



## Evaluation of Iran's Rail Freight Transport Efficiency using Data Envelopment Analysis

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### ABSTRACT

Planning for rail transportation requires an assessment of past performance to identify and address weaknesses and gaps. Efficiency assessment is one of the tools for evaluating performance. In this study, the efficiency of Iran's rail freight transportation during the period April 1982-April 2022 (due to the use of the Solar Hijri calendar, the year starts in April) was evaluated using the data envelopment analysis (DEA) method, a non-parametric approach in operations research and economics. One of the policies in Iran's rail transportation sector in recent years has been privatization and the government's withdrawal from the management of the rail transportation system in order to improve performance and enhance efficiency. To examine the impact of privatization on Iran's rail freight transportation performance, the study time period has been divided into two distinct time periods: before privatization and after privatization. According to the results, privatization has had a positive impact on Iran's rail freight transportation performance and has led to improvements in efficiency in this sector. Based on the DEA-CCR model, the average efficiency score of Iran's rail freight transportation in the pre-privatization years was 0.893, and after privatization, it was 0.922. Furthermore, based on the DEA-BCC model, the average efficiency score before privatization was 0.953, and after privatization, it was 0.984.

## 1. Introduction

In the rail transportation industry, substantial investments are made in infrastructure, rolling stock, and operational expenses [1]. Consequently, governments around the world have sought to reform the rail transportation industry through structural reforms such as privatization and deregulation. For example, in countries like the United States, New Zealand, Mexico, and Japan, governments have decided to manage the rail transportation industry through a vertically integrated policy, which involves private companies competing for long-term operating contracts on specific routes. Contrary to this, the policies of European Union member countries involve the vertical separation

of infrastructure from operational activities [2]. A structural reform is a change in government policies, investment strategies, or management structures that has the objective of improving performance and has objectives such as reducing costs, reducing government commitments in the rail transportation sector, attracting private sector investment, improving financial performance, and enhancing service quality through increased efficiency [1].

In Iran, after the adoption of two strategic policies, namely "decentralization in implementation" and "outsourcing of operation management," the privatization process began through vertical separation in the late 1990s. Some subsequent reforms included the initiation of selling wagons in 2004, the enactment of the

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Permanent Law on Open Access to the Rail Network in 2005, the sale of a portion of freight locomotives in 2009, and the privatization of the passenger rail transport company, Raja, in 2010 [3]. In Iran, despite the emphasis on rail transportation development in laws and country policies, the share of rail travel in freight and passenger transport is very low and significantly deviates from the goals set by the government. The share of rail freight transport in Iran, measured in ton-kilometers over the past years, has been approximately 12% of the total land freight transported [4]. Iran's underdevelopment of rail transportation has various reasons beyond the scope of this study. One of the stages of planning for the growth and development of various industries is evaluating past performance and examining the utilization of resources and inputs to achieve optimal output. To ensure that the available resources in each mode of transportation are utilized efficiently and effectively, the operations of utilizing them should be carried out intelligently and aligned with the specific criteria of that mode of transportation, aiming to improve efficiency [5].

The current study evaluates the efficiency of rail freight transportation in Iran from April 1982 to April 2022 in two time periods before and after privatization, applying the data envelopment analysis (DEA) method to examine the effect of privatization on rail travel performance. According to the research background, researchers have generally utilized tonnage and ton-kilometers of transported freight as output parameters for evaluating rail freight transportation efficiency using the DEA method. In this study, the parameter of commercial speed of wagons is used as the output variable in the DEA model, which has not been previously utilized in past studies. The present study consists of six sections. In Section 2, the research literature is reviewed to identify the research gap. In Section 3, (Charnes, Cooper & Rhodes) CCR, (Banker, Charnes & Cooper) BCC, and super-efficiency models are introduced. Section 4 presents inputs and output data for evaluating rail freight transportation efficiency in Iran from April 1982 to April 2022. In the following section, the results of the research models are discussed, and finally, a summary and conclusion are provided.

