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Taxonomic and econometric analysis of road transport development in Poland – the voivodship approach

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ABSTRACT
Transport is considered one of the basic aspects of the movement of people, raw materials as well as goods from the place of origin to the destination. Moreover, in the wider sense, transport includes economic bodies that aim to achieve goals similar to those of businesses that produce a wide range of goods required by customers. Hence, the efficient operations of basic branches of the transportation system determine the entire national economy. Furthermore, transport is considered a basic factor of development, both on the macro- and microeconomic scales.
The aim of the paper is to attempt the assessment of the road transport in Poland as an important element of macro logistics. Furthermore, one of the aims of the investigation was the explanation of its influence on the level of economic development in Poland.
As the source of information, the research used the data drawn from the Central Statistical Office of Poland. The main methods implemented in this study were both classic and order synthetic measure construction. Further, these measures were used in econometric models as well as for the prediction of their values.
The main result of the analysis indicates that the development level of the widely considered infrastructure is strictly correlated with the socio-economic development of particular voivodships.
The study on the level of road transport development can lead to a better understanding of the socio-economic development of particular areas of Poland as well as the more efficient use of the support funds.

KEY WORDS
road transport, synthetic measure, econometric model, prediction

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Introduction

As a result of the accession of Poland to the European Union, Polish transportation policy must take into account the strategic aims of the EU in relation to transport. Transport is considered fundamental to the economy and society as mobility is especially important for the internal market and in the quality of life. Moreover, transport significantly affects the economic growth and job creation (White Paper, 2011).

In addition, there are relatively underdeveloped regions in the majority of the European Union countries. In this case, modern transportation infrastructure is created as one of the crucial elements of regional policy (Paprocki, 2013). Hence, in order to overcome differences in the development level, cohesion, and regional policies are implemented. Furthermore, financial tools have been developed in the form of support funds, including structural and cohesion ones (Witkowska, 2009).

Nevertheless, the financial resources received in the form of own funds and the funds of the European Union are limited. Therefore, the most important issue is to make a proper assessment of the current and future condition of the transportation system, which ought to have a positive influence on the use of the support funds. It should be emphasized that this goal is very complicated, and the difficulties are compounded by the fact that the transportation system is sophisticated, and its users are diversified. Moreover, there are different interrelations between public authorities and its users (Liberadzki, 2013). The road transport is considered a special area and one of the most important issues of the Polish transportation system on the national and regional level. Thus, this branch of transport is the object of the research.

The aim of the study is to investigate the development level of road transport in Poland and to identify underdeveloped regions in the research field. Also, the article aims to forecast the development level of this transportation branch in particular voivodships.

1. Literature review

The transportation system as a part of the logistics area is considered a complex as well as a multidimensional phenomenon. Hence, the research in this field can be done using two different approaches.

The first approach is referred to as one-dimensional or a classical. The level of transport development is specified with the use of factors in the form of separate and particular variables. Generally, this kind of approach brings many difficulties in the clear-cut assessment of analysed research objects.

The literature review covered many scientific papers that deal with transport as a system and its particular branches in different countries or regions and introduced support policy.

In the case of Poland, the development level of the transport infrastructure as well as its adaptation to the European Union standards has already been presented (Wojewódzka-Król, 2015). In this paper, the author indicates that the road transport is a branch where the most noticeable effects of infrastructure are observed. Moreover, all types of transport may generate the external effects such as congestion, accidents, air pollution, noise, impact on climate change, etc. (Gratiela, 2013b). Nowadays, in order to alleviate all negative effects, investment in infrastructure is considered as part of planning policy (Marshal, 2012) or achieving the aims of sustainable transport (Gratiela & Viorela-Georgiana, 2013a) or sustainable consumption in this area (Gratiela, 2013a). Going further, the analysis of the Trans-European Network programme as well as its reforms and implications for spatial planning has been performed (Marshal, 2014). On the whole, the most important objectives were specified by the European Union institutions in the document Europe 2020 (Europe 2020, 2010). The implementation of all of the proposed improvements and programmes are impossible without the proper financial policy of European Union. Consequently, the area of transport and energy network has the funding of EUR 59 billion (Gratiela, 2014).

