Economics and Organization of Logistics
6 (2), 2021, 19–32
DOI: 10.22630/EIOL.2021.6.2.10

Aleksandra Górecka✉
Warsaw University of Life Sciences – SGGW

Changes in the efficiency of passenger rail transport caused by the investments supported by EU funds

Zmiany efektywności pasażerskich przewozów kolejowych wynikające z realizacji inwestycji wspieranych z funduszy europejskich

Abstract. The aim of this paper is to present the comparison of the efficiency of passengers rail transport in Polish regions and to investigate its change. In the end, I present the correlation between the difference of efficiency index between 2004 and 2017 and the railway investments value which has been involved in modernization railway transport from 2004 until 2014. The research has covered 14 Polish regions. The results confirmed that the regions joining the EU with ineffective passenger rail transport have made the investments that contributed to the increase of the efficiency index for the last 14 years later and that the change of the level of passenger rail transport efficiency index is strongly correlated with the level of value of rail infrastructure investments made from 2004 until 2014.

Key words: rail transport, railways, DEA method, investments, Poland, EU funds

Synopsis. Celem artykułu było porównanie wskaźnika efektywności pasażerskiego transportu kolejowego w polskich województwach w latach 2004 oraz 2017. Badania objęły również wskazanie korelacji pomiędzy różnicą wskaźnika efektywności w latach 2004 i 2017 a wartością inwestycji infrastruktury kolejowej, które zrealizowano przy wsparciu funduszy UE. Badaniami objęto 14 polskich województw, które zrealizowały projekty inwestycyjne dofinansowane z funduszy UE. Wyniki potwierdziły, że regiony przystępujące do UE z nieefektywnym pasażerskim przewozem kolejowym dokonały inwestycji, które przyczyniły się do wzrostu wskaźnika efektywności przez ostatnie 14 lat później, a zmiana poziomu wskaźnika efektywności pasażerskiego transportu kolejowego jest silnie skorelowana z poziomem wartości inwestycji w infrastrukturę kolejową w latach 2004–2014.

Słowa kluczowe: transport kolejowy, linie kolejowe, metoda DEA, inwestycje, polska, fundusze unijne

JEL codes: O18, R42

✉ Aleksandra Górecka – Warsaw University of Life Sciences – SGGW; Department of Logistics;
e-mail: aleksandra_gorecka@sggw.edu.pl; https://orcid.org/0000-0002-2679-561X

Introduction

In 2021, it has been 17 years since Poland became a member state of the EU. Since 2004, the country has had full access to EU funds to support the modernization of most sectors of the economy. From 2004 to 2013, from the point of view of economic development, Poland used two basic funds, that is, The European Regional Development Fund and the Cohesion Fund [Rakowska and Wojewódzka 2010, Mosionek-Schweda 2012].

The development of the transport sector, especially of the infrastructure, was one of the strategic areas that needed to be modernized. Poland's transport infrastructure after 1991 radically collapsed, and the government was unable to meet the requests of modernizing existing infrastructure or starting new investments in this area. It was known, however, that transport infrastructure is an important part of the social life and economic condition. Its structure and scope determine the mobility of the inhabitants, the potential of the area for settlement, and, from the point of view of entrepreneurship development, the possibility of locating companies or conducting commercial cooperation [Górecka and Baran 2018]. The construction and maintenance of transport infrastructure are highly cost-consuming and often represent a significant financial resource for the government or self-government units. Therefore, EU subsidies have proven to be invaluable support for the country's infrastructure redevelopment [Bentyn et al. 2020]. Four years after the completion of the second aid program, the efficiency of the use of EU funds for the modernization of transport infrastructure can be summarized and assessed.

Literature review

The problem of rail efficiency has received considerable attention [Wiegmans et al. 2018]. The design, management, and optimization of passenger transport networks have been the subject of many analyses. Scientific attention also has been directed towards investments in infrastructure and the relationship with economic growth and social perspective [Witte et al. 2014, Chen et al. 2016, Patarchanov 2019]. The results suggest that rail investment has been a positive stimulus to the economy and added that there has been a historically growing demand for infrastructure investments to increase mobility at both inter-, and intracity levels in European countries caused by the increasing urbanization [Muñoz-Villamizar et al. 2020]. Therefore rail transportation is perceived as one of the fundamental elements of countries' development in the context of stability in passengers mobility and barrier-free freight flow.

