA and Tobit Regression	England	Inputs of the technical efficiency stage: number of platforms, percentage of through lines, station staff, platforms length Inputs of the service effectiveness stage: number of train stops, station catchment area population, job opportunities in the catchment area	The output of the technical efficiency stage: number of train stops Outputs of the service Effectiveness stage: number of passenger entries and exits, number of passenger interchanges
Kuang (2018)	Evaluating the efficiency of 18 railway Bureau in 2013	DEA(BCC) and Super-cross efficiency	China	Operating mileage, the number of employees, the number of locomotives, the average daily number of vehicles	Passenger turnover, freight turnover, transportation revenue
and Khalid Li, Li, (2018)	Evaluating technical efficiency of passenger and freight transport of 18 railway administrations in 2014	DEA (BCC, CCR, Scale) and Generalized DEA	China	The number of employees, line length (km), the number of the locomotives, the total energy consumption of locomotive (ton)	Locomotive workload (hundred million km), freight turnover (hundred million ton-km)

3. Theoretical foundations

3.1. DEA

DEA is one of the efficient methods for measuring efficiency. It is a non-parametric method using a mathematical programming model to evaluate the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs.
DEA model is a method based on efficiency analysis to compare DMUs with the efficient frontier. In this method, the efficient frontier curve is derived from maximum outputs obtained from different values of the given inputs and calculates the efficiency of each DMU based on the production possibility set. The efficient frontier is determined by the production possibility set.
It is a set of all combinations of inputs and outputs that demonstrates the set of all the production values for different sources; in other words, the production possibility set refers to all the possible combinations of inputs and outputs (Mehregan, 2013).
In DEA, there are two types of models: radial and non-radial. Radial models are represented by the CCR model. They consider the proportional changes of inputs or outputs, and the efficiency score in the CCR model represents the maximum proportional ratio of decrease (or increase) in all the inputs (or outputs) (Tone, 2017).
However, in real-world business, all the inputs (or outputs) do not have proportional behaviors. For instance, if we use labor, materials, and capital as input, some do not change proportionately. Another disadvantage of radial models is the slacks that are not considered in the efficiency score report. In case these slacks play a major role in evaluating managerial efficiency, if the efficiency score is used as the only index to evaluate the performance of DMUs, the radial approaches may make mistakes in the decision-making process.
In contrast, non-radial SBM models do not assume the proportional changes in inputs and outputs; simultaneously, reducing inputs or increasing outputs is taken into account inappropriately and the slacks and efficiency of units are determined (Tone, 2017).
SBM models are designed to meet the following two conditions:
1. Units-invariant: The measure should be stable relative to the input and output units.
2. Monotone: The measure should decrease in each input and output slack (Tone, 2017).

3.1.1. Radial models

In the DEA model, the efficiency of each DMU is the maximum ratio of weighted outputs to weighted inputs under the constraints.
In the DEA model, to achieve the maximum efficiency of n DMU with m inputs, and s outputs of the following fraction should be maximized:

$$\begin{aligned} & Max\ Z_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \\ & st: \\ & \quad \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \leq 1 \qquad j=1,2,\dots,n \\ & \quad \qquad , r=1,2,\dots,s \qquad , i=1,2,\dots,m \\ & \quad u_r, v_i \geq 0 \end{aligned} \tag{1}$$

x_{ij} =The amount of the ith input for the jth unit

y_{rj} = The amount of the rth output for the jth unit

u_r = Weight assigned to rth the output

v_i = Weight assigned to ith the input

Charnes, Cooper and Rhodes (1978) suggested this mathematical programming model for measuring optimal values of problem variables which are the weight of the inputs and outputs to maximize the efficiency of each DMU; this model is called the CCR ratio (Mehregan, 2013).
In DEA for each DMU, an efficiency score is calculated that is less than or equal to one. Therefore, DMUs are divided into efficient units and inefficient units. A unit with a score of one is efficient and a unit with a score of less than one is inefficient.

