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Multidimensional assessment of the European Union transport development in the light of implemented normalization methods

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ABSTRACT

Transport is considered a basis for socio-economic development. It is closely connected with the process of movement of products and humans. The main aim of the paper is to investigate the influence of different order normalization methods in the synthetic measure construction implemented in the assessment of the development of European Union member states in the area of logistic, especially transportation system. Moreover, the article attempts to investigate the influence of such methods on linear ordering in multi-criteria taxonomic approach.

The source of information in the research is the data drawn from Eurostat, the statistical office of the European Union. The main method in this study is the order synthetic measure constructed with Weber median in different forms due to implemented normalization methods.

The main result of the carried out analysis indicated that the development level of three main branches of a transportation system correlates with the socio-economic development of particular member states. Furthermore, the assessment process based on the synthetic measure construction can lead to differences in linear ordering due to the implemented normalization methods. The research on the transport development can bring a better understanding of the socio-economic development of particular areas of the European Union. Hence, the results can be helpful to European policy makers for the allocation of support funds.

KEY WORDS

transport, European Union member states, synthetic measure, normalization

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Introduction

As a European Union member state, Poland is a part of the structural policy. The main imperative of its activity is to increase the state, regional and local cohesion. It is caused by the fact that excessive spatial disproportions are considered a factor of negative external effects for the whole European Union. Moreover, it becomes much more important in the face of globalization effects because the world economy has changed significantly and globalization needs new logistic dynamics (Kherbash & Mocan, 2015). Hence, transport plays an important role in the management process of logistics and has already been considered one of the cornerstones of the globalization process (Kumar & Hoffmann, 2002).

The economic growth and foreign trade determine the level and structure of transportation demand (Proniewski et al., 2005). Going further, the Gross Domestic Product, consumption level, the structure of household expenditures, technology innovations, fuel prices and other phenomena are considered factors of transportation demand. On the other hand, transport influences the economic growth and job creation (White Paper, 2011), which results in the demand for many products and services. The relationships in the area of transport and their links with economy and society are mutual and very hard to quantify. Thus, transport is considered as a complex phenomenon where different and directly unobservable interactions play a key role. Hence, the studies in that area are especially sophisticated and require special tools. Taxonomy brings many opportunities to improve the assessment process that ought to have a positive impact on the transportation policy. Nevertheless, multidimensional statistical analysis, such as linear ordering, is ballasted with arbitrary aspects. The properly constructed synthetic measure depends on the data set selection, normalization methods, distance measure, statistical measures, etc.

The aim of the paper is to investigate the influence of order normalization methods in the synthetic measure construction implemented in the assessment process of transportation development in chosen European Union member states. Moreover, the article aims to investigate the influence of such methods on linear ordering in multi-criteria taxonomic approach to compare and improve the previous research in that area.

1. Literature review

The literature review showed that transport as a logistic branch is in the spotlight of different scientific fields and the analyses are carried out with many research tools. However, transport plays a key role in the process of reducing regional and social disparities in the European Union by strengthening economic and social cohesion (López et al., 2008).

On the one hand, transport is analysed because of its impact in the form of external effects on the environment and sustainable consumption (Gratiela & Viorela-Georgiana, 2013; Gratiela, 2013a, 2013b). Going further, the process of adaptation of the Polish transport system to the requirements of the European Union includes consideration of congestion, air pollution, impact on the environment, etc. (Wojewódzka-Król, 2015).

Moreover, transport disadvantages are strictly correlated with social exclusion and well-being (Currie et al., 2010). Transport plays an important role in the strategy development for cross-border regions (Lewczuk & Ustinovichius, 2015). Furthermore, a transportation system has already been analysed with future-oriented methods like foresight (Ejdys et al., 2015). In addition, the same research technique has been used by an interdisciplinary research team in the process of the prediction of the development of future-oriented road technologies in the context of environmental protection (Radziszewski et al., 2016).

Infrastructure adaptation is considered the most important thing in the achievement of social and economic goals, which have to improve the competitiveness of Europe and its regions. This phenomenon is very complex because of technical, economic, and environmental barriers and limitations. Hence, multi-criteria methods play a more significant role in the decision-making process in the development and modernization of transport infrastructure (Pawłowska & Koźlak, 2014).

