dr Joanna Baran
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie

The efficiency of the road transport sector in Poland and other member states of the European Union
Efektywność sektora transportu drogowego w Polsce i innych krajach Unii Europejskiej

Abstract: Transport is one of the most essential sectors of EU Member State economies. Road transport has the highest share of freight transport in the European Union. In 2010 the volume of goods transported, measured by transport performance in EU countries, amounted to 3831 billion t.km, and road transport accounted for nearly half the transport (45.9%).

From the perspective of the whole economy as well as companies operating in the transport sector it is crucial to measure the efficiency of transport operations. This measurement can be made based on traditional, one-dimensional financial and economic indicators or using methods which allow to compare the relationship of several inputs and outputs. The purpose of this article is to determine the efficiency of road freight transport in Poland and in other countries of the European Union based on the Data Envelopment Analysis method. The calculated DEA model uses the following variables: number of employees, turnover of road transport undertakings and the volume of freight transport of goods by road. The highest efficiency of the transport sector was achieved by 5 countries (Germany, Netherlands, Luxemburg, Austria, Slovakia).

Keywords: transportation, efficiency, DEA method

Streszczenie: Transport drogowy ma największy udział w przewozach towarów w Unii Europejskiej. W 2010 r. wielkość przewozu ładunków, mierzona pracą przewozową, w krajach Unii Europejskiej wyniosła 3831 mld t.km, a blisko połowa tych przewozów (45,9%) odbywała się transportem drogowym.

Z perspektywy całej gospodarki, jak i podmiotów działających w sektorze transportu kluczową kwestią staje się ocena efektywności działalności transportowej. Ocenę tę można wykonać bazując na tradycyjnych, jednowymiarowych wskaźnikach finansowo-ekonomicznych lub stosując metody wielowymiarowe pozwalające porównać relację kilku nakładów i kilku efektów. W artykule określono efektywność transportu drogowego towarów w Polsce na tle krajów Unii Europejskiej w oparciu o metodę Data Envelopment Analysis (DEA). Jako zmienne do modelu DEA przyjęto: liczbę pracujących, przychody przedsiębiorstw transportu drogowego towarowego oraz wielkość przewozów ładunków. Najwyższą efektywnością sektora transportu drogowego towarów wśród 24 badanych krajów UE charakteryzowało się 5 państw (Niemcy, Holandia, Luksemburg, Austria, Słowacja).

Słowa kluczowe: transport, efektywność, metoda Data Envelopment Analysis

Introduction

Transport supports the remaining sections of the economy and its development and is an important factor of economic growth. The appropriate development of transport (among others the adaptation of infrastructure, adjustment of market offers by operators) positively influences the functioning of individual sections of the economy, as well as, the efficiency of the entire national economy[1]. It is difficult to picture intensive economic growth, which generates employment and prosperity, without an efficient transport system allowing for the flow of goods not only on the internal market, but also on the international market[2]. On the other hand the development of transport is directly dependent on the development of the remaining sectors of the national economy which generate needs for transport services, thus stimulating the development of transport.

Until the moment of Poland's accession to the European Union, road transport of goods was subject only to insignificant increases or decreases. Since 2005 it has developed at a significantly faster rate than the entire economy − between 2005 and 2010 the mass of transported goods increased by as much as 44% while at the same time the GDP (in constant prices) has increased by 26%[3]. As compared to other European Union states Poland is placed very high in the ranking of work performed in road transport of goods. Only Germany and Spain are placed higher. Research of other authors indicates that the increasing significance of Polish road transport on the market of the European Union is mainly based on the access to a large fleet of road vehicles[4].

In spite of a significant increase in the tonnage of loads transported by means of road transport, between 2003 and 2008 the number of entities conducting activity in this sector has fallen. Such a situation was created by structural changes, including mainly the proceeding consolidation and increasing competition, as well as, business changes, i.e. the crisis which some of the enterprises could not withstand.

Taking into account the regional diversification of the functioning of transport sectors and the efficiency of enterprises acting in this industry, the aim of this article is to create a ranking based on the efficiency of sectors of transport in individual member states of the EU and the determination of the position of the Polish transport sector on the European market.