Although there is still an economic legitimacy to investigate the problem of rail transportation development, it is crucial to underline that it is a result of many factors, such as safety, environmental protection, costs, and profits of investment implementation or the use of current resources [Jacyna 2001]. The modernization efficiency is affected by many aspects, which is why the analysis of investments in rail infrastructure should be multicriterial [Gawrońska 2020]. Hence, the complexity of making investment decisions is difficult due to many technical, economic, and political factors [Guo et al. 2018]. Furthermore, the rail infrastructure investments are highly costly and as the EU calms its funding from governments budgets is the dominant source of funds which hardly can be extended because of increasing budget constraints [European Parliament 2015], so the external funds must be provided to start and proceed the investments. Despite that, there is evidence [Francisco et al. 2021] that heavy investment in existing rail lines is not the best way to increase rail market share.

Poland is the country that used EU funds to rebuild the whole transportation infrastructure, including railways, however, to the best of my knowledge, very few studies have investigated the changes in efficiency in passenger rail transport caused by the investments co-funded from external (non-governmental) sources at the same time. In the paper, there is a try to fill this gap.

Materials and methods

The aim of this paper is to assess the efficiency of passengers rail transport in 2004 and 2017, to investigate its change, and to establish a ranking of the Polish regions according to the efficiency index. In the end, presented the correlation between the difference of efficiency index and the amount of money which has been involved in the modernization of Polish railway transport from 2007 until 2014. There are two hypotheses in this research:

H_1: The regions joining the EU with ineffective passenger rail transport have made the investments that contributed to the increase of the efficiency index 14 years later.

H_2: The change of the level of passenger rail transport efficiency index is positively correlated with the level of value of rail infrastructure investments made from 2004 until 2014.

The research covered 14 regions in Poland (NUTs-2 – Voivodships, Provinces) which benefited from EU funding for the improvement of rail infrastructure until 2014 (Figure 1). The other two NUTs-2 had not applied for EU found and therefore were excluded from the research. The assessment of the efficiency of the investments made on Polish railway infrastructure was conducted using the Data Envelopment Analysis (DEA) method, and the correlation was calculated based on Spearman rank correlation.

In research used secondary data sources including the Office of Rail Transport database for indexes on railways, train stations, and the number of passengers, and the National Information System (KSI SIMIK 04-13) for searching for data on EU founding in railway infrastructure in Poland.

A popular technique for efficiency assessment is Data Envelopment Analysis (DEA). DEA method is widely used throughout the world in railway system performance research. It is a non-parametric technique and its scope is to determine the efficiency of similar Decision-Making Units (DMUs) with respect to multiple inputs and outputs. DMUs are divided into two groups named as efficient and inefficient, then derive a piecewise linear frontier with pareto-efficient DMUs and give an efficiency score of 1 (one). Their efficiency score is determined by the distance between the frontier and the coordinates of each of the inefficient DMUs. The method also determines the source and the amount of inefficiency so that DEA becomes indispensable for decision-makers [Bal and Gölcükcü 2002]. Depending on the model orientation, a calculation of the efficiency is made focused on: the input minimization or on the output maximization. However, taking into account the type of returns to scale two models are distinguished, which are as follows: the CCR model providing for constant returns to scale, and the BCC model provides for changing return to scale. The CCR model is used to calculate the overall technical efficiency (Technical Efficiency – TE) and the BCC model is used to calculate pure technical efficiency (Pure Technical Efficiency – PTE) [Baran and Górecka 2019].

Figure 1. Administrative division of Poland
Figure 1. Podział administracyjny Polski
Source: own elaboration.

Charnes et al. [1978] had evaluated the measure of efficiency for each DMU that is obtained as a maximum of a ratio of weighted outputs to weighted inputs. The weights for the ratio are determined by a restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to single "virtual" input and single "virtual" output without requiring preassigned weights. The efficiency measure is then a function of weights of the "virtual" input–output combination. The efficiency measure for the DMU$_o$ is calculated as follows [Charnes et al. 1978].

$$\max w_0 = \sum_r m_r y_{r0}$$

subject to

$$\sum_i v_i x_{i0} = 1$$

$$\sum_r m_r y_{rj} \qquad \sum_i v_i x_{ij} \le 0 \tag{1}$$

$$\mu \geq \varepsilon$$

$$v_i \geq \varepsilon$$

The variables m_r and v_r are the weights of output and inputs (r = 1, …, p), (x_{ij} = 1, …, k) represent outputs and inputs respectively (j = 1, …, n) and ε is non-archimedean constant. The index 0 represents the DMU in the objective function whose efficiency would be calculated. Each DMUs achieve the efficiency score between [0; 1]. The efficiency score 1 means being 100% efficient. When the efficiency score is below 1 (one) which means that DMUs are below the frontier, the DMU is inefficient. This is because their efficiency score is determined by the distance between the frontier and this coordinated [Bal and Gölcükcü 2002].

