ORGANIZATION OF PUBLIC TRANSPORT IN THE CITY AS THE MAIN TASK OF URBAN LOGISTICS - INFRASTRUCTURE REGIONAL BACKGROUND IN POLAND

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Abstract

The high tempo of urbanization results in a dynamic development of cities. Urban logistics deals with the flow of materials, people and information within a city, and transport is one of its elements. The aim of this article is to pint out the problems connected with the state and the use of public transport infrastructure in cities, and to identify the factors which influence the regional development in terms of urban transport in Poland. The data for the years 2012-2013 were analyzed in relation to individual Polish voivodships (provinces). For this purpose the factor analysis was used.

Key words: *public transport, transport infrastructure, urban logistics, factor analysis*

INTRODUCTION

Dynamic development of cities entails continuous customization of their functions to the changing needs of economic subjects and residents. The needs concern, among other things, the flows of goods and people within the boundaries of cities the realization of which necessitates transport processes. The transport system of a city is examined in the context of urban logistics whose main goal is composed of the following sub-goals (Mesjasz-Lech, 2014):

- economic: ensuring the development of cities through stimulating business activities in urban areas,
- social: ensuring the desired quality of life in urban areas,
- ecological: considering the ecological requirements in the realization of the economic and social goals.

Urban logistics is, therefore, focused on the coordination of all kinds of resources flows between the dispatch and reception places to improve the quality of residents' lives and foster the economic development of the city at the lowest possible costs and respecting the environment. The task of urban logistics in this context is also the organisation of transport which is one of the elements of an effective city communication system (Roháčová, 2015) which contributes to:

- lesser congestion through the reduction of passenger car transportation (Pawlak, 2012; Tirachini, 2014),
- city's economic growth and social prosperity increase thanks to the development of transport infrastructure and job creation, and, effectively, the increase in the management efficiency, social mobility and communication integration of the population (Heres et al., 2014; Willoughby, 2013; Fistung et al., 2014),
- investment and innovation increase through the generation of new ideas in the sphere of marketing, IT systems, new technologies, time and journey quality organizational solutions, etc. (Szymczak, 2011; Ibraeva & de Sousa, 2014; Simony et al., 2014; De Lieto Vollaro et al., 2014; Leahy et al. 2014; Alessandrini, 2014),
- reduction of the environmental impact of transport (Eißel & Chu, 2014; Bubeck et al., 2014; Chaturvedi, Son H. Kim, 2014).

Therefore, the development of urban transport system influences the functioning of the city in the economic, social and environmental aspects, and in this way it realizes the principles of sustainable development, in other words:

- "operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development,
- allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promises equity within and between successive generations
- limits emissions and waste within the planet's ability to absorb them, uses non-renewable resources at or below the rates of development of renewable substitutes while minimizing the impact on land and the generation of noise" (Alonso et al., 2015).

Urban transportation system should be discussed from the standpoint of four factors determining its accessibility (Hadas et al., 2014):

- spatial - where the service is provided,
- temporal - when the service is provided,
- information - how to use the service,
- capacity - space available for the passenger.

Entities responsible for the urban transport system look for solutions ensuring the most functional, socially adjusted and cost-effective services (Nicolás et al., 2014). It is all the more so important in the light of the fact that passengers expect services meeting a specific quality criteria which include: 1) Comfort and cleanness, 2) Service's accessibility, 3) Information's availability, 4) Service organization, 5) Staff's behaviour, 6) Behaviour of inspectors, and 7) Reliability and safety, 8) Costs (d'Ovidio et al., 2014; Jain et al., 2014). An important criterion for the choice of a transport system is its synchronization which is not always feasible due to the dynamic, stochastic and uncertain nature of traffic (Liu et al., 2014).