Research Method

The source material for the research is data for 2011 pertaining to the road transport sector in member states of the European Union published in yearbooks of the Central Statistical Office of Poland.

The non-parametric method of Data Envelopment Analysis (DEA) has been utilized for researching the efficiency of transport sectors. The DEA model may be presented mathematically in the following manner[5]:

[1] J. Burnewicz , W. Grzywacz, *Ekonomika transportu,* WKŁ, Warszawa 1989, s. 42.
[2] W. Rydzykowski, K. Wojewódzka-Król (red.), *Transport,* PWN, Warszawa 2007, s. 2.
[3] *Transport - wyniki działalności*, Roczniki GUS.
[4] Raport Sektor Transportu i Logistyki w czasie i przestrzeni, Grupa Doradców Biznesowych BAA Polska.
[5] W.W. Cooper, L.M. Seiford, K. Tone, *Data Envelopment Analysis, A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, New York 2007.

$$\max \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$u_r, v_i \geq 0$$

where:
s – quantity of outputs,
m – quantity of inputs,
u_r – weights denoting the significance of respective outputs,
v_i – weights denoting the significance of respective inputs,
y_{rj} – amount of output of r-th type (r =1,…,R) in j-th object,
x_{ij} – amount of input of i-th type (n =1,…,N) in j-th object; (j =1,…,J).

In the DEA model m of inputs and s of diverse outputs come down to single figures of "synthetic" input and "synthetic" output, which are subsequently used for calculating the object efficiency index[6]. The quotient of synthetic output and synthetic input is an objective function, which is solved in linear programming. Optimized variables include μ_r and v_i coefficients which represent weights of input and output amounts, and the output and input amounts are empirical data[7].

By solving the objective function using linear programming it is possible to determine the efficiency curve also called the production frontier, which covers all the most efficient units of the focus group. Objects are believed to be technically efficient if they are located on the efficiency curve (their efficiency index equals 1, which means that in the model focused on input minimization there isn't any other more favourable combination of inputs allowing a company to achieve the same outputs). However, if they are beyond the efficiency curve, they are technically inefficient (their efficiency index is below 1). The efficiency of the object is measured against other objects from the focus group and is assigned values from the range (0,1). In the DEA method Decision Making Units (DMU) represent objects of analysis[8].

The DEA models may be categorized based on two criteria: model orientation and type of returns to scale. Depending on the model orientation, a calculation is made of technical efficiency focused on the input minimization (model input-oriented) or of technical efficiency focused on the output maximization (model output-oriented)). But taking into account the type of returns to scale the following

[6] G. Rogowski, *Metody analizy i oceny banku na potrzeby zarządzania strategicznego*, Wydawnictwo WSB, Poznań 1998, s. 133-135.
[7] W.W. Cooper, L.M. Seiford, K. Tone, *Data Envelopment Analysis, A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, New York 2007.
[8] A. Charnes, W.W. Cooper, A. *Rhodes, Measuring the Efficiency of Decision Making Units*, European Journal of Operational Research, 1978, 2 (6), s. 429-444.

models are distinguished: the CCR model providing for constant returns to scale (the name derives from the authors of the model: *Charnes-Cooper-Rhodes*), the BCC model providing for changing return to scale (the name derives from the authors of the model: *Banker-Charnes-Cooper*)[9].

Foreign reference books include numerous publications concerning the evaluation of the efficiency of transport based on the DEA method. As an example, it has been used for the evaluation of maritime transport by Roll and Hayuth (1993)[10], Tongzon (2001)[11], Barros (2003)[12] or for researching air transport by, among others, Oum et. al. (2002)[13], Sarkis and Talluri (2004)[14], Yoshida and Fujimoto (2004)[15]. It has also been used for analyzing municipal transport in the elaboration of, among others, Fancello (2014)[16].

Research Results

For the purposes of specification of the efficiency of road transport sectors in individual 24 member states of the European Union the CCR model oriented at the minimization of expenditures and the model oriented at maximizing effects have been used. The following variables have been adopted for the calculated models:

- effect y_1 − sales revenues (EUR mln),
- effect y_2 − load transports (thousands of tons),
- expenditure x_1 − number of persons employed in the sector (thousands of persons),

The first stage of research included the determination of the efficiency of the transport sectors in individual countries, preparation of a ranking based on the transport sector efficiency (figure 1) as well as drawing up of the curve of efficiency (figure 2).