## 2. Literature review

The rail freight sector plays a significant role in the economy and supply chain of various industries. In many cases, the transportation of goods using other modes is not justified. For example, in the transportation of goods, the road competes with the railway. Under these circumstances, if a road transportation system is used, many heavy vehicles will move on the roads. In these circumstances, it can be expected that accidents, fuel consumption, and traffic density will increase significantly. Rail transportation systems, due to their characteristics such as low-cost cargo transportation, less environmental pollution, high safety, and relatively precise scheduling, have always been of interest to various governments around the world. Governments always face limited resources and must use them optimally. Given the high costs of railway investment, governments need to ensure that rail transportation systems respond to their goals and policies. In other words, they need the best return on their resources. Furthermore, countries have different topographies that affect their efficiency. Switzerland and Japan are both countries with abundant mountainous terrain, which makes infrastructure construction and maintenance more expensive. Settlement patterns and population density also affect train efficiency and utilization. France, Sweden, and Canada all have lower population densities than Belgium, Germany, or Switzerland, which may affect the use of expensive railway assets. Given the breadth and diversity of factors affecting the evaluation of rail transportation system efficiency, reviewing past research to identify influential factors and efficiency indicators is important [1].

Studies on transportation system efficiency can be conducted internationally or focused on a single country. In the international context, Kabasakal and colleagues [6] evaluated railway system efficiency in 31 countries worldwide between 2000 and 2009 using DEA. In this study, the impact of each output on efficiency and overall productivity was determined by panel regression. Operational costs, number of employees, main track length, number of locomotives, and number of wagons were introduced as inputs, while income, passenger numbers, passenger-kilometers, freight tonnage, and ton-kilometers were introduced as output variables in their model. Moreover, Doomernik [7] used network DEA and the Malmquist

productivity index to compare the performance of high-speed rail systems in four Asian and four European countries between 2007 and 2012. The most efficient high-speed rail systems and the factors influencing improved service delivery and marketing were identified in this study. Length of high-speed rail tracks, number of high-speed trains, and number of seats were introduced as inputs, while train-kilometers, seat-kilometers, passenger numbers, and passenger-kilometers were introduced as output variables. Furthermore, Niu et al. [8] examined the efficiency of 38 rail companies worldwide between 2000 and 2020 using two DEA methods: classical DEA and bootstrapped three-stage DEA. The results showed that China, Japan, India, and Russia all had the highest efficiency levels. Additionally, Kapetanovic et al. [9] investigated the performance of 34 large-scale European railway companies between 2004 and 2013. In this study, the efficiency of these companies was first calculated using an input-oriented DEA model, and then the impact of various inputs and outputs on efficiency was examined by various statistical analyses. The study revealed that only a limited number of companies that operate in both the freight and passenger sectors have high performance in both sectors.

In addition to the above cases, some studies have been conducted at the national level, examining the efficiency of the rail transportation system in a particular country. In their research, Shi et al. [10] investigated the technical efficiency and productivity of first-class American railway companies during the years 2001-2007 using data envelopment analysis and the Malmquist productivity index. The results of this research have shown that the Burlington Northern Santa Fe company has had the best performance among other companies during this period of time, with a 4.6% increase in productivity, and has been operating smoothly in its most efficient state. In another research [11], Li and Hu evaluated the efficiency and productivity of railways in China from 2001 to 2006 using data envelopment analysis and the Malmquist productivity index. Also, in this research, using Tobit regression, the most effective factors affecting the efficiency of China's rail transport have been identified. In this research, the two variables of the number of employees and the length of railway lines are used as inputs, and the variables of passenger-kilometer and ton-

