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## Technological effectiveness of urban transport in selected Polish cities

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**Technological effectiveness of urban transport in selected Polish cities**

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## **Technological effectiveness of urban transport in selected Polish cities**

**JEL Classification:** *O18;R58;C10*

**Keywords:***technological effectiveness, urban transport, city management.*

### **Abstract**

**Research background:** An efficient and effectively functioning transport in the city is of great importance both for the people residing in its territory, as well as companies doing business there. However, apart from a positive impact, transport also carries many social costs including congestion, traffic accidents and a negative influence on the natural environment. Consequently, urban transport is an increasingly important area of city management.

**Purpose of the article:** The aim of this study is to analyze and to assess the transport technological effectiveness in selected Polish cities. The author received a ranking of cities and identified ways to improve the efficiency.

**Methodology:** The test procedure used non-parametric method of Data Envelopment Analysis. Data for analysis were drawn from the Local Data Bank of the Central Statistical Office defining expenses in the transport section as well as data on the condition and use of transport infrastructure. The calculations have been made using Frontier Analyst Application software. The performance results were determined using the BCC model.

**Findings & Value added:** The main result is the author's ranking of transport effectiveness in Polish cities. The analysis showed that urban transport characterized by a rather low technological effectiveness.

### **Introduction**

Urban transport is an increasingly important area of city management [Pact of Amsterdam, 2016]. However, apart from having a positive impact, transport also carries many social costs including congestion, traffic accidents and a negative influence on the environment. According to data presented by the European Commission this situation, over the next few decades, may become significantly worse in many European cities. Forecasts show that the intensity of freight

transport in cities will increase by 40% by 2030 and rise by over 80% by 2050 when compared to 2005. At the same time it is expected that passenger transport will also increase by approximately 34% by 2030 and by more than 50% by 2050 (in comparison to 2005) [White Paper, 2011]. One of the things which the European Union requires of its member countries is the need to develop a sustainable mobility strategy, including both passenger and freight transport [Hajduk, 2016]. Unfortunately many cities, in their plans and activities regarding the field of transport, included only those tasks that relate to the movement of people, often without consideration for freight [National urban policy, 2015].

City management concerning the field of urban transport could be viewed as management which is directed both to the inside (the city office management) and to the outside (the city management as a whole) [Noworól, 2011, pp. 25-41]. On the one hand it involves the identification within the organizational structure of city hall of those responsible for the coordination of the flow of people and goods. It becomes their task to formulate long-term goals in this area. On the other hand, it is the municipal government, in cooperation with other stakeholders including residents, forwarders, recipients, transport companies and public transport operators, who should emerge as the initiator of actions which aim to improve the flow of people and goods in the city. Nevertheless, it is the municipal government who should become the coordinator and initiator of all activities meaning to improve urban transport, for example, by including it into some area of city management.

The assumptions of sustainable development established in the 1990's have become a priority in the transport policy of the European Union. The need to change trends in transport is also visible in the Europe 2020 Strategy and documents resulting from this strategy [Toledo Declaration, 2010]. Reducing the use of natural resources for the purposes of transport has become a priority within the transport policy of many countries [Transport Development Strategy, 2013].

The aim of this article is to examine, through the use of Data Envelopment Analysis, transport effectiveness of Polish cities. This method requires the definition of variables representing inputs on the one side and outputs on the other. The study used information from the Local Data Bank of the Central Statistical Office of Poland defining expenses within the transport department (expenditures) and data on the condition and use of transport infrastructure (effects). The analysis was conducted for 18 cities with district status meaning those having from 150 to 500 thousand inhabitants. The territorial units were then compared and a ranking of the effectiveness of urban transport was prepared.

## **1. Background literature**

In recent years many institutions have created state of development rankings of countries, regions and industries. These mainly concern economic performance, investment attractiveness, the level of innovation and research potential. Assessment is made on the basis of analysis of variables both quantitative and qualitative in character, which in turn allows the ranking of the units surveyed in

terms of resources and achieved results. It may be interesting to create a ranking of cities in terms of effectiveness.

The simplest definition of efficiency describes it as the ratio of achieved effects to incurred expenses. According to the principle of rational management, the greater the effect per unit of expenditure the higher the effectiveness. Nowadays, high competition requires an increase in effectiveness and this poses a challenge. Economists understand effectiveness as a lack of stoppage time and unnecessary waste generation in the company. Effective enterprises are located at the lowest possible cost curve, which means that they achieve results in the cheapest way possible.

The Data Envelopment Analysis method was initially presented in 1978 by Charnes, Cooper and Rhodes. These researchers based their assumptions on the concept of productivity formulated by Debreu and Firrelle and understood as the quotient of a single result and a single effort. The DEA method was used in situations in which there is more than one effect and more than one effort. Using linear programming to estimate the efficiency measures they created their first model called CCR with constant return-to-scale in which they accepted the assumption that scale effects are constant. In time both the methodology and its application become more widely used. In 1984, Banker, Charnes and Cooper proposed a model, called BCC with the variable return-to-scale. These models are used to study company efficiency.