On the other hand, particular branches of the transportation system are considered sophisticated areas, which generate many external effects (Mężyk, 2014; Chruzik & Sitarz, 2014; Brach, 2014). However, the phenomena of transport and its scope play a significant role in the multifunctional development strategy for regions, especially the cross-border ones (Lewczuk & Ustinovichius, 2015).

The latter approach to transport analysis is considered the multidimensional data research. Implementation of taxonomic methods make it possible to support the logistic policy of the state by the specification of rules as well as procedures in the multidimensional ordering and classification process. Thus, it creates the possibility to work out a more cohesive and effective structure of information relationships. Moreover, it also makes it possible to increase the existing knowledge in this area, which provides tools for improvement as well as the way of conclusion construction. All in all, it is reflected in decision-making processes in the area of the state logistics policy (Figura, 2013, p. 159).

On the one hand, the empirical assessment with the implementation of taxonomic methods in Polish voivodships was implemented by Cheba (2011). On the other hand, multidimensional methods were introduced into the empirical assessment of transport development in the European Union countries (Tarka, 2012; Kauf & Tłuczuk, 2014). Generally, the analyses were based on no-pattern development methods of linear ordering. All analyses of the transportation development use classical statistical measures such as the arithmetic mean and the standard deviation. The study of the literature proved that these measures were implemented even in the case of strong distribution skewness of particular variables (Cheba, 2011). Moreover, the author presents the approach to prediction of road transport development. However, only the classical synthetic measure was implemented in the process of construction of econometric models.

Apart from the presented ways of analysis and predictions in the transport area, there are other applicable future-oriented methods. For example, the foresight is one of those methods, which applies to the entire transportation system (Ejdys et al., 2015).

To sum up, there is a lack of taxonomic analysis in the literature, which takes into account the sophisticated character of the transportation system and mutual interactions among its particular elements. It should be emphasized that the research gap is also connected with econometric predictions of the road transport development, which are based on the construction of the order synthetic measure. Hence, this kin of a synthetic measure construction could have some influence on the correctness of taxonomic analysis and prediction process.

2. Research methods and selection of the data set

The literature study, both in the area of taxonomy and the type of implemented statistical measure, shows that there are two basic ways of synthetic measure construction depending on of implemented statistical measure. The former introduces the arithmetic mean and the standard deviation as the basis for the implemented algorithms (Hellwig, 1968). Thus, the normalization process of particular variables in their classical form, which is standardization, is expressed as follows:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (1)$$

The latter attitude to synthetic measure construction replaces classical statistical measurers with order ones. This kind of taxonomic analysis was first implemented in the research by Poznań statisticians (Lira et al., 2002). Hence, the order version of standardization takes the following form:

$$z_{ij} = \frac{x_j - \theta_j}{1{,}4826 * mad(X_j)} \quad (2)$$

where Θ_j is considered particular values of the multidimensional median vector, that is border median or Weber one, while the mad (median absolute deviation) of particular variables is expressed by the equation:

$$mad(X_j) = \underset{i=1,2,\ldots,n}{med} \left| x_j - \theta_j \right| \quad (3)$$

The implementation of Weber median, the history and construction of which is presented in literature (Młodak, 2009), allows taking into account interactions in the set of diagnostic variables. It should be emphasized that there are other forms of multidimensional median vector construction in the literature (Domański et al., 1998). Those methods take into account interactions in the set of diagnostic variables as well. Furthermore, there are other ways of the normalization process, i.e. the unitarization or ratio transformation, which has already been used in research (Dębkowska & Jarocka, 2013; Czech, 2014).