As one of the research fields of logistics, transport causes many difficulties because of its multidimensional and multi-criteria character. This sophisticated feature disables the clear-cut evaluation process of research objects. Taxonomy can be considered a solution because the implementation of these methods simplifies the assessment process of research objects described by many variables and creates a possibility for support in the logistics policy (Figura, 2013). The author argues that it can be performed by implementing the ordering and classification procedures.

As a result of literature research in the area of taxonomy, two main approaches emerged in the synthetic measure construction in the field of ordering methods due to implemented statistical measures.

One of them is known as a classical approach and uses arithmetic mean and standard deviation in its construction. It was introduced presented by Hellwig and implemented into the research in different fields (Hellwig, 1968). In the scope of transport development, empirical assessment has already been performed in relation to roads and voivodships (Cheba, 2011). Furthermore, the taxonomic development level has already been introduced into transport research in the context of sustainable development, where particular synthetic measures were constructed in the areas of four orders, that is environmental, social, economic, and transport investment (Przybydłowski, 2014).

On the other hand, international evaluation of the European Union transport development was presented as well (Tarka, 2012; Kauf & Tłuczuk, 2014). Most of the evaluations are mainly based on non-pattern methods of the synthetic measure construction and classical statistical measures like arithmetic mean and standard deviation.

The other attitude is called the order and implements the multidimensional median vector and *mad* (the median absolute deviation), (Lira et al., 2002). It was implemented for the first time in the area of logistics for the assessment of road transport development in voivodships (Czech & Lewczuk, 2016a). The further analyses are connected with three main modes of the European Union transport, i.e. roads, railways and air (Czech & Lewczuk, 2016b). Both analyses use the multidimensional Weber median account for interactions in the set of diagnostic variables and among three means of transport. It is worth mentioning that the issue of including indirect impacts is very important for transport, for example in the project appraisal (Ward et al., 2016; Hayashi & Morisugi, 2000). Moreover, this issue is widely discussed among experts, and a consensus has not yet been reached (Vörös et al., 2015).

The review of literature proved that available taxonomic analyses of transport development are usually based on normalization in the shape of standardization. Also, there are other linear transformations, such as unitraization or ratio transformation (Jajuga & Walesiak, 2000; Walesiak, 2011; Dębkowska & Jarocka, 2013). Nevertheless, the research is mainly based on the classical normalization methods.

In the light of literature review findings, the order version of normalization can be implemented not only in the form of standardization but as unitarization and ratio transformation (Młodak, 2006). The Weber median transformation methods have already been introduced into indirect consumption research (Czech, 2014).

To sum up, there is a lack of taxonomic analysis with other normalization methods, besides standardization, which accounts for the sophisticated character of the transportation system and mutual interactions among its elements. It should be emphasized that the research gap is also connected with the multi-criteria taxonomic analysis, which is based on the order synthetic measure construction. Hence, the analysis of synthetic measure construction with the implementation of different normalization methods could have an influence on the correctness of taxonomic analysis in the field of logistic evaluation, especially in the area of transportation.

2. Theoretical basis of implemented research methods and the selection of the data set

The final set of diagnostic variables, which is implemented in the process of synthetic measure construction usually must be transformed to bring particular features into comparability. This process is called normalization and is implemented in the case of classification methods, multidimensional calibration or linear ordering. There are three main normalization methods, namely standardization, unitarization, and ratio transformation, which can be used in the construction process of different classical and order statistic measures. This situation may cause a problem in clear taxonomic assessment with the synthetic measure construction. Therefore, it would be helpful to investigate chosen normalization methods in the process of evaluation of the European Union transportation system.

In reality, transport is considered a complex phenomenon where mutual directly unobservable interactions have a crucial impact on the research field. That is why the wide range of normalization methods will be limited to those that implement the multidimensional Weber median.

Standardization, in its original order version, implements the median and *mad* (the median absolute deviation). It was first presented by a Poznań statistician, and the normalization process is expressed by the following formula (Lira et al., 2002):

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

where θ_j is considered the Weber median vector and *mad* (the median absolute deviation) is expressed:

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

The history of the Weber median and its construction is widely discussed in the literature (Młodak, 2009).