The efficiency of urban communication depends on the integration level of the transport system which is an organizational process enabling a close cooperation of carriers in order to improve the quality of transport services. The effectiveness of urban transport depends on the level of its integration, an organizational process supporting the close and effective cooperation of agents offering transport services in order to improve the quality of their services (Dydkowski, 2009). The level of urban transportation integration is determined by the variety of transport modes and types of passenger transport means. The share of individual transport types determines the demand for urban transport (Milioti & Karlaftis, 2014). Moreover, the process of integration should not concern only individual elements of the transport system but the elements and the process of transport planning (Kash & Hidalgo, 2014). The level of utilization and integration of infrastructure elements and urban transport resources depends on the region where the urban transport is realized. Regions differ in terms of the level of technological advancement, changes in production and consumption, and the level of urbanization and infrastructure modernity (Tsekeris, 2014). And so these factors influence the development of urban transport in a given region. Also, a negative correlation between the population density and bus transport use was observed (Jou & Chen 2014). For this reason, the article evaluates the development of urban transportation in Poland by voivodships. The aim is to identify the factors shaping urban transport in Polish voivodships and to determine the level of a given factor saturation in them. Accordingly, the following hypothesis is put forward: It is possible to distinguish factors determining the development of urban transport in Polish voivodships characterized by the explanatory variables: 1) urban transport lines, 2) inventory, use and operating of urban transport stock, 3) urban transport stock adjusted to carrying the disabled persons, and 4) stock capacity and transport of passengers by urban transport.

DATA AND METHODOLOGY

The verification of the hypotheses is based on a factor analysis. The analysis is based on data from the Central Statistical Office in Poland (Transport – wyniki działalności w 2013 r., 2015; Transport – wyniki działalności w 2012 r., 2015). The following variables were taken into account:

X1 - urban bus transport lines (kilometers),

X2 - urban tram transport lines (kilometers),

X3 - inventory number of bus stock,

X4 - share of vehicles in traffic in % of vehicles in the bus inventory,

X5 - total distance travelled by bus vehicles (thousand vehiclekilometres),

X6 - inventory number of tram stock,

X7 - share of vehicles in traffic in % of vehicles in the tram inventory,

X8 - total distance travelled by tram vehicles (thousand vehiclekilometres),

X9 - urban bus transport stock adjusted to carrying the disabled persons (number of buses),

X10 - urban bus transport stock adjusted to carrying the disabled persons (number of passenger seats in buses),

X11 - urban tram transport stock adjusted to carrying the disabled persons (number of trams),

X12 - urban tram transport stock adjusted to carrying the disabled persons (number of passenger seats in trams),

X13 - bus stock capacity (thousand seats in buses),

X14 - tram stock capacity (thousand seats in trams),

X15 - transport of passengers (million).

The values of variables are for the years 2012 and 2013. Choosing the years 2012 and 2013 for the analysis is dictated by the data accessibility and the possibility and relevance of examining their relationships.

The goal of the factor analysis was to verify the hypotheses concerning the existence and the nature of the general regularity shaping the relationships between variables determining the level of urban transport development. The factor analysis was carried out in the following steps:

1. The matrix of correlation between the analyzed variables was calculated in order to initially assess the correlations.
2. The Bartlett test was applied which allowed to determine if there exists sufficient ground for a factor analysis.
3. The factor analysis assumptions were tested.
4. The number of factors was determined on the basis of the Jolliffe criterion.
5. The factors were distinguished through the Principal Component Analysis.
6. The factors were rotated to obtain a clear and precise interpretation, Varimax, Biquartimax and Quartimax methods were used here.
7. The categories of the factors were determined.

RESULTS

The analysis focused on the variables characterizing urban transport in Polish voivodships. The singled out variables can be divided into four main groups: 1) urban transport lines (X1-X2), 2) inventory, use and operating of urban transport stock (X3-X8), 3) urban transport stock adjusted to carrying the disabled persons (X9-X12), and 4) stock capacity and transport of passengers by urban transport (X13-X15). The factor analysis explained if it is possible to replace the examined variables with a smaller number of non-correlated factors as the analyzed variables are lineally dependent on them and they explain the correlations between the variables in the best way. The correlations between the examined variables are indicative of the existence of a clear structure which should be detected and described through the factor analysis. It was carried out for the years 2012 and 2013 in order to see if urban transport in these periods can be described by the same factors.