kilometer are used as the outputs of the data envelopment analysis model. Marchetti and Vanck, in a study [5], used a data envelopment analysis model to investigate the efficiency of Brazilian rail transportation companies from 2010 to 2014. In this study, a short bootstrap truncated regression was used to test the importance of exogenous variables such as the type of transported goods, the width of railway lines, and the type of line operation (exclusive or shared) on the performance of Brazilian rail transportation companies. Additionally, Da Silva et al. [12] applied an input-oriented DEA model to investigate the monthly productivity of four Brazilian rail companies operated by a merged company from 2006 to 2018. The DEA model inputs in this study were the number of dispatched trains, wagon capacity, number of wagons, and number of locomotives. The outputs were tonnage, ton-kilometer, train-kilometer, and locomotive-kilometer. The results showed that in 75% of these months, the efficiency of these companies was between 0 and 0.3, and it was only the maximum in four cases. The average monthly efficiency during this 13-year period was 0.135. In a research [13], Zhang evaluated the technical efficiency and energy efficiency of 61 intra-city rail transportation systems in four metropolitan cities of China in 2021 using the data envelopment analysis method. The results of this research have shown that despite the differences in the efficiency of the investigated systems, in general, the average technical efficiency and energy efficiency are low and can be improved. The results also showed that lines managed by state-owned companies have higher average technical efficiency, and lines managed by other investors have higher energy efficiency. Turkmanpour and Khadem Sameni [14] have evaluated the efficiency of freight and passenger rail transport in Iran before and after privatization using the data envelopment analysis model, which includes inputs such as the length of lines, the number of wagons (freight and passenger), the number of locomotives, and outputs such as tons - kilometers and passenger-kilometers. The models are solved as variable returns to scale and constant returns to scale. The results show that in the freight sector, the efficiency of the railway has improved significantly after privatization, but the results in the passenger sector are more limited, which requires further investigation and study.

### 3. Methodology

Generally, a research methodology is chosen according to the purpose of the study, the type of data, and the literature review. The data envelopment analysis (DEA) methodology enables global technical efficiency scores, local pure technical efficiency scores, and finally scale scores of units. And by using DEA, it is possible to obtain an overall performance measure through the comparison of a group of decision units [5]. This method has been used because it is appropriate for use in the current research.

The DEA model evaluates the relative efficiency of each decision-making unit, among others. DEA is a non-parametric approach based on linear programming that estimates a piecewise linear production function, or, in other words, an efficiency frontier for decision-making units using a sequence of linear programs. This model seeks to maximize the efficiency of a decision-making unit expressed as the ratio of the weighted sum of its outputs to the weighted sum of its inputs compared to a set of other decision-making units. If a decision-making unit receives an efficiency score of one and lies on the production function frontier, it is considered efficient. Inefficient decision-making units have an efficiency score less than one and lie away from the production function frontier. The further a decision-making unit is from the production function frontier, the lower its efficiency will be [5].

In order to apply the DEA model, it is necessary to determine two essential characteristics: the model's nature and its efficiency at scale. Three types of models can be distinguished: input-oriented, output-oriented, and collective models. The goal of input-oriented models is to minimize inputs while assuming constant outputs. On the other hand, output-oriented models aim to maximize outputs while assuming constant inputs. Collective models aim to simultaneously maximize outputs and minimize inputs [15]. Scale efficiency in DEA is divided into two categories: constant and variable returns to scale. Constant returns to scale mean that any multiple of inputs produces the same multiple of outputs. The (Charnes, Cooper & Rhodes) CCR model assumes constant scale efficiency for decision-making units. Variable returns to scale mean that any multiple of inputs produces less or more than the same multiple of outputs. The (Banker, Charnes & Cooper) BCC model operates

without the assumption of constant returns to scale [15].