Since the first launching in 1978 in Charner's paper, the DEA method has been used in the fields as banking, agriculture, transportation, sport etc. Banker et al. [1984] extended the earlier work by providing for variable returns of scale and mitigates the impact of economies of scale on operational efficiency.

The BCC model adds variable u_0 to identify the returns of scale of the target DMU. The input-oriented BCC-model for the DMU0 can be written formally as [Bal and Gölcükcü 2002]:

$$\min_{\Theta,\lambda,s^+,s^-} z_o = \theta - \varepsilon\sum_{r=1}^{p} s_r^+ - \varepsilon\sum_{i=1}^{m} s_i^-$$

subject to

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{r0}, \quad r = 1,\ldots, p$$

$$\sum_{j=1}^{n} \lambda_j y_{ij} - s_i^- = \theta_{r0}, \quad i = 1,\ldots, k \qquad (2)$$

$$\sum_{j=i}^{n} \lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- > 0$$

The BCC-efficiency scores have similar interpretation as in the CCR model. With the overall technical efficiency and pure technical efficiency calculated, it is possible to determine the object scale efficiency (Scale Efficiency – SE). The scale efficiency is defined as a ratio of DMUs overall technical efficiency score (measured by the CCR-model) and pure technical efficiency score (measured by the BCC model), according to the formula: $SE = TE/PTE$ [Coelli et al. 2005]. Scale efficiency (SE) calculated in this manner denotes the degree to which the object is efficient concerning the optimum enabling the maximal use of inputs.

A review of research where the DEA method was used with the inputs and outputs examples and research areas in Table 1.

Table 1. Use of the DEA method in performance studies in passengers' rail transport – selected literature
Tabela 1. Zastosowanie metody DEA w badaniach wydajności w pasażerskim transporcie kolejowym – wybrana literatura

Author	**Research area**	**Inputs**	**Outputs**
Yu M-M and Lin E.T.J. [2008]	World	employees, wagons, line length, passenger cars, passenger trains.km, cargo trains.km	ton.km, passenger.km, passenger trains.km, cargo trains.km
Guzman I. and Montoya J.L. [2011]	Spain	tractive effort, seats available, available cargo capacity, distance travelled	revenues
Kutlar A. et al. [2013]	World	employees, locomotives, wagons, operating cost, line length and passenger cars	revenues, passengers, passengers/km, tons, ton/km
Doomernik J.E. [2015]	World	line length, seats available, seats.km	seats available, passenger.km, passengers
Djordjević et al. [2018]	Europe	number of railway level crossings, number of assets	railway passenger volume, railway freight volume, number of accidents at RLCs

Source: own elaboration.

A major problem in DEA is the choice of inputs and outputs to be included in the model. DEA is not a statistical technique and there are no tools – such as *t*-tests in regression – to assess if an input or an output is important or could be deemed to be redundant and removed from the data. It is known that efficiencies depend on the number of inputs and outputs included in the specification. The more inputs or outputs included in the model, the higher the calculated efficiencies will be [Bal and Gölcükcü 2002]:

Inputs (X):
x_1 – number of railways in use (km)
x_2 – standard-gauge electrified railway lines (km)
x_3 – length of standard-gauge railway tracks with two or more tracks (km)
x_4 – number of train stations serving passengers

Outputs (Y):
y_1 – number of passengers
y_2 – use of railways by passengers (rail trip per passenger)

Input variables are both related to the technical efficiency of rail transport and the investments which were made in Poland to improve rail transport efficiency, and the outputs represent the rail used by the passengers. However, it is significant to remember, that the effects of investments in the railway infrastructure can be reflected on passengers' rail use indirectly, e.g. increasing safety or speed, which can translate into passenger satisfaction. Moreover, investments can also lead to an increase in the price of tickets, which again has a great influence on passenger transport choice.

Spearman rank correlation (ρ) test was used to investigate if the change of efficiency of rail transport index is correlated with the value of rail transport infrastructure investments in the region from 2004 until 2014.

$$\rho = \frac{\frac{1}{6}(n^3-n)-(\sum_{i=1}^{n} d_i^2)- T_d- T_v}{\sqrt{\frac{1}{6}(n^3-n)- 2T_d)(\frac{1}{6}(n^3-n)-2T_v)}}, \quad (3)$$

where:
$d_i = Rd_i - Rv_i$ – the difference between the *i*-th rank for variable *d* and the *i*-th rank for variable *v*

T_d T_v – factors for tied ranks described by:

$$T = \frac{1}{12} \sum_j (t_j^3 - t_j), \quad (4)$$

where:
t_j – number of observations for the *j*-th rank in the analysed data set.