On the basis of a correlation table, it was found that the majority of variables are correlated and the correlations indicate a certain explicit structure. The Bartlett test showed that on the 0.01 level of significance the null hypothesis with the value of all correlation coefficients for the examined years equal to zero should be rejected. The adequacy of the correlation matrix was obtained on the basis of Kaiser-Meyer-Olkin (KMO) coefficient whose value for the years 2012 and 2013 was 0.99. This high value of the KMO coefficient confirms the validity of the Principal Component Analysis in our case.

The next stage of the analysis determined the number of factors on the basis of the Jolliffe criterion which labels factors with a value higher than 0.7 eligible for analysis. Further analysis uses, then, four factors and their eigenvalues are presented in table 1.

Table 1. Eigenvalues of analyzed variables for years 2012 and 2013

2012					2013				
Factors	Eigenvalue	% of Total variance	Cumulative eigenvalues	% cumulative	Factors	Eigenvalue	% of Total variance	Cumulative eigenvalues	% cumulative
1	11,54529	76,96857	11,54529	76,9686	1	11,66833	77,78885	11,66833	77,7888
2	1,14114	7,60759	12,68642	84,5762	2	1,17882	7,85880	12,84715	85,6476
3	0,93057	6,20383	13,61700	90,7800	3	0,92921	6,19473	13,77636	91,8424
4	0,84730	5,64865	14,46430	96,4286	4	0,85690	5,71267	14,63326	97,5550

Source: Own calculation in Statistica software.

The first four factors explain 96% of the total variance in the year 2012, and 97% in 2015. Such a result confirms the validity of using the four factors for the analysis. The analysis of the residuary correlation coefficients confirms that assumption as well. In order to determine the relations of the factors with the output variables, factor loadings were calculated. They can be interpreted as correlations between the factors and variables. Table 2 shows raw factor loadings for the analyzed variables.

Table 2. Raw factor loadings for the analyzed variables for years 2012 and 2013.

Variable	2012				2013			
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4
X1	**-0,71927**	-0,405278	-0,512495	-0,068328	-0,68701	-0,622919	0,085004	-0,300412
X2	**-0,88486**	0,145585	-0,389678	-0,116335	**-0,89765**	-0,008332	0,086161	-0,415635
X3	**-0,95639**	-0,284246	0,009903	0,032958	**-0,94545**	-0,311508	0,055506	0,067711
X4	-0,40985	-0,050349	0,290499	**-0,862872**	-0,30290	-0,097872	**-0,943786**	-0,075768
X5	**-0,93872**	-0,324709	-0,048148	0,015979	**-0,94975**	-0,296427	0,020337	0,062874
X6	**-0,94171**	0,196449	-0,134842	-0,009788	**-0,93582**	0,198858	0,092323	-0,177396
X7	-0,63964	**0,607675**	-0,268688	-0,102872	**-0,71761**	0,387959	-0,043378	-0,524232
X8	**-0,94901**	0,229984	-0,110114	0,048575	**-0,96359**	0,207362	0,072385	-0,000544
X9	**-0,94552**	-0,131761	0,252140	0,121291	**-0,96652**	-0,088739	0,008330	0,230156
X10	**-0,94281**	-0,133347	0,261367	0,108761	**-0,96209**	-0,070625	-0,006232	0,243575
X11	**-0,87619**	0,271901	0,277695	0,153446	**-0,88013**	0,351428	-0,042698	0,223703
X12	**-0,88196**	0,223314	0,336945	0,122604	**-0,88663**	0,319101	-0,041444	0,273805
X13	**-0,94465**	-0,301805	0,006092	0,034791	**-0,95142**	-0,279555	0,024611	0,094268
X14	**-0,94756**	0,201434	-0,045411	-0,046843	**-0,94899**	0,216422	0,016039	-0,098741
X15	**-0,98277**	-0,124775	0,046208	0,040555	**-0,97847**	-0,001131	-0,013335	0,131845
Variance	11,54529	1,141139	0,930575	0,847298	11,66833	1,178820	0,929209	0,856900
Share	0,76969	0,076076	0,062038	0,056487	0,77789	0,078588	0,061947	0,057127

Source: Own calculation in Statistica software.