The main models of DEA are constant returns to scale (CRS) and variable returns to scale (VRS). The return to scale represents the relationship between changes in the outputs and inputs of a system. This ratio can be fixed, ascending, or descending.
Constant returns to scale: The outputs are varied equally depending on changes in inputs.
Variable returns to scale: The outputs are varied more or less depending on changes in inputs.
Ascending return to scale refers to the higher increase in outputs than the increase in inputs and descending return to scale refers to the lower increase in outputs than the increase in inputs.
Accordingly, Banker, Charnes and Cooper (1984) proposed the BCC model by developing the CCR model and performed the calculations with the assumption of variable returns to scale by adding a constraint $\sum_{j=1}^{n} \lambda_j = 1$ to the CCR model (Mehregan, 2013).
CCR and BCC models are divided into input- and output-oriented models from the perspective of inputs and outputs.
In DEA models, the way to improve inefficient units is to reach the efficient frontier. The efficient frontier consists of DMUs with the efficiency of one. Therefore, this perspective is used to make inefficient units efficient.
Input-oriented model: Minimizing the inputs assuming the outputs are fixed. In an input-oriented model, a unit is inefficient if it is possible to reduce any of the inputs without increasing the other inputs or reducing any of the outputs.
Output-oriented model: Maximizing the outputs assuming the inputs are fixed. In an output-oriented model, a unit is inefficient if it can increase any of the outputs without increasing any input or reducing another output (Mehregan, 2013).
Accordingly, the CCR ratio model can be transformed into a linear programming model. CCR and BCC models are also defined in two forms of multiplier and envelopment models.
Therefore, the output-oriented envelopment CCR model is as follows:

$$
\begin{aligned}
& Max\ Z_0 = \theta \\
& st: \\
& \quad \sum_{j=1}^{n} \lambda_j y_{rj} \geq \theta y_{ro} \qquad r = 1, 2, \ldots, s \\
& \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} \qquad i = 1, 2, \ldots, m \\
& \quad \lambda_j \geq 0 \quad free\ in\ sign\ \theta \qquad j = 1, 2, \ldots, n
\end{aligned} \tag{2}
$$

Modified output-oriented envelopment CCR model, considering the values of the model decision variables, u_r and v_i, that are larger than a very small value such as ε, is as follows:

$$
\begin{aligned}
& Max\ Z_o = \theta - \varepsilon\left(\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^-\right) \\
& st: \\
& \quad \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \theta y_{ro} \\
& \quad \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \\
& \quad \lambda_j \geq 0 \qquad j = 1, 2, \ldots, n \\
& \quad s_i^- \geq 0 \qquad i = 1, 2, \ldots, m \\
& \quad s_r^+ \geq 0 \quad free\ in\ sign\ \theta \qquad r = 1, 2, \ldots, s
\end{aligned} \tag{3}
$$

s_r^+ and s_r^- refer to slacks. In this model, $\theta^* \geq 1$ and $\frac{1}{\theta^*}$ demonstrate the efficiency.
A DMU is efficient when:

1. $\theta^* = 1$

2. $s_r^+ = s_r^- = 0$ (Mehregan, 2013).

3.1.2. Non-radial models

SBM model was proposed by Tone (2001). It includes an input-oriented model, output-oriented model, and both input- and output-oriented model (Tone, 2017). A set of DMUs is shown by $j=\{1,2,\ldots,n\}$. Each DMU contains m inputs and s outputs. The input and output vectors for $DMUj$ are represented by $x_j=(x_{1j},x_{2j},\ldots,x_{mj})^T$ and $y_j=(y_{1j},y_{2j},\ldots,y_{sj})^T$.