Further, the synthetic measure in its classical form is constructed according to the formulas:

$$MK_i = 1 - \frac{d_i}{\overline{D} + 2 * S_D} \quad (4)$$

where: D is the mean of distance vector, and
S_D is the standard deviation of the distance vector.

In the case of order form, the synthetic measure is constructed with the following formulas:

$$MP_i = 1 - \frac{d_i}{med(D) + 2{,}5 mad(D)} \quad (5)$$

where: *med(D)* is the median of distance vector,
mad(D) is the median absolute deviation of distance vector.

Furthermore, both synthetic measures can be implemented in the process of prediction of its future value. Going further, they are perceived as an endogenous variable in the econometric models. This kind of forecast construction is referred to as synthetic prediction in the literature (Zeliaś, 1991). On the one hand, the constructed model of the development trend in its classical version takes the following form:

$$MK_i = f(t, \varepsilon) \quad (6)$$

On the other hand, the presented method of prediction can be modified by replacing the endogenous variable in the classical form with the order one. Hence, the implementation of the order version of the synthetic measure construction leads to the econometric model expressed by the formulla:

$$MP_i = f(t,\varepsilon) \quad (7)$$

Every proper taxonomic analysis needs a set of diagnostic variables. Hence, the research is based on the data drawn from the Local Data Bank of the Polish Cent ral Statistical Office and relates to 2008-2014. It has been noticed, that the collected data is included in three mutual interrelated areas, which are presented in Fig. 1.

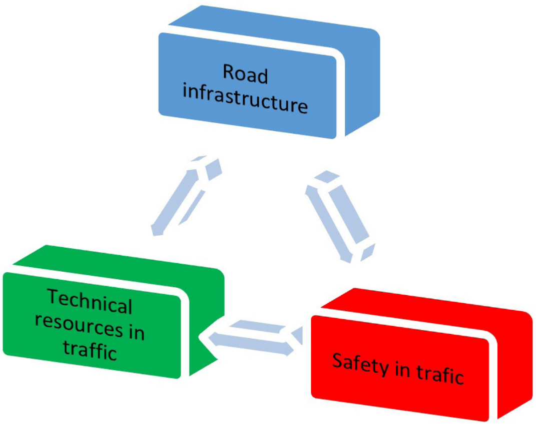


Fig 1. Relationships among particular areas in road transport

The first of the indicated areas in road transport is connected with road infrastructure and has been described by the following features: X_1 – hard surface roads per 100 km², X_2 – hard surface urban roads per 100 km², X_3 – the length of hard surface rural roads per 100 km², X_4 – the road of improved hard surface per 100 km², X_5 – urban roads of improved hard surface per 100 km², X_6 – rural roads of improved hard surface per 100 km², X_7 – expressways and motorways per 100 km², X_8 – state hard surface roads per 100 km², X_9 – the share of municipal and powiat roads in all roads (in %), X_{10} – the number of bridges and viaducts per 100 km², X_{11} – the number of tunnels and underpasses per 1000 km², X_{12} – the number of ferries per 10 000 km².

The second area is connected with technical resources used in traffic and includes the following variables: X_{13} – the number of passenger cars per 1000 citizens, X_{14} – the number of lorries per 1000 citizens, X_{15} – the number of motorbikes per 1000 citizens.

The third area presents the safety in road traffic and is followed by the variables: X_{16} – road accidents per 100 000 citizens, X_{17} – the number of casualties per 100 000 vehicles, X_{18} – the number of casualties per 100 000 citizens, X_{19} – the number of injured per 100 000 vehicles.

The potential set of diagnostic variables was investigated because of the variation and correlation analysis. Hence, the classical variation coefficient based on the arithmetic mean and the standard deviation was implemented as well as its order form. The latter, in its construction, uses the multidimensional median vector and the median absolute deviation (Młodak, 2006). The carried out analysis proves that in the majority of variables, the values of all three kinds of variation coefficients exceed the threshold value of 10%. All in all, the acceptations of the rules of that variation analysis were presented by variables X_{13} and X_{14}. The chosen statistical measures are presented in Table 1.