The variables have the closest correlation with the first factor - almost all variables (except X4 and X7 in 2012 and X1 and X4 in 2013) have high factor loadings (above 0.7) with the first factor. The second and third factor in 2012 and the second and fourth in 2013 seem to be redundant, which, however, does not go along the previous remarks on correlation coefficients. That is why the obtained structure was revised through rotating and re-calculating factor loadings. Varimax, Biquartimax and Quartimax rotations were applied. From the perspective of obtained results, the Varimax method yielded the clearest interpretation. Table 3 demonstrates factor loadings after Varimax rotation for the analyzed variables.

Table 3. Factor loadings after Varimax rotation for the analyzed variables for years 2012 and 2013.

Variable	2012				2013			
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4
X1	0,167391	0,244841	**0,926177**	0,056176	0,089224	**0,939359**	0,076814	0,247453
X2	0,323880	**0,701081**	0,595591	0,135724	0,369475	0,573808	0,053398	**0,719307**
X3	0,692108	0,220739	**0,666142**	0,158657	0,605238	**0,756249**	0,084888	0,230530
X4	0,172742	0,117135	0,122216	**0,970029**	0,119293	0,110609	**0,981673**	0,087479
X5	0,638819	0,207192	**0,716893**	0,155744	0,609729	**0,741781**	0,119049	0,241007
X6	0,558933	**0,649806**	0,440483	0,122518	0,614815	0,385388	0,017391	**0,654575**
X7	0,218089	**0,891160**	0,106655	0,089873	0,304424	0,154850	0,130339	**0,899188**
X8	0,598494	**0,662976**	0,405729	0,075092	0,747890	0,359392	0,027942	**0,536162**
X9	**0,862311**	0,223314	0,420081	0,140502	**0,795371**	0,551113	0,103000	0,219358
X10	**0,861987**	0,218204	0,415037	0,154656	**0,806482**	0,529463	0,114282	0,214849
X11	**0,827048**	0,488661	0,112849	0,082252	**0,876077**	0,140897	0,103239	0,389838
X12	**0,859521**	0,432130	0,114061	0,133282	**0,901367**	0,162044	0,102403	0,339723
X13	0,682803	0,203101	**0,673268**	0,154727	0,636274	**0,724143**	0,111423	0,226263
X14	0,606457	**0,622669**	0,390851	0,185540	0,678171	0,352764	0,087411	**0,604509**
X15	**0,730304**	0,340279	0,557728	0,158062	**0,770888**	0,500300	0,124410	0,338994
Variance	6,044767	3,380554	3,846751	1,192225	6,248828	4,176996	1,092231	3,115202
Share	0,402984	0,225370	0,256450	0,079482	0,416589	0,278466	0,072815	0,207680

Source: Own calculation in Statistica software.

Now it is possible to distinguish the following categories of factors:

1) for the year 2012:

- Factor 1 – urban transport stock adjusted to carrying the disabled persons and number of transported passengers,
- Factor 2 – tram transport lines, inventory, use, operating and capacity of tram stock,
- Factor 3 – bus transport lines, inventory, use, operating and capacity of bus stock,
- Factor 4 – share of buses vehicles in traffic.

2) for the year 2013:

- Factor 1 – urban transport stock adjusted to carrying the disabled persons and number of transported passengers,
- Factor 2 – bus transport lines, inventory, use, operating and capacity of bus stock,
- Factor 3 – share of buses vehicles in traffic,

- Factor 4 – tram transport lines, inventory, use, operating and capacity of tram stock.

The same factor categories were distinguished for both examined years. The X7 variable was somewhat problematic which according to its factor loading value should end up in group one in 2013. Considering its significance, though, it seems reasonable to assign it to group four, notwithstanding the fact that the value of factor loading for factor four is 0.536 which is smaller by 0.259 than the value for the first factor.