On the other hand, there are other versions of the normalization process. It is worth mentioning that all forms of transformations were proposed by Młodak (2006).

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Another form of order standardization uses only the median absolute deviation, and the transformation process is in accordance with the following formula:

$$z_{ij} = \frac{x_j}{mad(X_j)} \tag{3}$$

Unitization is considered as the next form of normalization. The basis for this transformation is a range of a variable, and the order version of it is expressed by the following formula:

$$z_{ij} = \frac{x_j - \theta_j}{R(X)} \tag{4}$$

where *R(X)* stands for the range of a variable that is the difference between the higher and smaller value in the distribution of a particular feature. Besides, the presented form of order unitarization, there are other untypical forms expressed by the two following formulas:

$$z_{ij} = \frac{x_j - \theta_j}{\max\left|x_j - \bar{x}\right|} \tag{5}$$

$$z_{ij} = \frac{x_j - \theta_j}{\max\left|x_j - \theta_j\right|} \tag{6}$$

The last form of normalization is known as ratio transformation where the order form is expressed by the equation:

$$z_{ij} = \frac{x_j}{\theta_j} \tag{7}$$

Furthermore, another form of this transformation, which introduces the multidimensional median vector is based on square values of diagnostic variables and expressed by the following:

$$z_{ij} = \frac{x_j}{\theta_j (x_j)^2} \tag{8}$$

All presented normalization methods are called linear transformations and the synthetic measures constructed on their basis can have different values. Hence, the position of the research objects in the ranking can differ as well.

The basis of synthetic measure construction is a set of diagnostic variables that describe three different areas of transportation, namely, roads, railways, and air. This approach resulted from the terminology accepted in the logistic literature. The data was drawn from the Eurostat database for 2012. The set of twenty-one potential diagnostic variables was treated as a basis of taxonomic analysis with the implementation of different normalization methods for the special assessment of the development level of the transportation system in different areas.

Roads as the first mode of transport is presented by the following variables: X_1 – length of motorways (km/100 km^2), X_2 – length of state roads (km/100 km^2), X_3 – number of motorcycles per 1000 citizens, X_4 – number of passenger cars per 1000 citizens, X_5 – number of lorries and road tractors per 1000 citizens, X_6 – goods transported by roads in 1 million tonne-kilometre per 1000 citizens, X_7 – number of killed in road accidents per 1 million citizens.

Railways as the second mode of transport includes the following features: X_8 – length of railway lines (km/100 km^2), X_9 – number of passengers per one citizen, X_{10} – number of passenger-kilometre per one citizen, X_{11} – goods transported by railways in tonnes per one citizen, X_{12} – railways-goods transported in 1 million tonne-kilometre per 1000 citizens, X_{13} – number of suicides connected with railways per 100 thousand citizens, X_{14} – number of killed per 1 million passengers, X_{15} – number of injured per 1 million passengers, X_{16} – number of railway accidents per 1 million citizens.

Air is the third mode of transport and includes the following variables: X_{17} – number of airports (with over 15000 passenger units per year) per 10 000 km^2, X_{18} – number of airline passengers per one citizen, X_{19} – number of commercial aircraft fleet per 1 million passengers, X_{20} – freight and mail transported by air in tonnes per 1000 citizens, X_{21} – number of killed in commercial air transport per 1 million passengers.

It is worth mentioning that all three branches of transportation include variables that are related to cargo transport changes in the country. Moreover, there are some facts about these modes of transport. On the one hand, road transport plays a key role in the cargo transportation. Nevertheless, the transport absorption is decreasing due to economic growth. On the other hand, the railway transport is not efficiently used, and inland waterways cannot compensate for cargo transportation by railways or roads (Strojny, 2013). It is worth emphasizing the fact that all modes of transport are complex and generate external effects (Chruzik & Sitarz, 2014).

Furthermore, the inland waterways transport is not greatly significant that is why it was omitted from the research. On the other hand, the pipeline transport is considered to be specific and significant for the economy. Nevertheless, it is very difficult to access interdependence with other branches of the transportation system.