The following variables were used in the calculation of Spearman rank correlation:
d – change in of DEA rail transport efficiency index from 2004 until 2017
v – the value of rail transport infrastructure investments in the region from 2004 until 2014.

Passenger rail transport in Poland

From 2004 until 2014 there were 106 investments accomplished on the Polish railway lines for the total amount of 6,132,987,935.40 EUR[1]. 59.37% of costs was covered by external funds, with 3,641,376,584.52 EUR[2] support by EU. The highest number of investments was carried out in Pomorskie and Dolnośląskie regions, Lubelskie, Mazowieckie and Małopolskie regions, simultaneously the largest amount of money has been absorbed in Mazowieckie, Pomorskie and Małopolskie regions (Table 2).

Since 2004, there has been no significant change in density of railways in Polish regions (Figure 2). Southern and southern-east Polish regions characterise by the highest number of railways per 100km. There has been increase of this index in three regions, in two –the index has not changed, while in 11 regions the density of used railways has decreased. Still, the lowest density of railways in use is in Podlaskie region (3.6 km/km^2) and Podkarpackie (4.2 km/km^2). Apart from that, for 13 years the density of railways in used has increased only in two regions, which are Podlaskie (change by 0.3 point) and Świętokrzyskie (change by 0.2 point).

[1] PLN 26,310,518,242.85 with PLN 4,29 = EUR 1 average exchange rate.
[2] PLN 15,621,505,547.57 PLN with PLN 4,29 = EUR 1 average exchange rate.

Table 2. Railway investments and their value in Poland from 2004 until 2014
Tabela 2. Inwestycje kolejowe i ich wartość w Polsce od 2004 do 2014 roku

Voividship	Number of investments	Investments total value (PLN)
Pomorskie	16	4,608,676,596.63
Dolnośląskie	15	266,522,1654.00
Lubelskie	11	1,216,762,787.16
Mazowieckie	11	4,988,179,648.23
Małopolskie	10	4,300,489,463.43
Łódzkie	9	3,938,604,806.60
Śląskie	7	977,978,233.32
Kujawsko-pomorskie	5	900,114,107.18
Wielkopolskie	5	692,852,042.57
Zachodniopomorskie	5	206,980,550.66
Opolskie	4	1,230,011,249.63
Lubuskie	3	129,451,434.13
Podkarpackie	3	277,561,158.84
Warmińsko-mazurskie	2	177,634,510.47
Total	**106**	26,310,518,242.85

Source: own elaboration based on National Information System [KSI SIMIK 04-13].

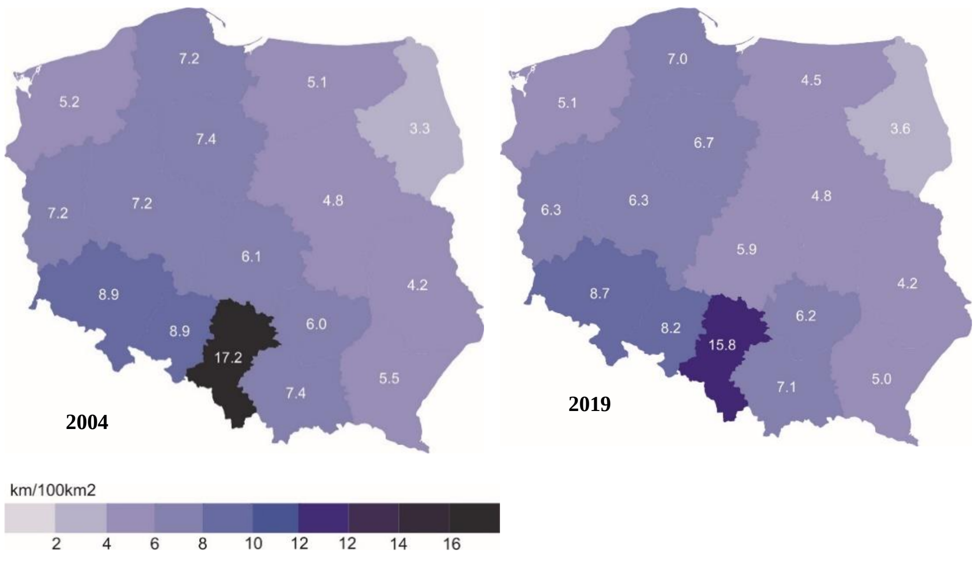

Figure 2. Density of railways in use in Polish regions in 2004 and 2019 (km/100km^2)
Rysunek 2. Zagęszczenie linii kolejowych użytkowanych w regionach Polski w latach 2004 i 2019 (km/100km^2)
Source: own elaboration based on Polish Local Data Bank.