#### 3.1. Classical Data Envelopment Analysis

The CCR model is one of the classical DEA models that assumes constant returns to scale as the basis of production. This means that increasing inputs by an appropriate amount provides a desirable increase in outputs. The objective function and constraints of the CCR model are as follows [9]:

$$(\max h_k) = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}} \tag{1}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad j = 1, \dots, n \tag{2}$$

$$u_r > 0 \quad r = 1, \dots, s \tag{3}$$

$$v_i > 0 \quad i = 1, \dots, m \tag{4}$$

In Equation 1,  $h_k$  represents the efficiency of the  $k$ -th decision-making unit ( $k=1, \dots, n$ ),  $y_r$  represents the  $r$ -th output ( $r=1, \dots, s$ ),  $x_i$  represents the  $i$ -th input ( $i=1, \dots, m$ ), and  $u_r$  and  $v_i$  represent the weighting coefficients.

In 1984, an innovative model for classical DEA was introduced by Banker, Charnes, and Cooper, which became known as the BCC model. This model evaluates decision-making units' efficiency without assuming constant returns to scale. The model with constant returns to scale is more restrictive than the model with variable returns to scale, since the model with constant returns to scale includes fewer efficient units and results in lower efficiency values. The objective function and constraints of the BCC model are as follows [16]:

$$(\max h_k) = \frac{\sum_{r=1}^s u_r y_{rk} + w}{\sum_{i=1}^m v_i x_{ik}} \tag{5}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^s u_r y_{rj} + w}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad j = 1, \dots, n \tag{6}$$

$$u_r > 0 \quad r = 1, \dots, s \tag{7}$$

$$v_i > 0 \quad i = 1, \dots, m \tag{8}$$

In Equation 5,  $h_k$  represents the efficiency of the  $k$ -th decision-making unit ( $k=1, \dots, n$ ),  $y_r$  represents the  $r$ -th output ( $r=1, \dots, s$ ),  $x_i$  represents the  $i$ -th input ( $i=1, \dots, m$ ), and  $u_r$  and  $v_i$  represent the weighting coefficients. Also,  $w$  is a free variable.

Clearly, the difference between the BCC and CCR models lies in the presence of a free variable denoted by "w." In the BCC model, the sign of the "w" variable determines the type of return to scale for each decision-making unit. If

"w" is positive, the returns to scale increase; if "w" is zero, the returns to scale are constant; and if "w" is negative, the returns to scale are decreasing.

### 3.2. Super-Efficient DEA

In the classical DEA models, the decision-making units under investigation are divided into two groups: efficient and inefficient. In these two methods, since the efficiency score for all efficient units is equal to 1, it is impossible to rank them. To rank efficient units, the super-efficient DEA model introduced by Anderson and Petersen in 1993 is used. In this model, efficient units can have an efficiency score of more than one, and thus they can be ranked. The objective function and constraints of the super-efficient DEA model are as follows [17]:

$$(\max h_k) = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}} \quad (9)$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad \begin{matrix} j = 1, \dots, n \\ j \neq k \end{matrix} \quad (10)$$

$$u_r > 0 \quad r = 1, \dots, s \quad (11)$$

$$v_i > 0 \quad i = 1, \dots, m \quad (12)$$

In Equation 9,  $h_k$  represents the efficiency of the  $k$ -th decision-making unit ( $k=1, \dots, n$ ),  $y_r$  represents the  $r$ -th output ( $r=1, \dots, s$ ),  $x_i$  represents the  $i$ -th input ( $i=1, \dots, m$ ), and  $u_r$  and  $v_i$  represent the weighting coefficients.

## 4. Data

The DEA model requires data on decision-making units' inputs and outputs to evaluate their efficiency. In this study, the available data from the annual reports, the monthly reports, and the website of the Railway of the Islamic Republic of Iran were used to evaluate the efficiency of rail freight transportation in Iran.