Looking at the data included in tables 1 and 3 we discover that factor one determines the use and condition of urban transport infrastructure in Poland to the highest degree because it explains as much as 79.97% and 77.789% of the total variability of primary variables in 2012 and 2013 respectively. This factor concerns five variables, especially: urban bus transport stock adjusted to carrying the disabled persons, urban bus transport stock adjusted to carrying the disabled persons, urban tram transport stock adjusted to carrying the disabled persons, urban tram transport stock adjusted to carrying the disabled persons and transport of passengers. This means that the factor can be treated as determining the development of transport for the disabled and the utilization of it and can be used to intensify urban passenger transport.

The second factor in 2012 which is also fourth in 2013 explains 7.61 and 5.71% of the total variance respectively and is associated with the variables: urban tram transport lines, inventory number of tram stock, share of vehicles in traffic in % of vehicles in the tram inventory, total distance travelled by tram vehicles and tram stock capacity. This factor, therefore, can be connected with the condition and utilization of tram infrastructure.

The factor which is third in 2012 and second in 2013 explains 6.20 and 7.86% of the total variance respectively and concerns the following variables: urban bus transport lines, inventory number of bus stock, total distance travelled by bus vehicles and bus stock capacity. This factor is the determinant of the utilization of bus transport in urban transport system.

The fourth in 2012 and third in 2013 is the factor which explains 5.65 and 6.19% of the total variance respectively. This factor is identified by only one variable - the share of vehicles in traffic in % of vehicles in the bus inventory.

Although the same factor categories were distinguished for both examined years, they explain a different percent of the total variance. Only variables connected with the first factor are identical for both years. In addition, some variables seem to be related with more than one factor, which is the case for the following variables: X2 (the first and second factor in 2012 and second and fourth in 2013), X3 (the first and third factor in 2012 and first and third in 2013), X5 (the first and third factor in 2012 and first and second in 2013), X6 (the first and second factor in 2012 and first and fourth in 2013), X8 (the first and second factor in 2012 and first and fourth in 2013), X13 (the first and third factor in 2012 and first and second in 2013), X14 (the first and second factor in 2012 and first and fourth in 2013) and X15 (the first and third factor in 2012 and first and second in 2013). This can mean than:

1) In the year 2012:
   - tram transport lines, inventory, use, operating and capacity of tram stock and bus transport lines, inventory, use, operating and capacity of bus stock are independent of each other but both factors influence urban tram transport lines,
   - urban transport stock adjusted to carrying the disabled persons and the number of transported passengers and the number of transported passengers and bus transport lines, inventory, use, operating and capacity of bus stock are independent of each other but both factors influence the inventory number of bus stock, total distance travelled by bus vehicles, bus stock capacity and the transport of passengers,
   - urban transport stock adjusted to carrying the disabled persons and the number of transported passengers and tram transport lines, inventory, use, operating and capacity of tram stock but both factors influence the inventory number of tram stock, total distance travelled by tram vehicles and tram stock capacity.

2) In the year 2013:

- tram transport lines, inventory, use, operating and capacity of tram stock and share of bus vehicles in traffic are independent of each other but both factors influence the urban tram transport lines,
- urban transport stock adjusted to carrying the disabled persons and the number of transported passengers and the number of transported passengers and tram transport lines, inventory, use, operating and capacity of tram stock and share of bus vehicles are independent of each other but both factors influence the inventory number of bus stock, total distance travelled by bus vehicles, bus stock capacity, transport of passengers,
- urban transport stock adjusted to carrying the disabled persons and the number of transported passengers and the share of bus vehicles in traffic are independent of each other but both factors influence the inventory number of tram stock, total distance travelled by tram vehicles, tram stock capacity.

On the basis of the individual principal factors' values the level of a given voivodship saturation with a specific factor was determined. The higher the value of a factor in a voivodship the greater the degree of its influence. Figures 1-4 show the arrangement of voivodships according to the values of the consecutive four principal factors for the years 2012 and 2013.