Irrespective of the utilized DEA model the average efficiency of the road transport sector in the analyzed sample has been at the level of 0.67. Five countries of the 24 were characterized in a fully effective transport sector with their efficiency indicator amounting to 1. The following countries have been placed in the group of efficient DMU: Germany, Austria, Slovakia, Netherlands, Luxembourg −

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

[10] Y. Roll, Y. Hayuth, *Port performance comparison applying data envelopment analysis (DEA),* Maritime Policy and Management, 20(2), 1993, pp. 153-162.

[11] J.K. Tongzon, *Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis*, Transportation Research, Part A, 35, 2001, pp. 113-128.

[12] C. Barros, *Incentive Regulation and Efficiency of Portuguese Port Authorities*, Maritime Economics&Logistics, 5(1), 2003, pp. 55-69.

[13] T.H. Oum, C. Yu, Y. Fu, *A comparative analysis of productivity performance of the words major airports: summary report of the ATRS global airport benchmarking research report 2002*, Journal of Air Transport Management, 2003, 9, pp. 285-297.

[14] J. Sarkis, S. Talluri*, Performance Based Clustering for Benchmarking of US airports*, Transportation Research Part A: Policy and Practice, 2004, 38(5), pp.329-346.

[15] Y. Yoshida, H. Fujimoto, *Japanese-airport benchmarking with the DEA and endogenous-weight TFP methods: testing the criticism of overinvestment in Japanese regional airports*, Transportation Research Part E: Logistics and Transportation Review, Elsevier, 2004, vol. 40(6), pp. 533-546.

[16] G. Fancello, B. Uccheddu, P. Fadda, *Data Envelopment Analysis (D.E.A.) for Urban Road System Performance Assessment*, Procedia-Social and Behavioral Sciences, Volume 111, 5, 2014, pp. 780-789.

these countries have formed the efficiency curve (figure 2). The efficiency indicator for the remaining countries amounted to 0.29 to 0.98. The lowest efficiency of the transport sector was noted for Lithuania and Romania. The transport sector in Poland has been ranked 9th, with an efficiency indicator (0.61) close to the average value of the entire group (figure 1).