### 4.1. Inputs

In efficiency measurement, if the input values increase while the outputs remain constant, efficiency decreases. In other words, there is an inverse relationship between inputs and efficiency [18]. This study uses the following inputs: (1) Main track length: It refers to the length of the tracks located between two stations; (2) Spur track length: Spur track length refers to the total length of accepted and dispatched trains, maneuver, branching, industrial and commercial, facility, warehouse, turn, triangle,

blind, escape, and supply tracks; (3) Number of stations: The total number of active stations in Iran's railway regions; (4) Number of wagons in circulation: The average daily number of ready-to-work and short-term maintenance wagons during a one-year period; (5) The share of the public sector in the wagons: In order to achieve the specific goals set out in the country's Economic and Social Development Plan, a part of the public-owned wagons has been transferred to the private sector since April 2004. This input has been considered to investigate the impact of privatization on Iran's freight rail transportation performance; (6) Number of freight locomotives in circulation: This shows the average daily number of ready-to-work and short-term maintenance freight locomotives during a one-year period; (7) The share of the public sector in freight locomotives: Similar to wagons, a portion of the country's public-owned freight locomotives has been transferred to the private sector as part of its economic and social development plan. This input has also been considered to investigate the impact of privatization on Iran's freight rail transportation performance; and (8) The number of employees of the Railway of the Islamic Republic of Iran (RAI): It shows the total number of RAI employees in Tehran and other regions, except the passenger sector.

In this research, the share of the public sector in the wagons and the share of the public sector in freight locomotives have been used as inputs to investigate the effect of privatization on the efficiency of rail freight transportation, which were not used in previous studies. However, other inputs have been selected according to the inputs used in previous research.

### 4.2. Outputs

In efficiency measurement, if the output values increase while the inputs remain constant, efficiency increases. In other words, there is a direct relationship between inputs and efficiency [18]. In most studies, for evaluating rail freight transportation efficiency, the two parameters of tonnage and ton-kilometer of transported freight are used as outputs in DEA. In this study, the commercial speed of wagons (the speed of wagon cycles) is used as an output in efficiency evaluation, which is the distinctive feature of this study compared to previous studies. The method for calculating this parameter is extracted from

the Guild of Rail Transport Companies and Related Services [19].

The commercial speed of wagons refers to the speed of all operation activities in the freight transport sector, including route planning, locomotive allocation, train formation, train travel, loading and unloading operations, marketing, and commercial activities. To calculate the commercial speed of wagons, first, the average freight movement in the rail network is calculated according to the first equation in Figure 1. This is done by dividing the ton-kilometers by the tonnage of transported freight. According to the second equation in Figure 1, the number of loading times for each wagon is determined by dividing the number of loaded wagons by the total number of wagons in circulation. In the next step, according to the third equation in Figure 1, the number of days during a specific period will be divided by the number of loading times for each wagon to obtain the time period between two loadings of a wagon. Finally, according to the fourth equation 4 in Figure 1, the average freight movement in the rail network is divided by the number of loading times for each wagon, then divided by 24 hours and multiplied by 2 to calculate the commercial speed, in kilometers per hour, for loaded and empty freight wagons. In this study, the assumption is that a wagon moving towards a particular destination is loaded, and its return to its initial origin is empty.

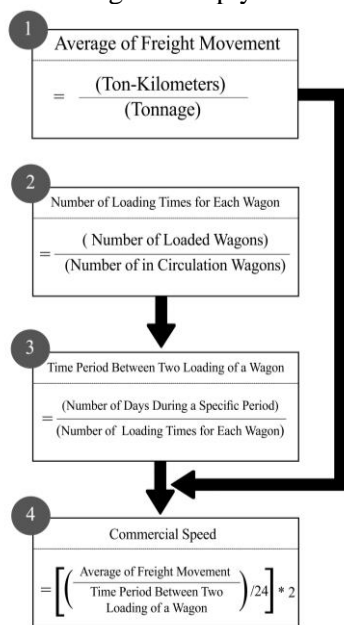


Figure 1. Steps to calculate commercial speed.