In the same time period, the structure of passengers railway stations has changed. Before 2000, all the buildings with equipment had been owned by PKP Group, however since 2001, due to the new national regulations [Ustawa z dnia 8 września 2000 r.], PKP Group was able to transfer the ownership of 345 railway stations to the local governments, what allowed to apply for EU money for their reconstruction, modernization, and adaptation.

There have been changes in the use of railways by passengers (Figure 3). The average number of rail trips per passenger per year in Poland was 6.1 in 2004, while in 2017 it was 6.6.

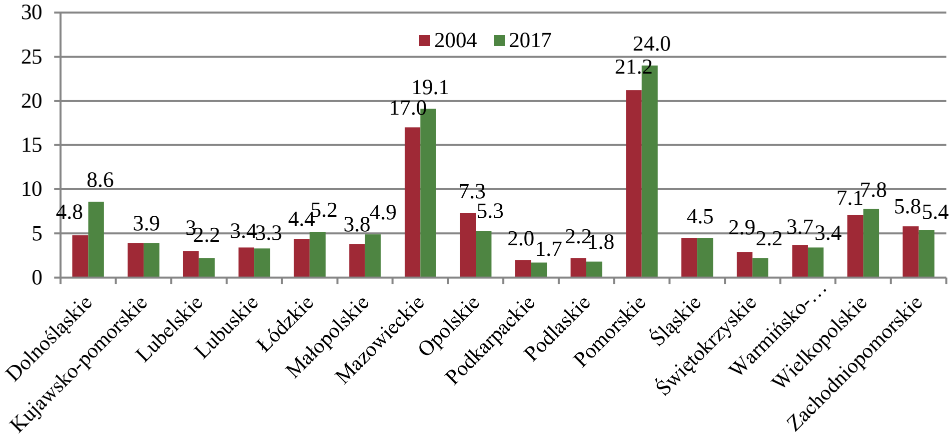

Figure 3. The use of railway transport by passengers (number of trips per passenger per year)
Rysunek 3. Korzystanie z transportu kolejowego przez pasażerów (liczba przejazdów na pasażera rocznie)
Source: own elaboration based on PKP S.A. data

The average percentage change of rail trip per passenger was +6.0%, however, there is a huge difference and disproportion in its structure in the several regions (Table 3).

Table 3. Percentage change in rail trips per passenger per year in 2004 and 2017
Tabela 3. Procentowa zmiana liczby podróży koleją w przeliczeniu na pasażera rocznie w latach 2004 i 2017

Region	2004	2017	% change
Dolnośląskie	4.8	8.6	+79%
Łódzkie	4.4	5.2	+18%
Małopolskie	3.8	4.9	+29%
Mazowieckie	17.0	19.1	+12%
Pomorskie	21.2	24.0	+13%
Wielkopolskie	7.1	7.8	+10%
Lubelskie	3.0	2.2	-27%
Opolskie	7.3	5.3	-27%

Region	2004	2017	% change
Świętokrzyskie	2.9	2.2	–24%
Podlaskie	2.2	1.8	–18%
Podkarpackie	2.0	1.7	–15%
Warmińsko-mazurskie	3.7	3.4	–8%
Zachodniopomorskie	5.8	5.4	–7%
Lubuskie	3.4	3.3	–3%
Kujawsko-pomorskie	3.9	3.9	0%
Śląskie	4.5	4.5	0%

Source: own calculation.

The highest change was in Dolnośląskie region (+79%), and at the same time, the biggest decrease in Lubelskie, Opolskie (–27%), and Świętokrzyskie regions (–24%).

Passengers' rail transport efficiency and its correlation to the investment value – results and discussion

This section of the paper focuses on the difference in the efficiency of passengers' rail transport in 2004 and 2017. Two rankings of Polish regions were created according to the efficiency index for the passengers' railway transport. The average technical efficiency of that sector in 2004 was fairly low with the DEA indicator in the CCR model being 0.4752. The rail transport sector was effective only in 2 out of 16 studied regions (with an efficiency ratio of 1); these included Pomorskie and Mazowieckie regions (Figure 4).