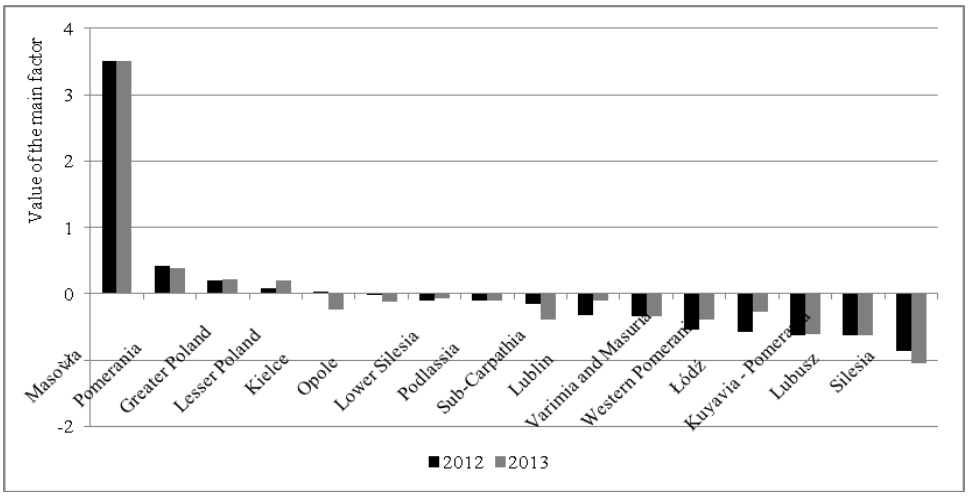


Fig. 1. Arrangement of voivodships according to the values of the factor “urban transport stock adjusted to carrying the disabled persons and number of transported passengers”

Regarding the urban transport stock adjusted to carrying the disabled persons and the number of transported passengers factor, ranked highest are the voivodships: Masovia, Pomerania, Greater Poland and Lesser Poland. This means that these voivodships are characterized by the highest level of urban transport development in terms of urban transport stock adjusted to carrying the disabled persons and the number of transported passengers, and the Masovia Voivodship is far ahead the other ones in terms of this determinant. The population density of this voivodship undoubtedly contributes to the development of transport, especially the one adjusted to carrying the disabled. The last positions in the ranking are held by the following voivodships: Kuyavia-Pomerania, Lubusz and Silesia.

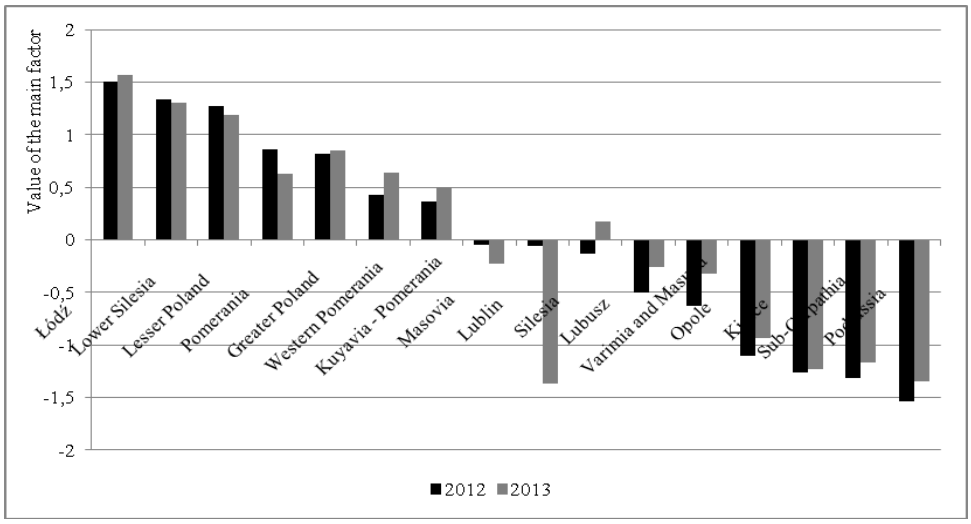


Fig. 2. Arrangement of voivodships according to the values of the factor "tram transport lines, inventory, use, operating and capacity of tram stock"

The voivodships leading in both years in terms of the tram infrastructure were: Łódź, Lower Silesia and Pomerania. The worst developed voivodships in respect of this determinant in 2012 were: Kielce, Sub-Carpathia and Podlassia, in 2013: Kielce, Podlassia and Lublin. The ranking of voivodships, especially those with the lowest development level of tram transport lines, inventory, use, operating and capacity of tram stock changed in 2013 in comparison to 2012.