Tab. 1. Chosen statistical measures of particular variables and values of the main diagonal of inverted Pearson correlation matrixes

Variable	Means of transport	Mean	M_B	M_W	A_S	S_x	Mad (W)	R	V_s	V_W	MDIM
X_1	Roads	1.37	1.12	1.38	0.85	1.17	0.90	3.79	85.18	65.20	2.11
X_2		15.22	9.51	12.51	0.65	12.05	7.73	34.87	79.17	61.80	1.93
X_3		33.11	21.03	34.89	1.46	29.91	19.94	104.72	90.36	57.16	1.87
X_4		453.28	464.77	447.34	-0.57	108.22	82.31	400.99	23.87	18.40	2.13
X_5		57.06	54.62	66.04	0.82	22.27	20.66	75.36	39.03	31.28	2.02
X_6		4.20	4.04	4.62	0.58	1.84	1.31	6.33	43.90	28.47	1.82
X_7		634.00	62.50	64.24	0.27	21.27	17.50	72.00	33.24	27.24	2.16
X_8	Railways	5.51	5.06	5.26	0.94	3.03	2.26	10.38	54.90	43.01	4.78
X_9		12.61	10.89	10.38	0.97	9.05	5.27	30.51	71.72	50.83	9.29
X_{10}		612.47	471.94	502.80	0.73	396.56	261.99	1304.65	64.75	52.11	6.83
X_{11}		8.16	5.39	6.97	1.88	9.57	5.07	33.63	117.22	72.69	5.16
X_{12}		1.88	1.32	1.62	2.82	2.53	1.04	10.67	134.50	64.02	4.51
X_{13}		0.63	0.44	0.54	1.81	0.51	0.24	2.02	81.17	44.73	2.98
X_{14}		0.78	0.24	0.71	2.34	1.13	0.64	4.47	145.22	90.08	4.80
X_{15}		0.60	0.39	0.54	1.27	0.70	0.50	2.28	116.43	91.67	6.62
X_{16}		7.57	7.73	7.59	0.28	5.44	4.31	17.76	71.91	56.84	3.41
X_{17}	Air	0.70	0.62	0.64	1.03	0.44	0.30	1.70	63.23	47.00	1.67
X_{18}		1.90	1.82	1.87	0.85	1.31	1.10	4.87	69.18	59.04	2.20
X_{19}		9.91	6.74	9.35	2.07	7.11	3.61	29.63	71.75	38.59	3.05
X_{20}		16.65	12.97	11.91	1.11	15.32	8.72	53.94	92.01	73.21	2.01
X_{21}		0.29	0.00	0.30	4.24	1.21	0.30	5.14	421.38	100.00	3.17

Notation: M_B – border median, M_W – Weber median, A_S – skewness, S_x – standard deviation, mad (W) – median absolute deviation (Weber Median), R – range, V_S – classical variation coefficient, V_W – order variation coefficient based on Weber median, MDIM – main diagonal of inverted Pearson correlation matrixes.

It is worth mentioning that the objective causes of railway disasters and railway accidents were the basis for treating this variable as a separate one. However, suicides are considered as a specific form of death, which results from personal decisions, and that is why this variable should not be combined with the number of killed.

All potential diagnostic variables were put under statistical investigation due to variation as well as correlation analysis. The chosen statistical measures of particular features are presented in Table 1.

The investigation of classical and order form of variation coefficients proved that all diagnostic variables have a strong differentiation, which results in their inclusion into the process of the synthetic measure construction.

In the scope of dealing with correlation analysis, three inverted matrixes of Pearson correlation coefficients have been constructed (Malina & Zeliaś, 1997). The values located on the main diagonal of particular inverted matrixes in three areas of the transportation system are presented in Table 1. The analysis of correlation measures proved that all potential variables could be taken for the further analysis.

To sum up, it should be mentioned that all three investigated areas are described by the features connected with infrastructure, equipment, people, and freight transport as well as safety. Moreover, there are mutual interactions among these three areas as well as in the whole set of diagnostic variables. Furthermore, some of the diagnostic features have strong skewness, which encourages to use order statistic measures instead of the classical ones. Hence, the process of synthetic measure construction of transport development should be based on normalization methods, which implement the multidimensional Weber median.