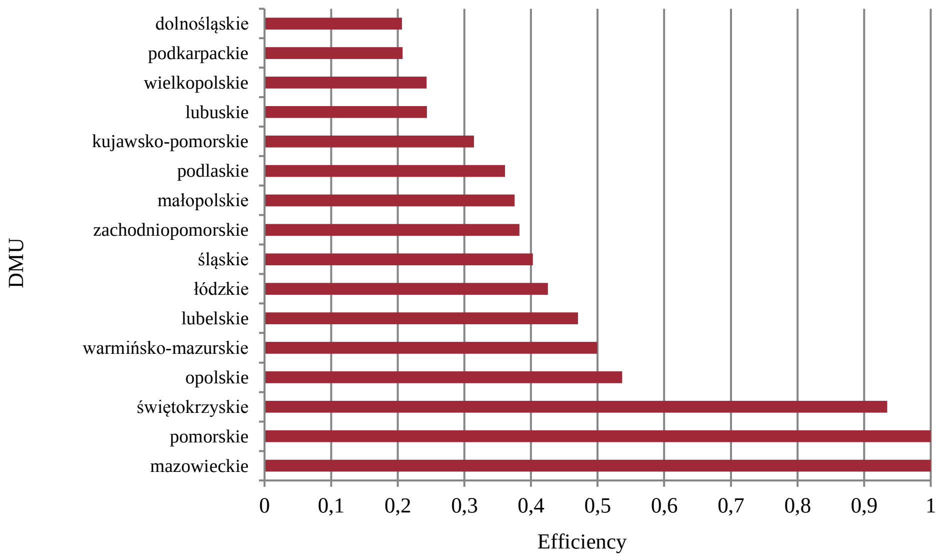

Figure 4. Passengers' rail transport efficiency index in 2004
Rysunek 4. Wskaźnik efektywności transportu kolejowego pasażerów w 2004 roku
Source: own calculation.

The same regions, and only those two, were effective in 2017 (with an efficiency ratio of 1). After 14 years of modernization and investments, the rest 14 regions were highly ineffective (Figure 5). The average technical efficiency indicator for passengers' rail transport sector was estimated at 0.408.

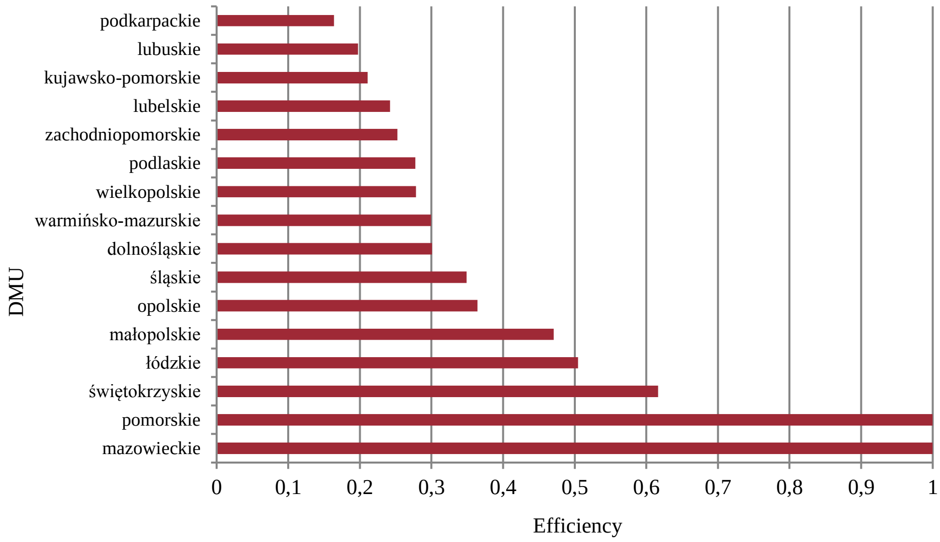

Figure 5. Passengers' rail transport efficiency index in 2017
Rysunek 3. Wskaźnik efektywności transportu kolejowego pasażerów w 2017 roku

Source: own calculation.

Despite new infrastructural investments, the difference between DEA indexes in 2004 and 2017 (Table 4) indicates lowering efficiency in 10 regions, stable situation in two regions, and raising the levels of effectiveness in four regions.