Making the analysis of the presented data in the table, it was observed that the variable X_{13} should be rejected. It was recognized that this variable significantly differs depending on the level of road transport development. In the scope of the variation analysis, the variable X_{14} appeared suspicious. The classical variation coefficient achieved high values because of strong skewness of empirical distribution

Tab. 1. Statistical measures of chosen diagnostic variables

Variable	Statistical Measure	2008	2009	2010	2011	2012	2013	2014
X_{13}	A_S	0.75	0.59	0.48	0.40	0.32	0.24	0.75
	V_S	8.84	7.97	7.95	7.85	7.86	7.85	8.84
	V_B	6.42	5.01	5.12	5.20	4.97	4.86	5.03
	V_W	9.97	5.01	4.92	5.16	4.97	5.22	5.50
X_{14}	A_S	1.40	1.27	1.37	1.29	1.27	1.17	1.40
	V_S	16.28	15.20	15.22	14.81	14.54	14.23	16.28
	V_B	8.21	8.67	8.79	8.64	8.95	8.42	7.98
	V_W	11.46	10.50	10.15	10.61	8.62	8.67	9.74

Explanations: A_S – skewness, V_S – the classic variation coefficient, V_B – the order variation coefficient with the border median, V_W – the order variation coefficient with the Weber median.

Tab. 2. Chosen statistical measures of the final set of diagnostic variables

Variable	Statistical Measure	2008	2009	2010	2011	2012	2013	2014
X_4	arithmetic mean	78.26	81.23	82.69	85.27	85.36	86.19	87.63
	border median	76.35	78.80	80.40	81.70	82.55	83.35	84.60
	Weber median	75.70	76.19	78.24	80.95	80.96	82.49	84.19
X_{12}	arithmetic mean	3.00	2.96	2.16	2.03	2.12	2.11	1.46
	border median	2.22	1.93	1.38	0.95	1.28	1.03	1.09
	Weber median	3.13	3.10	2.19	1.56	2.23	2.06	1.32
X_{14}	arithmetic mean	68.37	70.79	74.69	78.56	79.84	81.71	84.29
	border median	65.20	68.05	71.70	75.20	76.55	78.35	80.85
	Weber median	67.43	69.89	73.85	78.19	79.50	81.57	84.16
X_{15}	arithmetic mean	24.89	26.57	27.26	28.69	29.69	30.90	31.86
	border median	25.40	27.10	27.90	29.30	30.30	31.50	32.40
	Weber median	24.94	26.80	27.35	28.99	30.40	30.80	31.67
X_{16}	arithmetic mean	124.84	113.32	98.76	101.26	94.30	91.44	89.09
	border median	119.65	108.90	89.15	98.05	84.80	86.75	82.45
	Weber median	118.32	107.19	92.04	97.81	90.64	88.19	84.67

in particular years under investigation. On the other hand, the order form of variation coefficients with the border median caused a decrease in its value. Therefore, this situation excludes these variables from the further analysis. Nevertheless,the implementation of the multidimensional Weber median meant that the order variation coefficients increased significantly because of mutual interactions in the set of diagnostic variables. Moreover, the values increased by more than 10%. Therefore, this variable was included in the further taxonomic analysis.

Further, the potential set of diagnostic variables was put under the correlation analysis in order to eliminate variables that carry the same information. Hence, the parametric Hellwig's method based on the matrix of the Pearson correlation coefficients was introduced (Panek, 2009). The result of the analysis is the set of central, satellite and isolated variables. The satellite variables were excluded from the taxonomic analysis because they carry the same information.

To sum up, the final set of diagnostic variables includes both central features (X_4, X_{14}, X_{16}) as well as the isolated ones (X_{12}, X_{15}). Furthermore, all road transport areas which are presented in Fig. 1 have been taken into consideration.