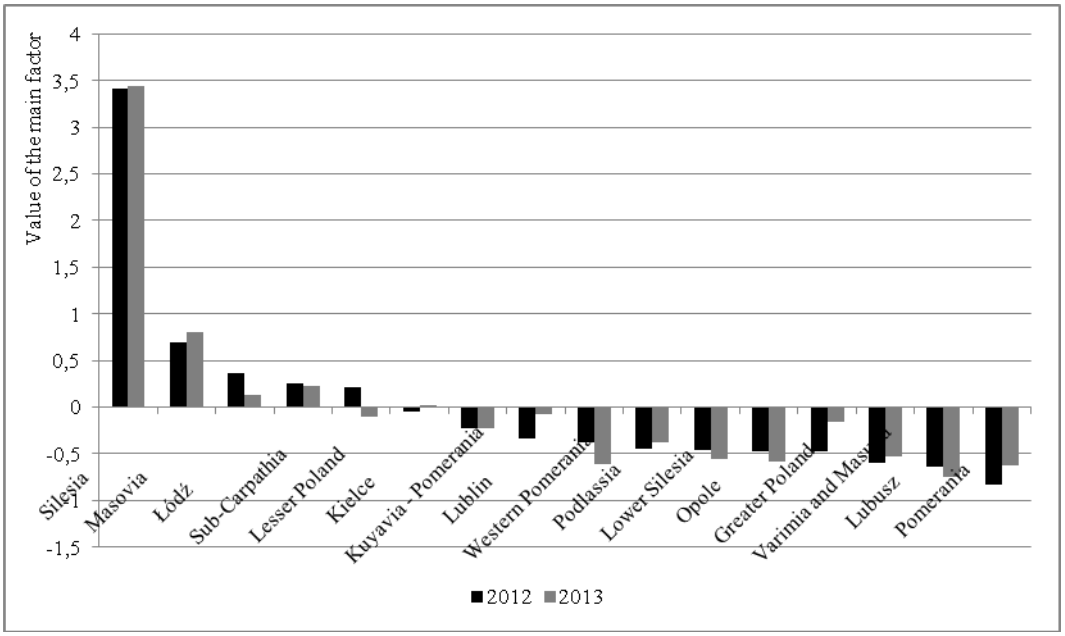


Fig. 3. Arrangement of voivodships according to the values of the factor "bus transport lines, inventory, use, operating and capacity of bus stock"

High values of the bus transport lines, inventory, use, operating and capacity of bus stock factor were observed in both examined years in the voivodships of Silesia, Masovia and Łódź. The Voivodship of Silesia leads in terms of the condition and use of bus stock. The factor value here is much higher than in the Mazovia Voivodship which comes second in this respect. The lowest level of development in

bus transport lines, inventory, use, operating and capacity of bus stock characterizes the following voivodships: Varimia and Masuria, Lubusz and Pomerania in the year 2012 and Opole, Western Pomerania, Pomerania and Lubusz in the year 2013.