In the output-oriented SBM model, the efficiency ρ_O^* of $DMU_h=(x_h,y_h)$ is defined with [SBM-O-C]:

$$1/\rho_O^* = \max_{\lambda,s^-,s^+} 1+\frac{1}{s}\sum_{r=1}^{s}\frac{s_r^+}{y_{rh}}$$

$$st:$$

$$x_{ih}=\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- \quad (i=1,2,\ldots,m)$$

$$y_{rh}=\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ \quad (r=1,2,\ldots,s)$$

$$\lambda_j \ge 0\ (\forall j),\ s_i^- \ge 0\ (\forall i),\ s_r^+ \ge 0\ (\forall r) \tag{4}$$

s^- and s^+ refer to input and output slacks and λ is intensity vector.

The optimal solution of the model [SBM-O-C] is put with $(\lambda^*, s^{-*}, s^{+*})$.

Efficient output-oriented SBM model:

$DMU_h=(x_h,y_h)$ is called an SBM model with the efficient output if $\rho_O^*=1$.

Namely $s^{+*}=0$, all output slacks are zero, although input slacks may be non-zero.

Projection:

Using an optimal solution $(\lambda^*, s^{-*}, s^{+*})$, is defined a projection of $DMU_h=(x_h,y_h)$:

$$(\overline{x_h},\overline{y_h})=(x_h-s^{-*},y_h+s^{+*}) \tag{5}$$

Projected DMU is an efficient output-oriented SBM model (Tone, 2017).

4. Evaluating the efficiency of railway stations by DEA

Measuring the performance of the railway stations as part of the rail transport system is of particular importance in order to allocate the resources optimally, for improving the quality of transportation and station services in terms of technical infrastructure and providing welfare facilities. This research aims to measure the efficiency of Iranian railway passenger stations centers in 19 zones by DEA. The railway network is divided into 19 zones in terms of management, repair, and maintenance of lines and rail vehicles, operation, etc. Each zone is composed of a railway center and several stations. Each railway station center is a DMU with several inputs and outputs. The required data are the inputs and outputs of each station, which were selected via field research and following the comments of experts with knowledge and experience in the field of the railway industry, and library studies of scientific resources. In this research, five inputs and three outputs were considered per station.

In the present research, the output-oriented SBM model with the constant returns to scale assumption was used to calculate the efficiency of railway stations in 2017. In this evaluation, each DMU with the efficiency of 1 was identified as an efficient station, and units with an efficiency of less than one was identified as inefficient stations.

Also, in order to determine the efficiency of railway stations, the problem was solved with Lingo by mathematical modeling and the results were analyzed.

In the DEA model, the inputs include the total area of the station, the number of platforms, the number of staff, the number of available seats, the total cost of the station, and outputs are the number of passengers carried, the number of trains stopped, and the total revenue of the station as follows:

- The total cost of station services: Station operating costs, including station service contract, maintenance, water, electricity, etc. and equipment purchase
- The total area of the station: Area of non-commercial and commercial space
- Platform: Number of station platforms
- Staff: Number of station staff
- Available Seats: Number of available seats on trains
- Passenger carried: Number of passengers carried at the station
- Trains stopped: Number of trains stopped at the station
- Total revenue of station services: Operating revenue from ticket sales and non-operating revenue from commercial space and station service

Inputs and outputs of each railway station are presented in table 2:

Table 2: Research variables

Station	Inputs	Outputs
Station	Total area Number of platforms Number of Staff Number of available seats Total cost	Number of passengers carried Number of trains stopped Total revenue

5. Research results

Relative efficiency of railway stations centers using the output-oriented SBM model with the assumption of constant returns to scale was evaluated and its results, including unit efficiency values, input surplus, output slack of inefficient units, and the related reference units, are presented in Table 3. The research results demonstrated that, out of 19 railway stations centers, six were efficient and 13 were inefficient.
Tehran, Mashhad, Shahroud, Zanjan, Qom, and Kerman stations had an efficiency of one. They were located on the efficient frontier with input surplus and output slack values equal to zero. The other stations were also ranked based on efficiency. At these stations, in order to increase efficiency, the efficient stations were identified as reference units.