The DEA method focuses on studying the dependence between the level of multiple inputs and outputs. The technological efficiency score is calculated without knowing the initial weights. The DEA calculations are based on searching weights that maximize the efficiency of each object. Finally, the DEA method allows the determination the limiting curve of effectiveness. If objects are on the curve then they are considered to be efficient. Otherwise, they are seen as inefficient [Guillermo, & Vincent, 2016, pp. 328-350; Nazarko *et al.*, 2008, pp. 89-105]. The object's effectiveness is measured in relation to other objects being studied. Analysis units of the DEA are called Decision Making Units's (DMU). The subject of analysis, on the other hand, is the productivity with which DMU's transforms inputs to outputs. The measure of efficiency is the dependence between the productivity of a given object and its maximum productivity or that which can be achieved under specific technological conditions.

The DEA models can be used to determine effectiveness but also, at times, for setting benchmarks, the benefits of scale, ranking objects, as well as for figuring out ways to improve the efficiency and structure of optimal technologies for inefficient objects. An important advantage of the DEA method is its non-parametric character, allowing its use without the knowledge of functional dependencies between outputs and inputs. Another advantage of this method is the possibility of using data expressed in different units of measure for both inputs and outputs. In relation to variables, the configuration of the DEA model is therefore characterized by high flexibility which significantly affects the range of applications in which the method can be used [Sarkar, 2016, pp. 740-751; Chodakowska, 2015, pp. 112-125]. Environmental variables which influence DMU's effects or inputs and which are not controlled by the object can also be introduced as part of

analysis. These variables reflect geographical, legal or economic conditions. The DEA method also presents some limitations including: high sensitivity to erroneous data and variables which differ significantly from others, sensitivity to changes to the number of test items or the need for appropriate balance between the number of objects and the number of variables.

DEA is a method which is well-known worldwide and is often used to solve problems related to the analysis of effectiveness. This is supported by a very rich bibliography available through many foreign studies, connected to this method [Liu *et al.*, 2013, pp. 3-15]. In Poland this method has been mainly used to analyze the effectiveness of financial and educational institutions. This is the reason this study attempts to use the DEA method to investigate urban transport effectiveness.

## 2. Methodology of investigations

The research focuses on technological effectiveness of urban transport. The study uses the BCC model. The scope of the research consists of three steps which includes: selection, evaluation and analysis.

Source data comes from the Local Data Bank of the Central Statistical Office and refers to the year 2015. The selection of variables in the model was carried out based on the analysis of literature and was determined by the limited scope of the statistics given concerning city [Díaz, & Charles, 2016, pp. 328-350; Wiśnicki *et al.*, 2017, pp. 9-15]. The sample for analysis includes 18 cities with poviats status from 150 to 500 thousands inhabitants. The calculation has been made using Frontier Analyst Application software dedicated to the DEA method.

Prior to initiating the study an assessment was made whether all the variables included in the expenditures are characterized by sufficiently high volatility. Coefficients of variation were calculated for each feature (V). It was found that all variables were characterized by high volatility and therefore could carry important information about the phenomenon being examined. In order to determine the technological effectiveness for the transport cross-section of cities with poviat status the following variables were isolated, which included three effects:

$Y_1$  - the length of gmina and poviat hard surface roads per 10 thousand residents [kilometers/10000 residents];

$Y_2$  - the length of bus-line per 10 thousand square kilometers [kilometers/10000 square kilometers];

$Y_3$  - the length of bicycle paths per 10 thousand square kilometers [kilometers/10000 square kilometers].

Adopted a set of results included a one variable: X - expenditure of poviats budgets in the transport section [PLN/1 person].

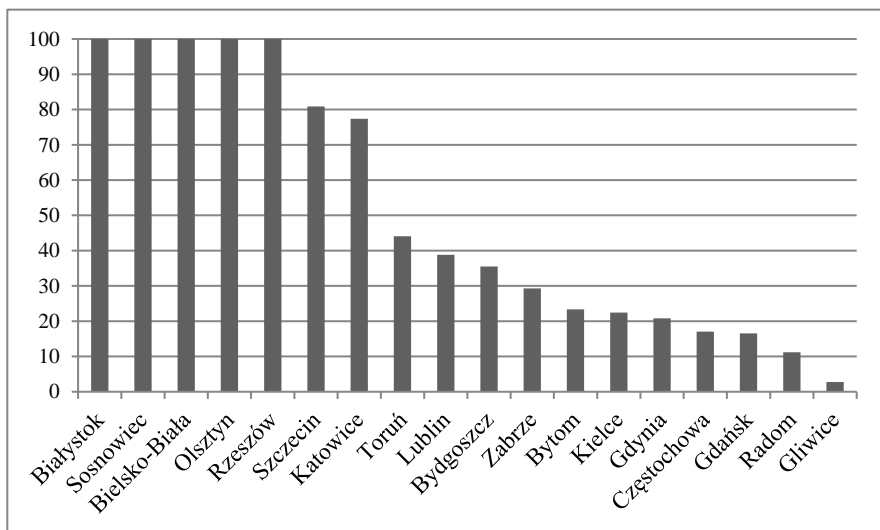
Variables used in the model and expressed as expenditures were also checked in respect to the existence and the strength of their correlation with the effects. The highest correlation was shown between the length of bicycle paths ( $Y_3$ ) and the expenditures for transport (X).