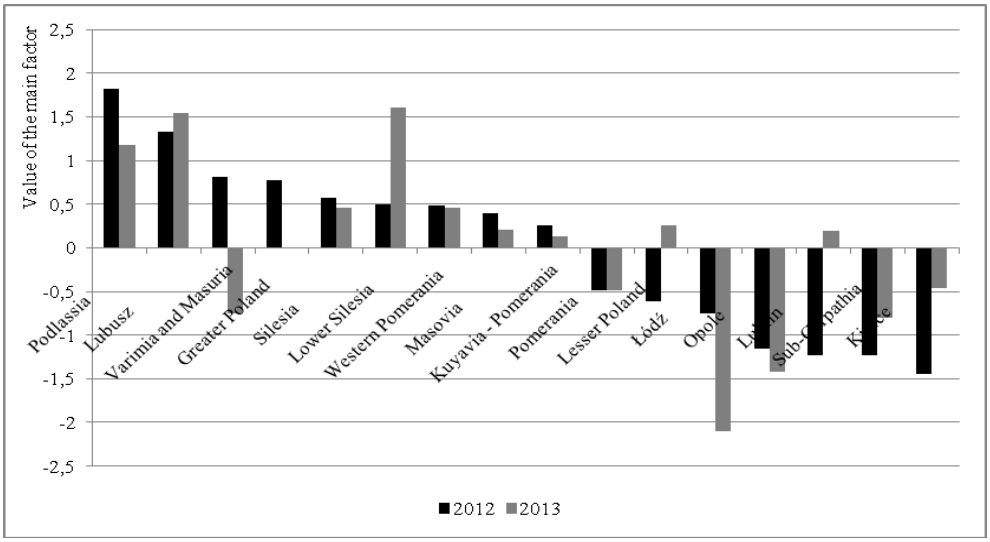


Fig. 4. Arrangement of voivodships according to the values of the factor "share of buses vehicles in traffic"

Regarding the share of bus vehicles in traffic the following voivodships dominte: Podlassia, Lubusz and Varmia and Masuria in 2012 and Lower Silesia, Lubusz and Podlassia in 2013. The lowest in the ranking in terms of this determinant are the voivodships: Lublin, Sub-Carpathia and Kielce in the year 2012 and Sub-Carpathia, Opole and Łódź in 2013.

CONCLUSIONS

In the field of the urban transport, there is a search for solutions embracing all three pillars of sustainable development. One suggestion here is the public transport form of DRT (Demand Responsive Transport) understood as an indirect form of public transport accessible for the general public. Transportation is realized using small low-floor buses and taxis which realize highly personalized transport services (Ryley et al., 2014; Wang et al., 2014). Another crucial element is the integration of urban transport in terms of available transport means and the process of passenger transport planning within the city boundaries. The maximization of the number of passengers is often the primary, although not sole, aim of urban public transit network optimization (Klier & Haase, 2015).

The development of urban transport in Poland is mainly connected with activities concerning: (1) changes in transport lines, (2) the condition, use and exploitation of stock, (3) urban transport stock adjusted to carrying the disabled, (4) stock capacity and the number of passengers carried. The main types of urban communication in Poland are tram and bus transport. Underground and trolleybus transport make only a fraction of the urban transport in Poland which is why the article does not concentrates on them. The level of urban transport saturation in Poland depends on the region, and especially on a given voivodship. The factor analysis distinguished four types of factors identified by variables corresponding to the four basic groups of activities oriented on urban transport:

1. urban transport stock adjusted to carrying the disabled persons and number of transported passengers,
2. tram transport lines, inventory, use, operating and capacity of tram stock,

3. bus transport lines, inventory, use, operating and capacity of bus stock,
4. share of buses vehicles in traffic.

Considering the four factors, the analysis results for the years 2012 and 2013 are convergent, although they explain a different level of the total variance in individual years. The analysis of the voivodships saturation with the distinguished factors allowed for the statement that in both examined years the same voivodships dominated in terms of specific determinants of urban transport development, and differences appeared only in voivodships ranked on last positions. But most voivodships were characterized by a similar level of the principal factor in both years, which can be indicative of the continuation of the policy concerning urban transport development in individual Polish voivodships. Distinguishing the principal factors and the analysis of the changes in the factors saturation in voivodships can be a tool enabling a proper planning of urban transport on a regional scale because factor analysis allows to not only confirm the existence and the nature of the general regularities influencing the relationships between the variables characterizing urban transport, but also to find the weights determining the significance that should be attached to individual factors and variables in further research.

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