3. Research results

To bring the variables to comparability, seven presented normalization methods were introduced into the analysis in the form of standardization, unitarization, and ratio transformation. Additionally, these forms of transformation implemented the Weber median to take into account the sophisticated

Tab. 2. Positions of countries in the ranking according to different normalization methods

COUNTRY	ROADS							RAILWAYS						
	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)
Bulgaria	14	15	15	15	16	12	12	15	14	15	15	14	15	12
Czech Republic	12	13	13	13	13	15	17	8	16	14	13	13	13	18
Germany	5	3	4	4	4	2	2	3	6	6	5	5	5	11
Estonia	11	14	14	14	14	16	14	17	10	12	12	12	11	13
Ireland	13	9	9	8	9	9	9	13	9	9	9	9	9	2
Spain	9	2	1	1	1	3	3	9	8	8	8	8	8	4
France	7	5	5	5	5	6	6	1	4	3	1	2	4	6
Italy	1	12	10	10	10	11	16	5	5	5	4	4	6	3
Latvia	17	17	17	17	17	17	15	12	1	4	6	6	1	1
Lithuania	3	11	12	12	12	13	11	18	17	17	17	17	17	17
Hungary	16	16	16	16	15	14	13	6	13	13	14	15	14	16
Austria	4	6	6	6	6	4	5	2	2	1	3	3	2	9
Poland	8	7	8	9	8	8	8	10	12	11	11	11	12	8
Romania	18	18	18	18	18	18	18	16	18	18	18	18	18	15
Slovenia	6	1	2	2	2	1	1	14	11	10	10	10	10	10
Slovakia	15	10	11	11	11	10	10	11	15	16	16	16	16	14
Finland	2	4	3	3	3	5	4	7	7	7	7	7	7	7
United Kingdom	10	8	7	7	7	7	7	4	3	2	2	1	3	5
	AIR							TOTAL MEASURE						
Bulgaria	16	14	14	15	15	14	14	17	15	16	16	17	13	11
Czech Republic	15	12	13	13	12	13	13	13	14	14	13	13	14	18
Germany	1	3	3	3	4	2	1	1	1	2	2	2	3	3
Estonia	7	7	9	9	9	9	10	8	10	11	11	14	16	17
Ireland	4	1	1	1	1	1	2	6	4	4	4	9	15	7
Spain	11	9	5	5	5	7	7	10	5	6	6	1	2	2
France	6	5	6	6	6	6	5	5	6	5	5	4	4	10
Italy	10	13	12	12	13	12	12	7	9	8	8	8	8	6
Latvia	8	6	8	8	8	8	8	12	8	9	10	11	10	8
Lithuania	12	10	10	10	10	10	11	11	12	15	15	15	17	16
Hungary	14	15	15	16	16	15	15	16	17	17	17	16	12	13
Austria	5	2	2	2	2	3	4	4	2	1	1	5	6	12
Poland	17	17	18	18	18	17	17	14	13	12	12	10	5	4
Romania	18	16	17	17	17	16	16	18	18	18	18	18	18	15
Slovenia	9	18	16	14	14	18	18	9	16	10	9	7	1	1
Slovakia	13	11	11	11	11	11	9	15	11	13	14	12	11	14
Finland	3	4	4	4	3	4	3	2	3	3	3	3	9	5
United Kingdom	2	8	7	7	7	5	6	3	7	7	7	6	7	9

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitraization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

character of particular branches of the transportation system. Furthermore, the multidimensional median allowed making the taxonomic analysis immune to the skewness of particular features. The values of synthetic measures for railway transport development, which were put together with different normalization methods, are presented in Figure 1.

limitation of the Pearson's coefficient, which can incorrectly indicate the character of interdependence (Luszniewicz & Słaby, 2008). To assure adequate results of carried out research, box and whisker plots were put together and presented in Figure 2.