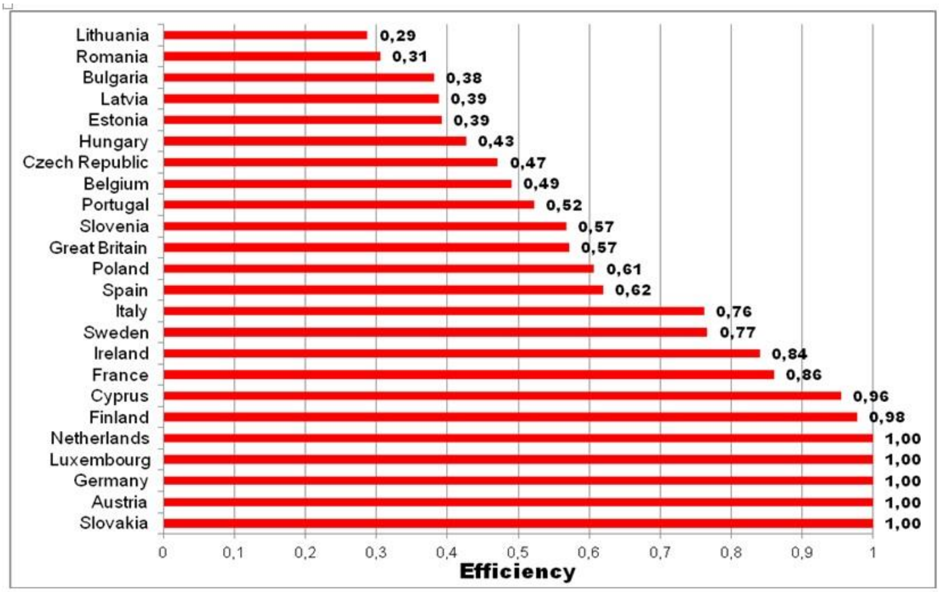

Figure 1. Efficiency of the transport sectors in the EU
Source: own study

The second research stage included the definition of efficiency benchmarks for ineffective DMU on the basis of the DEA method. On the basis of these benchmarks a combination of technologies allowing for the achievement of the same effects with lower expenditures has been specified for ineffective transport sectors in individual countries. Calculations have been performed on the basis of values of coefficients of linear combinations of common technology − λ (table 1). For example the following combination is optimal for the transport sector in Poland: 33% of technology (employment) of Germany and 233% of technology (employment) of Slovakia. Road transport sectors of Germany and Slovakia (fully efficient) have become the reference points (so called benchmarks) for the ineffective transport sector in Poland. In other words, in order for the transport sector in Poland to become efficient, it should construct its technology on the basis of transport sectors of regions being its benchmark. Therefore the sales revenues and transport values of 2011 should be achieved by the Polish transport sector by means of employing 151.56 thousand employees (0.33*357.6+2.33*14.4=151.56) − in such a situation it should be able to be included in the group of efficient sectors. The above indicates that the employment in the Polish transport sector should be decreased by 39%.