5. Results

In this study, the results of all models are presented as output-oriented. In the output-oriented model, the goal is to maximize outputs while keeping inputs constant. Since maximizing the use of available resources and facilities in the rail freight transportation industry to increase the tonnage and ton-kilometers of transported freight, or in other words, to increase the commercial speed of freight wagons, is an appropriate approach to improve efficiency, in this study, DEA models with an output-oriented approach are used. All the models in this research have been solved using the R programming language. Figure 2 shows the commercial speed of Iranian wagons, which is considered the output of the DEA model, during the years April 1982 to April 2022 in this study.

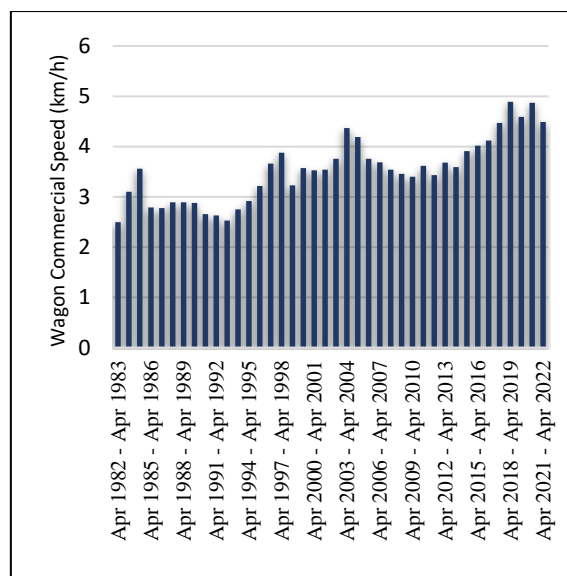


Figure 2. Wagon commercial speed in Iran.

5.1. Results of classical data envelopment analysis models

Based on classical output-oriented DEA models, this section evaluates the efficiency of rail freight transportation in Iran. According to the results of the output-oriented CCR model, Iran's rail freight transportation industry has been operationally efficient for eight consecutive years during the past 40 years, with an average efficiency score of 0.922 over these 40 years.

If April 2004 is considered the starting point of the privatization process in the rail transportation industry of the country, the average efficiency scores before privatization were 0.893, whereas

after privatization, the average efficiency improved to 0.958. Furthermore, it is noteworthy that five out of eight years with an excellent efficiency score occurred during privatization. The BCC model indicates that Iran's rail freight transportation industry has been operationally efficient in 26 non-consecutive years over 40 years. The average efficiency score over these 40 years is 0.967. If April 2004 is considered the starting point of the privatization process in the rail transportation industry of the country, the average efficiency scores before privatization were 0.953, whereas after privatization, the average efficiency improved to 0.984, according to the results. Moreover, 14 of the 26 years with excellent efficiency scores occurred during the period of privatization. Based on two classical DEA models, CCR and BCC, Table 1 illustrates the average efficiency scores of Iran's rail freight transportation before and after the privatization of wagons and freight locomotives. The table indicates that the efficiency of Iran's rail freight transportation industry has improved through the entry of private sector capital, which is in line with expectations. The privatization of an industry is expected to increase its efficiency. It should be noted that due to the difference in scale efficiency between the CCR and BCC models, the efficiency scores in the BCC model are always higher than those in the CCR model.

Table 1. Average efficiency score of Iran's rail freight transportation before and after privatization of wagons and freight locomotives.

Average efficiency scores (BCC)	Average efficiency scores (CCR)	Time period
0.953	0.894	Before the privatization of wagons (April 1982 - April 2004)
0.984	0.958	After the privatization of wagons (April 2004 - April 2022)
0.956	0.902	Before the privatization of and freight locomotives (April 1982 - April 2010)
0.992	0.970	After the privatization of freight locomotives (April 2010 - April 2022)

### 5.1.1 Reference set in classical DEA

For each inefficient unit, there is at least one efficient unit known as the reference unit. The

obtained weights for the reference unit allow the inefficient unit to reach a full efficiency score. The efficient units are known as reference groups for the inefficient units. Tables 2 and 3 indicate how many inefficient years have been referenced for each efficient year in the CCR and BCC models, respectively. For example, in Table 2, the years April 1984-April 1995 have been referenced 31 times out of the years April 1982-April 2022 as an efficient benchmark to achieve a full efficiency score. In Table 3, the years April 1984-April 1995 have been referenced nine times out of the years April 1982-April 2021 as an efficient benchmark to achieve a full efficiency score.