### 3. Results and discussion

The technological efficiency results, shown in figure 1, were determined using the BCC model. The initial step of the study was to create a ranking of urban transport efficiency and to identify city-benchmarks. Units which are considered to be fully efficient achieved a factor of 100%. The ranking of the objects in order of efficiency from highest to lowest can show which cities are inefficient and which can be classified as leaders. Five cities have been established as benchmarks: Białystok, Sosnowiec, Bielsko-Biała, Olsztyn, Rzeszów. Eight cities did not reached the 30% threshold of efficiency. This class includes Zabrze, Bytom, Kielce, Gdynia, Częstochowa, Gdańsk, Radom, Gliwice. The lowest level of efficiency of 2.77% was attained by Gliwice. Cities which were considered in the study display an average technological efficiency of 51.11% with standard deviation reaching 36.97%.

The analysis of the classes of efficiency was the next step within the research process. Efficient cities made up the most numerous class. These benchmarks represented 27.7% of all objects considered in the study. The next step of research was concerned the examination of the relationship between the efficiency score and transport expenditures. An increase in transport expenditures reduced the efficiency score. Cities displaying full efficiency allocate anywhere from PLN 21.26 to PLN 902.24 per 1 inhabitant for transport. In contrast, the city with the lowest efficiency spends as much as PLN 2110.04 per 1 inhabitant.

**Figure 1.** The technological efficiency of the urban transport



Source: author's elaboration.

Designated lambda values show how the level of technology in ineffective cities should be adjusted for them to become effective. The last step of the study was to determine ways in which inefficient cities could improve in relation to benchmarks. For instance, Szczecin's level of technology should be equal to the sum of technologies of: (1) Bielsko-Biała multiplied by 13.1, (2) Sosnowiec multiplied by 59.7 and (3) Olsztyn multiplied by 27.2. The same interpretation applies to other inefficient cities, ie. Katowice, Toruń, Lublin, Bydgoszcz, Zabrze, Bytom, Kielce, Gdynia, Częstochowa, Gdańsk, Radom, Gliwice. Lambda values for inefficient cities present table 1.

**Table 1.** Lambda values for inefficient cities

DMU	Białystok	Sosnowiec	Bielsko-Biała	Olsztyn	Rzeszów
Szczecin	0.0	59.7	13.1	27.2	0.0
Katowice	0.0	65.5	10.2	24.3	0.0
Toruń	68.1	0.0	27.3	0.0	4.6
Lublin	31.0	0.0	3.0	66.0	0.0
Bydgoszcz	0.0	59.3	0.0	40.7	0.0
Zabrze	0.0	94.9	0.0	5.1	0.0
Bytom	0.0	67.3	0.0	32.7	0.0
Kielce	0.0	5.7	2.3	92.0	0.0
Gdynia	0.0	66.9	0.0	33.1	0.0
Częstochowa	0.0	48.2	20.3	31.5	0.0
Gdańsk	0.0	28.6	1.8	69.9	0.0
Radom	0.0	75.2	0.0	24.8	0.0
Gliwice	0.0	77.7	20.9	1.5	0.0

Source: author's elaboration.

## Conclusions

The DEA method enriches the methodology used by scientists to study urban transport efficiency. In comparison to parametric methods it presents many advantages. It makes the determination of the unit's effectiveness in the presence of many inputs and outputs possible. At the same time it does not require knowledge of functionality between the variables. Additionally, it allows the expression of inputs and outputs in different units.

The article presents the evaluation of urban transport efficiency on the basis of one input (transport expenditures) and three outputs (the length of urban roads, the length of bus-lines, the length of bicycle paths). The study shows that full efficiency occurred in 27.8% of units. The average urban transport efficiency was 51,1% in the BCC model and the lowest efficiency was only 5.56. This means

that substantial parts of cities do not use optimal inputs. The analysis shows that urban transport of considered cities was characterized by a rather low technological effectiveness. Although the method involved a number of simplifications these results provide a general overview of the level of efficiency of the units surveyed, and can be a starting point for more detailed analysis of the efficiency of individual units. An important advantage of measuring effectiveness using this method is the identification potential improvements which inefficient units may implement and objects which they could imitate.

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