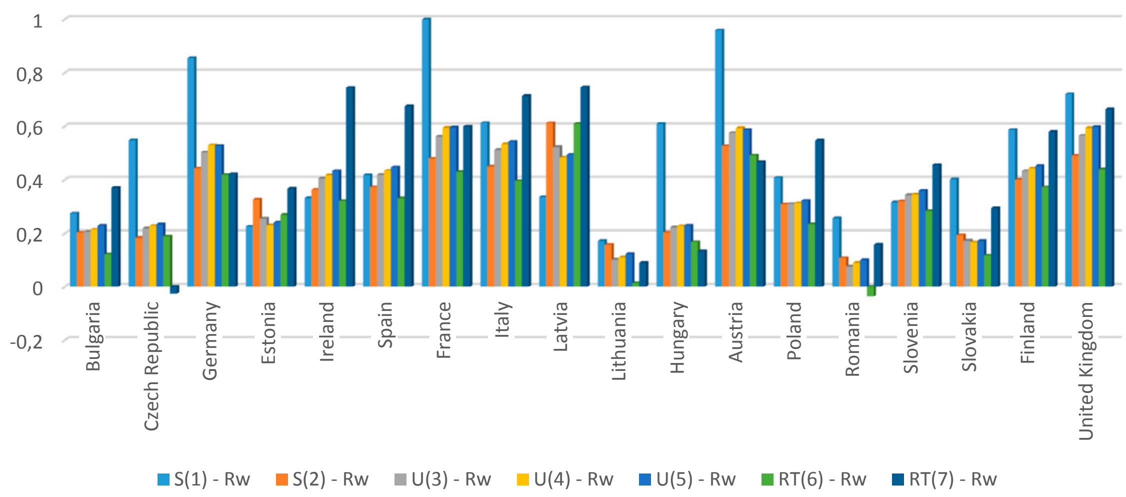

Fig. 1. Values of order synthetic measures constructed with different normalization methods in the area of railway transport

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitraization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

The analysis of graphical presentation proved that in most cases of normalization methods, the values of railway transport synthetic measures achieve similar values for particular member states.

Further, the values of synthetic measures in three different areas of transportation system were treated as the basis for the construction of the total European Union transport development measure. The maximum values of synthetic measures for modes of transport were treated as stimulants in the further analysis. This approach has already been introduced into poverty research because of the sophistic character of analysed phenomenon as well as a very wide range of diagnostic variables (Młodak et al., 2016). The location of European Union member states in the scope of transport mode development as well as the total approach are presented in Table 2.

The analysis of presented rankings of the European Union transport development according to different normalization methods proved that some of the constructed measures resulted in similar positions of particular member states. On the other hand, in few cases, constructed measures give quite different orders. It is to be noticed that rankings constructed with two forms of ratio transformations locate Austria the sixth or twelfth in the case of total development of transportation system. This proves that this kind of normalization is not applicable in linear ordering, however, Austria is considered as one of the most developed countries in Europe in the area of transportation.

Hence, to compare distributions of synthetic measures Pearson correlation coefficients were calculated and presented in Table 3.

The analysis of presented data indicates that the total synthetic measure of transportation development constructed with two forms of ratio transformation is very weakly correlated with other taxonomic measures. Furthermore, a similar phenomenon is noticed in the area of roads as well as air transport. Almost all synthetic measures are highly correlated, which proves the previous analysis in the transport development of chosen European Union member states. Evidence suggests that the suspicion regarding ratio transformation can bring results in the process of synthetic measure construction, which do not reflect the real state of transport development. Nevertheless, it is very important to be aware of the linear

Tab. 3. Matrixes of Pearson's correlation coefficients of synthetic measures constructed according to different normalization methods