Table 2. Number of inefficient years referenced to efficient years in CCR model.

Number of the inefficient years referenced to efficient year	Efficient year (Reference year)
31	Apr 1984 - Apr 1995
5	Apr 1997 - Apr 1998
22	Apr 2003 - Apr 2004
1	Apr 2004 - Apr 2005
8	Apr 2012 - Apr 2013
5	Apr 2013 - Apr 2014
15	Apr 2018 - Apr 2019
3	Apr 2020 - Apr 2021

Table 3. Number of inefficient years referenced to efficient years in BCC model.

Number of the inefficient years referenced to efficient year	Efficient year (Reference year)
8	Apr 1982 - Apr 1983
9	Apr 1983 - Apr 1984
9	Apr 1984 - Apr 1985
2	Apr 1988 - Apr 1989
4	Apr 1989 - Apr 1990
7	Apr 1996 - Apr 1997
5	Apr 1997 - Apr 1998
2	Apr 1998 - Apr 1999
1	Apr 1999 - Apr 2000
1	Apr 2000 - Apr 2001
1	Apr 2001 - Apr 2002
4	Apr 2003 - Apr 2004
4	Apr 2004 - Apr 2005
1	Apr 2006 - Apr 2007
1	Apr 2007 - Apr 2008
1	Apr 2008 - Apr 2009
3	Apr 2012 - Apr 2013
3	Apr 2013 - Apr 2014
3	Apr 2014 - Apr 2015
1	Apr 2015 - Apr 2016
1	Apr 2016 - Apr 2017
1	Apr 2017 - Apr 2018
3	Apr 2018 - Apr 2019
1	Apr 2019 - Apr 2020
1	Apr 2020 - Apr 2021
1	Apr 2021 - Apr 2022

### 5.2. Results of Super-Efficient DEA model

Since classical DEA models assign a maximum efficiency score of 1 to all efficient units, it is impossible to rank them. However, ranking efficient units is essential. To rank efficient units, the super-efficient DEA model has been used. In this model, by removing the constraint related to the efficient unit, it is allowed to have an efficiency score greater than one. This enables the ranking of efficient units.

Table 4. Efficiency of Iran's rail freight transportation using super-efficiency model during April 1982- April 2022

Rank	Efficiency Score	Year
17	0.944	Apr 1982 - Apr 1983
13	0.972	Apr 1983 - Apr 1984
1	1.148	Apr 1984 - Apr 1985
32	0.864	Apr 1985 - Apr 1986
36	0.831	Apr 1986 - Apr 1987
35	0.836	Apr 1987 - Apr 1988
33	0.859	Apr 1988 - Apr 1989
31	0.865	Apr 1989 - Apr 1990
34	0.837	Apr 1990 - Apr 1991
37	0.821	Apr 1991 - Apr 1992
40	0.784	Apr 1992 - Apr 1993
38	0.812	Apr 1993 - Apr 1994
39	0.806	Apr 1994 - Apr 1995
30	0.883	Apr 1995 - Apr 1996
10	0.983	Apr 1996 - Apr 1997
6	1.018	Apr 1997 - Apr 1998
29	0.890	Apr 1998 - Apr 1999
22	0.923	Apr 1999 - Apr 2000
20	0.930	Apr 2000 - Apr 2001
26	0.909	Apr 2001 - Apr 2002
24	0.912	Apr 2002 - Apr 2003
3	1.100	Apr 2003 - Apr 2004
8	1.005	Apr 2004 - Apr 2005
28	0.897	Apr 2005 - Apr 2006
23	0.922	Apr 2006 - Apr 2007
19	0.932	Apr 2007 - Apr 2008
16	0.946	Apr 2008 - Apr 2009
27	0.901	Apr 2009 - Apr 2010
14	0.966	Apr 2010 - Apr 2011
21	0.928	Apr 2011 - Apr 2012
7	1.010	Apr 2012 - Apr 2013
5	1.054	Apr 2013 - Apr 2014
9	0.987	Apr 2014 - Apr 2015
25	0.911	Apr 2015 - Apr 2016
18	0.941	Apr 2016 - Apr 2017
11	0.976	Apr 2017 - Apr 2018
2	1.136	Apr 2018 - Apr 2019
15	0.954	Apr 2019 - Apr 2020
4	1.068	Apr 2020 - Apr 2021
12	0.973	Apr 2021 - Apr 2022