3. Research results

Before the final set of diagnostic variables was used in the synthetic measure construction, it had been put through the normalization process. Additionally, these transformations were implemented with the use of both classical and order types of location measures as the dispersion ones. The former case was based on the arithmetic mean and the standard deviation. The latter introduces the equivalent of classical measures such as the Weber median and the median absolute deviation. All normalized formulas took the form of standardization and are considered a linear transformation. It should be emphasized that there are other forms of the normalization as unitization and ratio transformation, which were introduced, for example, to the research of regions innovation (Olszewska & Gudanowska, 2014) or indirect consumption analysis (Czech, 2014).

The chosen statistical measures, i.e. the arithmetic mean, the border median and the Weber median are presented in Table 2.

The data presented in the table shows that there are differences between the border and the Weber median values. It is caused by the fact that in the latter case, the mutual and indirectly observable relationships are taken into account. Hence, the Weber median takes both smaller and bigger values as compared to the border median.

In the scope of dealing with the road transport assessment with the implementation of mutual interaction in this area of the transportation system, it was crucial to make the empirical analysis resistant to the distribution skewness of particular variables. Both properties, interactions and skewness are taken

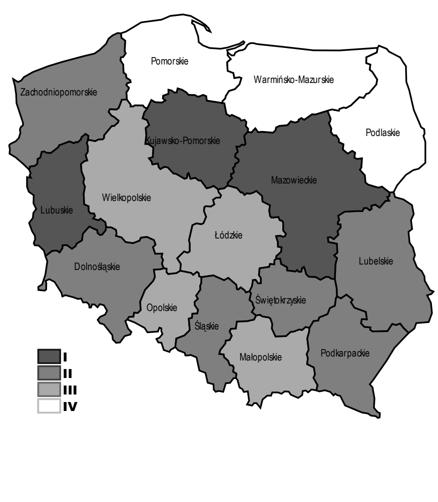
Tab. 3. Positions of voivodships in the ranking

Voivodship	2008		2009		2010		2011		2012		2013		2014	
	MK	*MP*	*MK*	*MP*	*MK*	*MP*	*MK*	*MP*	*MK*	*MP*	*MK*	*MP*	*MK*	*MP*
Dolnośląskie	8	7	8	7	9	10	12	9	14	14	14	13	13	13
Kujawsko-Pomorskie	2	5	2	2	3	3	3	3	3	3	1	2	2	2
Lubelskie	9	11	6	10	7	7	7	7	5	7	5	5	6	7
Lubuskie	3	8	5	8	6	8	6	8	7	9	7	8	8	9
Łódzkie	12	9	13	13	12	13	10	10	13	13	9	10	10	11
Małopolskie	10	3	11	6	13	9	8	6	11	8	11	9	12	12
Mazowieckie	1	2	1	1	2	2	2	2	1	1	2	1	4	3
Opolskie	13	13	12	12	11	11	13	13	12	11	13	11	11	10
Podkarpackie	5	6	4	5	5	6	5	5	6	6	6	7	3	4
Podlaskie	15	15	15	15	15	14	11	12	10	12	10	12	9	8
Pomorskie	14	14	14	14	14	15	15	15	15	15	15	15	15	15
Śląskie	6	1	7	3	8	4	16	16	8	5	8	6	7	6
Świętokrzyskie	4	4	3	4	4	5	4	4	4	4	4	4	5	5
Warmińsko-Mazurskie	16	16	16	16	16	16	14	14	16	16	16	16	16	16
Wielkopolskie	11	10	9	9	1	1	1	1	2	2	3	3	1	1
Zachodniopomorskie	7	12	10	11	10	12	9	11	9	10	12	14	14	14