Table 4. Difference between DEA indexes level in 2004 and 2017
Tabela 4. Różnica między poziomami indeksów DEA w latach 2004 i 2017

DMUs	Difference in DEA index
Dolnośląskie	0.09437
Kujawsko-pomorskie	–0.10331
Lubelskie	–0.22816
Lubuskie	–0.04589
Łódzkie	0.07914
Małopolskie	0.09536
Mazowieckie	0.00
Opolskie	–0.17258

DMUs	Difference in DEA index
Podlaskie	–0.08342
Pomorskie	0.00
Śląskie	–0.05383
Świętokrzyskie	–0.31808
Warmińsko-mazurskie	–0.19971
Wielkopolskie	0.03538
Zachodniopomorskie	–0.13013

Source: own calculation.

The results of Spearman rank correlation present (Table 5) that there is a significant non-linear correlation between difference of the passengers' transport efficiency level and the total value of infrastructure investments in Polish regions.

Table 5. Spearman Rank Correlation
Tabela 5. Korelacja rang Spearmana

Variable	Spearman Rang Correlation Marked correlations indexes are significant for *p* <,05000	
	Difference in DEA index	**Total investments value**
Difference in DEA index	1.00000	**0.581738**
Total investments value	**0.581738**	1.00000

Source: own calculation in Statistica 12.0 software

Summary

From the practical point of view the results of this analysis can be summarized as follows:

- The assessment of the efficiency of passengers' railway transport at the moment of Polish accession to the EU (2004) indicates that only two out sixteen regions (Mazowieckie and Pomorskie) were effective. They had the highest position in the ranking. At the same time, the most ineffective rail transport for passengers was in Dolnośląskie, Podkarpackie, Wielkopolskie, and Lubuskie Provinces.
- From 2004 until 2014 most money for rail transport infrastructure was absorbed by the most effective Mazowieckie and Pomorskie Voivodships, and additionally, ineffective Małopolskie region for a total number of 37 investments there.
- Although the second hypothesis of the paper was confirmed, and the Spearman correlation rank calculation indicates a significant positive correlation between the difference in DEA indexes and value of investments ($\rho = 0.581738$), still in 2017 there were only the same regions effective (Mazowieckie and Pomorskie) as in 2004. Despite the investments supported by EU, the overall condition has not ameliorated, and the regions in which passengers' rail transport had been ineffective in 2004 have not fully recovered to achieve DEA index 1.
- Małopolskie and Łódzkie Provinces, with a high total value of investments, have strengthened their position in DEA rank but not on a fully effective level.
- The first hypothesis of the paper was not confirmed (see Table 4 and Table 6), as each investment in an ineffective region has contributed neither to an increase in passengers' rail transport efficiency nor to strengthen the position in the DEA rank.

Table 6. The position of each DMU in DEA ranks in 2004 and 2017
Tabela 6. Pozycja każdego DMU w DEA w rankingach w 2004 i 2017 roku

DMU	2004	2017	Position in ranking	DMU	2004	2017	Position in ranking
Dolnośląskie	16	8	**+8**	Podkarpackie	15	16	–1
Kujawsko-pomorskie	12	14	–2	Podlaskie	11	11	0
Lubelskie	6	13	–7	Pomorskie	1	1	0
Lubuskie	13	15	–2	Śląskie	8	7	**+1**
Łódzkie	7	4	**+3**	Świętokrzyskie	3	3	0
Małopolskie	10	5	**+5**	Warmińsko-mazurskie	5	9	–4
Mazowieckie	1	1	0	Wielkopolskie	14	10	**+4**
Opolskie	4	6	–2	Zachodniopomorskie	9	12	–3

Source: own calculation.

The paper presents the phenomenon of the effectiveness of Polish passengers' railway it is crucial to set up next research which would expand the range of variables used to DEA model and also include the rail freight transportation, as EU funds support investments aiming at increasing of efficiency of goods flow by building the European network system. It is also worth mentioning that the feedback about infrastructural investments can appear later than 3–4 years after their completion, and can be a part of the total transport strategy improvement, so it could be reasonable to investigate the whole passenger transport system in the country, together with freight transport efficiency.

References

Bal H., Gölcükcü A., 2002: Data Envelopment Analysis: An application to Turkish banking industry, Mathematical & Computational Applications. 7, 1, 65–72.

Banker R.D., Charnes A., Cooper W.W., 1984: Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, Management Science 30(9), 1078–1092.

Baran J., Górecka A., 2019: Economic and environmental aspects of inland transport in EU countries, Economic Research – Ekonomska Istraživanja 32, 1, 1037–1059, https://doi.org/10.1080/1331677X.2019.1578680

Bentyn Z., Luetić A., Šerić N., 2020: Development of business strategies based on logistics performance of the Republic of Croatia, Ekonomiski Vjesnik 32, 1, 133–149.