Table 4 presents the results of the super-efficient DEA model and the ranking of the 40 years studied based on the efficiency scores obtained for each year. Similarly to the CCR model, the results from this model indicate that the rail freight transportation industry in Iran has been efficient for eight of the past 40 years. This model, however, assigns efficiency scores greater than one to the efficient years. Based on

the results of this model, April 1984-April 1995 ranks first in terms of efficiency among the 40 years studied, with a score of 1.148.

### 6. Conclusion

Any industry's development must be planned by analyzing its past performance and identifying its strengths and weaknesses. One of the executive policies adopted for the development of the rail freight transportation industry in Iran in recent years is the government's withdrawal from the operational sphere through privatization, specifically vertical separation. In this study, the performance of the rail freight transportation industry in Iran was evaluated, and the impact of the privatization policy on the development of this mode of transportation was investigated. From April 1982 to April 2022, the efficiency of this industry was examined in two time frames: pre-privatization and post-privatization. The (Charnes, Cooper & Rhodes) CCR, (Banker, Charnes & Cooper) BCC, and super-efficient data envelopment analysis (DEA) models were used during analysis.

Based on the results obtained from all three models, it can be concluded that Iran's rail freight transportation efficiency has been favorable and that it has improved during the privatization period. According to the ranking results obtained from the super-efficient DEA model, out of the eight years with efficiency scores greater than one, which means efficient years, five of them have occurred after privatization. It appears that with the entry of the private sector into the rail freight transportation industry, its efficiency has improved. On the one hand, the compound annual growth rate of the number of wagons before the privatization era (i.e., during the years April 1982 to April 2004) was 1.45%, and after that (i.e., during the years April 2004 to April 2022), it increased to 2.58%. On the other hand, the compound annual growth rate of the number of freight locomotives before the privatization of this type of rail fleet (i.e., during the years April 1982 to April 2010) was 4.55%, and after that (i.e., during the years April 2010 to April 2022), it decreased to 4.34%. It is worth mentioning that the annual growth rate of the main and spur railway tracks before the privatization process (i.e., from April 1982 to April 2004) was 2.13% and 0.12%, respectively. However, after privatization (i.e., from April 2004 to April 2022), these growth rates increased to 2.49% and



1.88%, respectively. The statistics and evidence suggest that with the initiation of the privatization process, the government has been able to allocate more focus and budget to the expansion of the railway network. The following topics are proposed for the continuation of this research: (1) Evaluation of the efficiency and productivity of private companies operating in the freight rail sector; (2) Assessment and comparison of freight rail transportation efficiency and productivity in Iran with other countries where rail privatization has taken place. One of the inputs for this comparison should be the number of active private companies in this sector; and (3) Evaluation of the efficiency and productivity of spur railway tracks and estimation of the existing demand for their expansion to further connect major freight and passenger centers to the railway network.

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