Table 3: Results of the efficiency evaluation of railway stations centers

Station	SBM model efficiency	Rank	Input surplus: Total cost (Thousand Rials) s_1^-	Input surplus: Total area (m^2) s_2^-	Input surplus: Staff (Number) s_3^-	Input surplus: Platform (Number) s_4^-	Input surplus: Available seat (Number) s_5^-	Output slack: Passenger (Number) s_1^+	Output slack: train stopped (Round trip) s_2^+	Output slack: Total revenue (Thousand Rials) s_3^+	reference units
Tabriz	0.437	17	2,217,418	2,369	0	0	0	740,483	9,285	23,413,890	Tehran, Mashhad, Shahroud
Arak	0.540	12	15,256,740	591	7	1	0	67,913	8,097	0	Shahroud, Zanjan
Isfahan	0.497	14	16,137,770	1,221	0	0	0	269,017	10,084	0	Mashhad, Shahroud, Zanjan
Tehran	1.000	1	0	0	0	0	0	0	0	0	–
Ahvaz	0.706	9	1,535,818	0	9	1	0	144,838	2,906	8,985,816	Tehran, Shahroud
Zahedan	0.468	15	4,227,558	247	2	1	0	123,751	2,784	0	Shahroud, Zanjan
Mashhad	1.000	1	0	0	0	0	0	0	0	0	–
Andimeshk	0.426	18	4,933,915	0	4	1	0	60,538	4,734	6,804,383	Tehran, Shahroud
Tabas	0.738	8	10,181,590	2,681	5	1	0	10,771	1,903	0	Shahroud, Zanjan
Sari	0.774	7	1,096,852	0	6	1	0	13,852	0	2,575,107	Tehran, Shahroud, Qom
Shahroud	1.000	1	0	0	0	0	0	0	0	0	–
Gorgan	0.560	11	5,329,772	0	2	0	0	42,894	2,755	2,013,644	Shahroud, Zanjan
Zanjan	1.000	1	0	0	0	0	0	0	0	0	–
Shiraz	0.444	16	8,095,006	7,765	0	1	0	204,112	4,160	0	Shahroud, Zanjan
Qom	1.000	1	0	0	0	0	0	0	0	0	–
Kerman	1.000	1	0	0	0	0	0	0	0	0	–
Dorud	0.283	19	1,328,816	0	3	1	0	149,528	3,573	4,438,341	Tehran, Shahroud
Bandar abbas	0.498	13	11,806,950	4,616	16	0	0	389,387	5,199	0	Tehran, Shahroud, Zanjan
Yazd	0.63	10	6,807,336	2,110	3	0	0	33,159	9,134	0	Tehran, Shahroud, Zanjan

6. Conclusion

The railway station is an important part of the rail transportation system to provide technical, operational, and commercial services. Therefore, evaluating the performance of the station is one of the considerable issues in the railway industry. In this study, the relative efficiency of Iranian railway passenger stations in 19 zones was evaluated by the DEA method. The study data was collected from the Iran Railway Company. Station efficiency was measured with the output-oriented SBM model by the assumption of constant returns to scale. According to the obtained results, the average total efficiency of railway stations centers was 0.68, i.e., the railway station must increase its output to 0.32. Also, by ranking DMUs, out of 19 Iranian railway stations centers, six centers were efficient, and 13 centers were inefficient. Given that in the non-radial SBM model the surplus inputs and slack outputs are measurable, in order to improve the efficiency of inefficient stations, the outputs can be increased or the inputs can be reduced, if possible. In this research, increasing outputs of the number of passengers carried, the number of trains stopped and the total revenue of station requires the necessary investments to improve the transport fleet, expand railway lines also develop commercial space, and improve the quality of welfare facilities in the station services. Therefore, the efficiency evaluation with the SBM model enables appropriate decision-making to manage infrastructure and optimal use of resources. Also, in order to measure the performance more precisely, a network DEA model can be used to evaluate the station efficiency for future study.

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