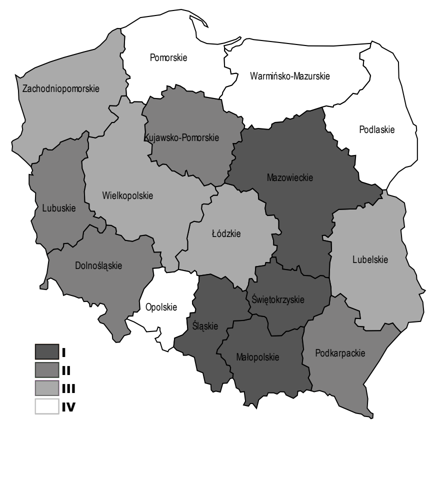
Explanations: *MK* – the classical measure, *MP* – the order measure.

into account in the Weber case, while only the former one is presented by the border median. Furthermore, the synthetic measure construction with the border median was omitted in the research. The implementation of the presented linear ordering algorithms in both cases allowed for synthetic measure construction of the road transport development. Moreover, their monotonic order allowed for ranking the construction in both classical and order forms of the taxonomic measure. The results of this analysis are presented in Table 3.

These methods can be implemented in the process of indicating the areas of similar road transport development. An example of this kind of classification



MK



MP

Fig. 2. Spatial diversification of road development level in Poland in 2008

Explanations: MK – classical measure, MP – order measure

Tab. 4. Prediction of spatial diversification of road transport development in 2015

Voivodship	Classical method		Order method	
	Measure	Rank	Measure	Rank
Dolnośląskie	0.113	14	0.166	11
Kujawsko-Pomorskie	0.494	2	0.485	2
Lubelskie	0.376	6	0.359	6
Lubuskie	0.278	8	0.254	8
Łódzkie	0.234	9	0.156	12
Małopolskie	0.194	12	0.236	10
Mazowieckie	0.424	3	0.459	3
Opolskie	0.229	10	0.154	13
Podkarpackie	0.406	5	0.389	5
Podlaskie	0.307	7	0.256	7
Pomorskie	0.102	15	0.068	15
Śląskie	0.218	11	0.240	9
Świętokrzyskie	0.422	4	0.402	4
Warmińsko-Mazurskie	0.049	16	0.005	16
Wielkopolskie	0.696	1	0.663	1
Zachodniopomorskie	0.192	13	0.142	14

with the use of three mean and three median method (Młodak, 2006) is presented in Figure 2.

Further, the constructed synthetic measures provide the possibility of prediction of future values. Thus, the predicted measures, with the implementation of both taxonomic approaches are presented in Table 4.

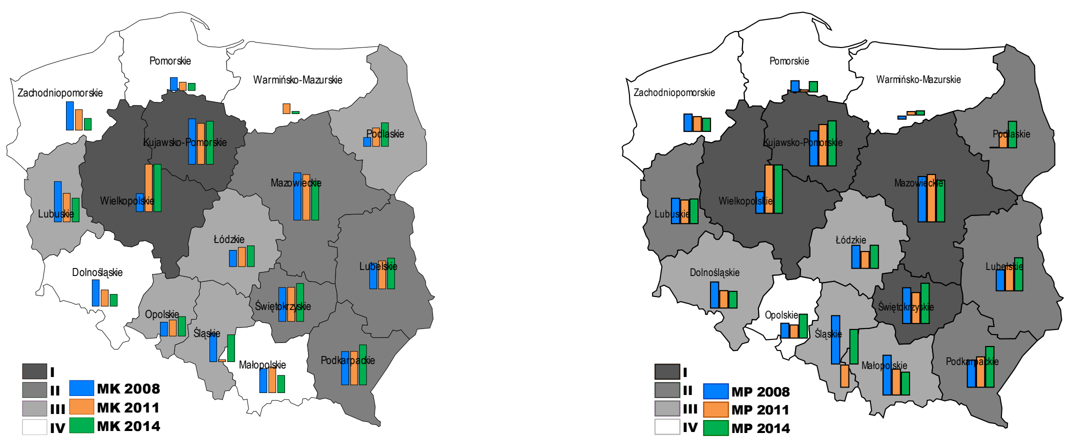
The colours of particular voivodships in Figure 3 presents the prediction of their position in the ranking.