	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)
	ROADS							RAILWAYS						
S(1)	1.00	0.78	0.77	0.78	0.78	0.64	0.55	1.00	0.55	0.71	0.75	0.73	0.57	0.22
S(2)	0.78	1.00	1.00	0.99	0.99	0.95	0.91	0.55	1.00	0.96	0.93	0.93	0.98	0.80
U(3)	0.77	1.00	1.00	1.00	1.00	0.95	0.90	0.71	0.96	1.00	1.00	1.00	0.95	0.79
U(4)	0.78	0.99	1.00	1.00	1.00	0.94	0.89	0.75	0.93	1.00	1.00	1.00	0.92	0.76
U(5)	0.78	0.99	1.00	1.00	1.00	0.93	0.88	0.73	0.93	1.00	1.00	1.00	0.92	0.78
RT(6)	0.64	0.95	0.95	0.94	0.93	1.00	0.96	0.57	0.98	0.95	0.92	0.92	1.00	0.76
RT(7)	0.55	0.91	0.90	0.89	0.88	0.96	1.00	0.22	0.80	0.79	0.76	0.78	0.76	1.00
	AIR							TOTAL						
S(1)	1.00	0.81	0.60	0.82	0.80	0.43	0.24	1.00	0.86	0.89	0.90	0.83	0.28	-0.01
S(2)	0.81	1.00	0.86	1.00	1.00	0.66	0.46	0.86	1.00	0.95	0.94	0.84	0.12	-0.25
U(3)	0.60	0.86	1.00	0.82	0.82	0.94	0.84	0.89	0.95	1.00	1.00	0.94	0.37	0.00
U(4)	0.82	1.00	0.82	1.00	1.00	0.60	0.39	0.90	0.94	1.00	1.00	0.95	0.39	0.02
U(5)	0.80	1.00	0.82	1.00	1.00	0.60	0.39	0.83	0.84	0.94	0.95	1.00	0.58	0.19
RT(6)	0.43	0.66	0.94	0.60	0.60	1.00	0.97	0.28	0.12	0.37	0.39	0.58	1.00	0.87
RT(7)	0.24	0.46	0.84	0.39	0.39	0.97	1.00	-0.01	-0.25	0.00	0.02	0.19	0.87	1.00

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitraization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

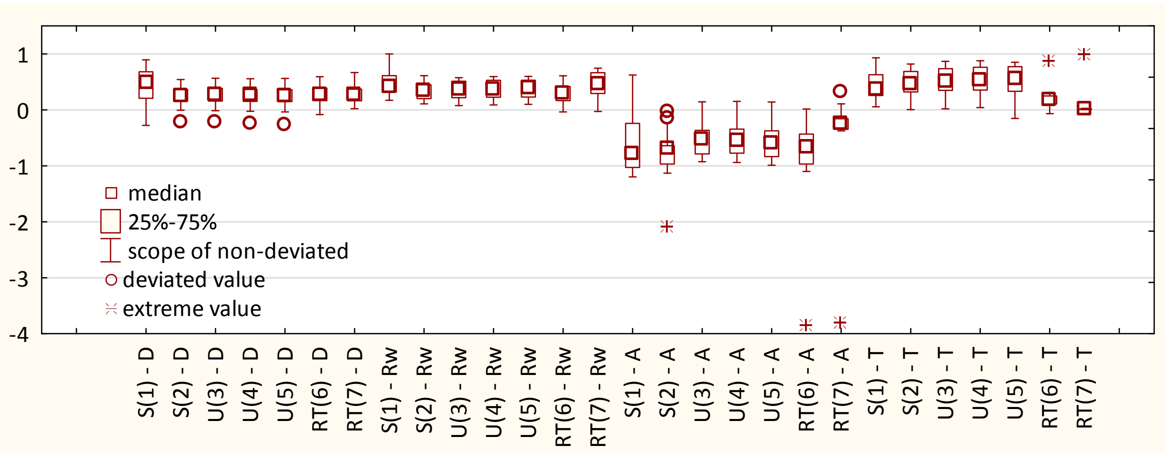

Fig 2. Distributions of order synthetic measures constructed according to different normalization methods

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitraization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II, D – roads, Rw – railways, A – air, T – total.

The analysis of presented graphical distributions of particular synthetic measures in three transport branches as well as the total one indicates the skewness in their distributions. Furthermore, the existence of non-typical (deviated and extreme) values of synthetic measures as well as the asymmetrical location of the median and a different length of whiskers in plots indicate that the implementation of the Pearson's correlation coefficients may not be proper. Hence, the Spearman correlation coefficient was introduced to compare the results of the taxonomic research. The exchange of values of synthetic measures on ranks eliminates the negative impact of non-typical observations (Stanisz, 2006). The results of carried out correlation analysis confirmed the results obtained with the Pearson's coefficient about synthetic measure construction with ratio transformation for the whole transportation system.