Charnes A., Cooper W.W., Rhodes A., 1978: Measuring the Efficiency of Decision Making Units, European Journal of Operational Research 2, 6, 429–444.

Chen Z., Xue J., Rose A.Z., Haynes K.E., 2018: The impact of high-speed rail investment on economic and environmental change in China: A dynamic CGE analysis, Research in Transportation Business & Management 28, 54–65, https://doi.org/10.1016/j.rtbm.2018.10.004

Coelli T.J., Prasada Rao D.S., O'Donnell C.J., Battese G.E., 2005: An Introduction to Efficiency and Productivity Analysis, Springer, New York.

Djordjević B., Krmaca E., Mlinarić T.J., 2018: Non-radial DEA model: A new approach to evaluation of safety at railway level crossings, Safety Science 103, 234–246.

Doomernik J.E., 2015: Performance and efficiency of high-speed rail systems, Transportation Research Procedia 8, 136–144.

European Parliament, 2015: The result and efficiency of railway infrastructure financing within the European Union, Directorate General for Internal Policies Policy Department D: Budgetary Affairs, Brussels, [electronic source] https://www.europarl.europa.eu/RegData/etudes/STUD/2015/552308/IPOL_STU(2015)552308_EN.pdf [access: 28/02/2022].

Francisco F., Teixeira P.F., Toubol A., Nelldal B.L., 2021: Is large technological investment really a solution for a major shift to rail? A discussion based on a Mediterranean freight corridor case-study, Journal of Rail Transport Planning & Management 19, 100271, 1–16, https://doi.org/10.1016/j.jrtpm.2021.100271

Gawrońska D., 2020: Analysis of investments in the modernization of railway lines as part of rail transport management scientific, Papers of Silesian University of Technology: Organization and management series 149, 167–174, http://dx.doi.org/10.29119/1641-3466.2020.149.16

Górecka A., Baran J., 2018: Efficiency of Investments in Regional Airports in Poland, Sosyoekonomi 26(38), 23–35.

Guo Q-W., Chen S., Schonfeld P., Li Z., 2018: Analysis of investments in the modernization of railway lines as part of rail transport management, Transportation Research. Part B 118, 172–192. https://doi.org/10.1016/j.trb.2018.10.009

Guzman I., Montoya J.L., 2011: Technical Efficiency and Productive Change in the Spanish Wide Gauge Railroad Sector (1910–1922), Innovar Journal 21, I40, 219–234.

Jacyna M., 2001: Modelowanie wielokryterialne w zastosowaniu do systemów transportowych, Prace Naukowe Politechniki Warszawskiej. Transport 47, 3–139.

Kutlar A., Kabasakal A., Sarikaya M., 2013: Determination of the efficiency of the world railway companies by method of DEA and comparison of their efficiency by Tobit analysis, Qual Quant 47, 3575–3602.

Mosionek-Schweda M., 2012: The absorption of EU funds by Polish regions in the 2007–2013 programming, Annales Universitatis Mariae Curie-Skłodowska. Sectio H. Oeconomia 46, 1, 95–106.

Muñoz-Villamizar A., Santos J., Montoya-Torres J.R., Velázquez-Martínez J.C., 2020 : Measuring environmental performance of urban freight transport systems: A case study, Sustainable Cities and Society 52, 101844. https://doi.org/10.1016/j. scs.2019.101844

Patarchanov P., 2019. Railway transport in regional and local development of the rural areas – Challenges and opportunities. 19th International Multidisciplinary Scientific GeoConference SGEM 2019 19, 5.4, 533–540.

Rakowska J., Wojewódzka A., 2010: Strategie rozwoju powiatów oraz fundusze strukturalne UE jako instrumenty kreowania ładu przestrzennego, Zeszyty Naukowe SGGW, Polityki Europejskie, Finanse i Marketing 4(53), 35–41.

Ustawa z dnia 8 września 2000 r. o komercjalizacji i restrukturyzacji przedsiębiorstwa państwowego „Polskie Koleje Państwowe” (Dz.U. 2000 nr 84 poz. 948).

Wiegmansa B., Champagne-Gelinasb A., Duchesneb S., Slackc B., Witted P., 2018: Rail and road freight transport network efficiency of Canada, member states of the EU, and the USA, Research in Transportation Business & Management 28, 54–65.

Yu M.M., Lin E.T.J., 2008: Efficiency and effectiveness in railway performance using a multi-activity network DEA model, International Journal of Management Sciences 36(6), 1005–1017.