It should be emphasized, that the height of bars in the figures represents the values of synthetic measures in the three chosen years.

It should be noted that the constructed predictions are short-term and do not take into account the effect of the technological progress. On the one hand, the presented approach seems to be pragmatic. On the other hand, this factor should be included in the case of long-term predictions. These important factors are reflected in the production of bituminous surfaces, which have an important impact on the quality of constructed road infrastructure. Furthermore, this kind of analysis has been carried out with the implementation of foresight methodology (Radziszewski et al., 2014).

4. Discussion of the results

The analysis of the road transportation development in Poland in particular voivodships



MK

MP

Fig. 2. Prediction of the spatial diversification of road transport development

Explanations: background of a voivodship – the prediction in 2015, MK – the classical measure, MP – the order measure.

leads to some interesting findings in two main areas, i.e. logistics and statistics.

The former is strictly connected with the spatial objects included in the research. The analysis has been carried out between 2008 and 2014, as there is no data for 2015. Hence, the assessment of spatial transport development level in 2015 was predicted with the use of econometric models based on data time-series.

During the analysis of the ranking of particular voivodships between 2008 and 2014, it has been noticed that Mazowieckie and Wielkopolskie voivodships enjoy the best transport conditions. Moreover, this conclusion is true for both the classical synthetic measure and the order one.

In the scope of the conducted analysis, there is only one voivodship, where the beneficial trend of the road transportation development is observed. Between 2008 and 2013, Podlaskie voivodship was between the eleventh and fifteenth positions. Later, in 2014, it moved up to the eighth position. Moreover, the prediction for 2015 ranked this area seventh out of sixteen voivodships.

In the case of Podlasie voivodship, the observed situation in the area of road transport indicates that the unfavourable circumstances of the development have been reversed. Furthermore, the similar conclusion of this phenomenon can relate to Wielkoposkie voievodship.

The latter group of findings reflects the statistical observations in the area of implemented taxonomic as well as econometric methods.

The research was determined by the availability of data, which was drawn from the Central Statistical Office of Poland. It has been noticed that the expansion of the potential set of diagnostic variables resulted in the limitation of the analysis period.

Moreover, the potential set of nineteen diagnostic variables was strongly limited mainly at the stage of the correlation analysis. The statistical variation analysis shows that the variable connected with owning a passenger car differentiates research objects poorly. Hence, it has been concluded that this kind of the market is getting saturated, and the existing differences are levelling.

Furthermore, the research results show that such strong limitation of the potential set of diagnostic variables determines the use of the Weber median. The implementation of this kind of location measure allows to take into account the additional indirectly observed information. These relationships are called interactions and occur among specified variables implemented in the description process of three defined areas of road transport as one of the logistic phenomena.

Moreover, despite the road transport being a multidimensional phenomenon, there is a lack of spatial analysis that considers interactions.

Conclusions

The results obtained in this research show that there is an interdependence in the area of socio-economic development in particular voivodships and the level of their road development. The higher are the economic parameters of the related position of a voivodship in the ranking, the higher is the level of road transport development. This phenomenon is strictly connected with the regions such as Wilkopolskie, Mazowieckie and Kujawsko-Pomorskie. The research objects such as Podlaskie and Warmińsko-Mazurskie are perceived as outsiders in the constructed classification.

The analysis proves that the road network has a significant impact on the development of different logistic enterprises. Hence, the logistic centres, which fundamentally depend on the existing transport branches will be located in the areas with a relatively beneficial economic infrastructure and transport conditions. Furthermore, these factors determine effectively the efficiency of those logistic enterprises.

To sum up, these observations relate to the Polish regions that have a high ranking in the research carried out in the paper.

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