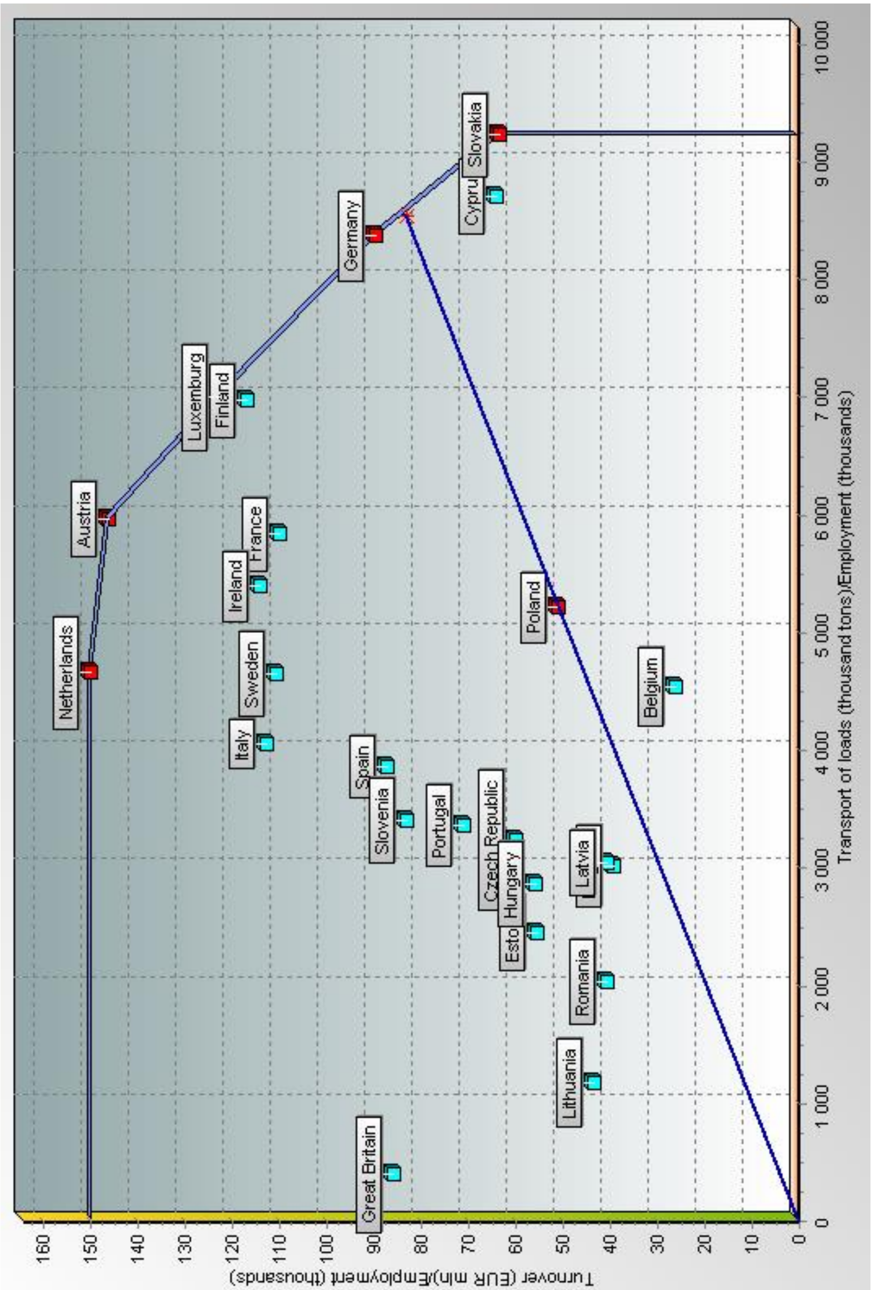

Figure 2. Efficiency curve of transport sectors in the EU (model input-oriented)
Source: own study

The potential changes which should be performed in the scope of employment in the transport sector in individual countries have been presented in table 2. These results suggest that ineffective countries should achieve the current rate of their effects with the use of appropriately lower expenditures (employment).

Table 2 also includes the potential changes in the scope of sales revenues and transport values of goods on the basis of the DEA model oriented at effects – i.e. how much should individual markets grow in order to be able to be included in the group of efficient markets while retaining a given level of employment.

Table 1. The values of coefficients of the linear combination of common technology for transport sectors

DMU	Efficient DMU				
	Austria	**Netherlands**	**Germany**	**Slovakia**	**Luksemburg**
Austria	Own technology				
Belgium				2.18	
Bulgaria			0.03		0.73
Cyprus			0.00	0.17	
Czech Republic	0.14				4.97
Estonia	0.07				0.14
Finland			0.01		4.63
France	1.15				27.90
Spain	3.10				6.57
Netherlands	Own technology				
Ireland	0.17				0.86
Lithuania		0.10			
Luxemburg	Own technology				
Latvia			0.01		0.34
Germany	Own technology				
Poland			0.33	2.44	
Portugal	0.33				1.73
Romania	0.20				1.92
Slovakia	Own technology				
Slovenia	0.22				0.01
Sweden	0.87				0.54
Hungary	0.15				2.17
Great Britain		1.53			
Italy	2.16	1.06			

Source: own study

Table 2. Projections values

Inefficient DMU	Model input-oriented	Model output-oriented	
	Employment (thousands)	Transport of loads (thousand tons)	Turnover (EUR mln)
Belgium	-51%	104%	146%
Bulgaria	-62%	162%	162%
Cyprus	-4%	5%	5%
Estonia	-61%	155%	155%
Finland	-2%	2%	2%
France	-14%	16%	16%
Spain	-38%	61%	61%
Ireland	-16%	19%	19%
Lithuania	-71%	305%	248%
Latvia	-61%	158%	158%
Poland	-39%	65%	65%
Portugal	-48%	92%	92%
Czech Republic	-53%	112%	112%
Romania	-69%	227%	227%
Slovakia	-43%	76%	76%
Slovenia	-23%	30%	30%
Hungary	-57%	134%	134%
Great Britain	-43%	1000%	75%
Italy	-24%	31%	31%

Source: own study

Summary

Apart from warehousing, loading and unloading activities transport constitutes one of the most fundamental logistical activities. An essential branch of transport in Poland and the entire European Union is road transport. A significant issue is therefore the specification of the position of the Polish road transport sector on the European market and the evaluation of the efficiency of transport in individual member states of the EU, which has become the subject of research in this article.

The conducted research validates the formation of the following conclusions:

- the average efficiency of transport sectors in the 24 countries of the EU in 2011, based on the DEA method, is shaped at a relatively low level - 0.67;
- the following countries were characterized by the most efficient transport sectors: Germany, Austria, Slovakia, Netherlands, Luxembourg;
- the lowest positions in the ranking on the basis of the transport sector efficiency indicator were occupied by: Lithuania and Romania;

- the Polish transport sector was ranked 9th with the efficiency indicator equal to 0.61;
- benchmarks for the Polish transport sector were German and Slovakian transport sectors, on the basis of which it has been specified that the Polish transport sector could be characterized as effective if it reduced employment by 39% with the current level of effects generated or increased turnover and tonnage of transported loads appropriately by 65% with the current level of expenditures (employment).

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