4. Discussion of the results

The task of the synthetic measure construction with different normalization methods was to confirm the previous research of the European Union transport development. The paper presents the results obtained in the process of taxonomic research with the Weber median to take into account interactions in a sophisticated transportation system.

The analysis of the data presented in Table 2 allows indicating some trends connected with the ranking of the selected European Union countries in the scope of the road, railway, and air transport development. There are large spans of the development of certain branches of the transportation system in European Union member states. In addition, there is a noticeable correlation between the socio-economic development of particular European Union member states and technical infrastructure, including the logistics one.

The largest European economies, such as Germany, the United Kingdom or France, are considered leading countries in the development of road and railway networks. The carried out analysis proved that the situation connected with the condition of road network and railway transport is more favourable to smaller countries, such as Latvia and Ireland, compared to large ones, such as Finland.

Hence, the observed situation arose due to the influence of the socio-economic policy of European Union member states. It should be noted that the sustainable development policy is considered a priority in some member states. Unfortunately, this kind of policy conflicts with the needs of transport infrastructure development, which creates conditions for the balanced development of regions in those countries. The constant saturation level of roads and railway tracks is observed in Germany, Italy, and the United Kingdom. However, the new investments in those fields are occasionally introduced. The burden of investment concerns modernization and upgrading the existing railway tracks and roads in Germany and France. In addition, the most dynamic growth is observed in air transport of those countries. The carried out analysis proved that both member states took leading positions. Furthermore, the leader of the ranking in the area of air transport is Germany. Apart from Germany, high positions are occupied by Ireland and Finland, which take the second and third place.

The research analysis, which took into account indirectly observed relationships, brought some unforeseen results. On the one hand, the ranking connected with the development level of traditional modes of transport that is roads and railways indicate the leading position of Germany, Slovenia, Spain, and France. Furthermore, Germany, Ireland, Finland, and the United Kingdom are placed highly in the area of air transport. On the other hand, the distant location in that ranking is taken by Romania, Poland, and Slovenia, which occupy positions sixteen to eighteen among the eighteen countries included in the analysis.

The research of the total synthetic measure of transport development led to several conclusions. The high positions of Slovenia, Poland or Latvia, can be considered unexpected. However, the leading positions according to the total ranking are occupied by the most developed and so-called old member states, such as Spain, Germany, Finland, and Italy. Nevertheless, the ninth, tenth and twelfth positions of Great Brittan, France, and Austria according to the synthetic measure constructed with the ratio transformation is unexpected. In addition, the choice of the improper normalization method can deliver the ranking, which does not reflect the socio-economic reality.

Conclusions

The conducted research according to some normalization methods allowed stating that in most cases, different normalization methods lead to similar results.

On the one hand, most of the so-called old member states have a well-developed logistics infrastructure, which is highly correlated with the whole socio-economic space. Going further, the well-developed railways, roads, motorways, and airports are the elements of this infrastructure. It is strictly connected with such countries as Germany, Spain or Finland.

On the other hand, the group of countries that take a distant place in the rankings of all three examined modes of transport was named. In general, the conclusion relates to the following countries: Romania, Czech Republic, and Lithuania. The underdevelopment of technical infrastructure of these countries is caused by historical conditions and the pace of construction of the so-called new market reality. This proposal is adjusted to most states and regions that have been under the influence of the Soviet Union.

In addition, there is a group of states with one better-developed branch of transport in comparison to two others. Slovenia is a member state that takes the first place in the summary ranking. Nevertheless, this country has the eighteen position in the scope of air transport development. Hence, the mountainous terrain and relatively small surface of this country have a significant impact on its state.

To sum up, the synthetic measure construction with most of the normalization methods relates to selected European Union countries and confirms the previous scientific research of the European Union transport development. The researcher feels that the study findings will facilitate such analysis and create more efficient transportation policy for the whole European Union. Moreover, the presented statistical research methods can be used by economic practices; however, the strict cooperation between science and business is a crucial factor.

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