TAXONOMIC ANALYSIS OF THE SUSTAINABLE TRANSPORT DEVELOPMENT IN CHOSEN EUROPEAN UNION COUNTRIES – A SPATIAL APPROACH

Artur Czech
Assistant Professor, PhD
Warsaw Management University, Poland
artcz@interia.eu

Abstract: *Transport is considered as the basis of socio-economic development in the European Union countries. As every activity it generates positive and negative external effects for the environment, society and economy. Therefore, all activities in this area should be balanced in order not to destabilize the economy of particular countries, help society and protect the natural environment. Hence, there is a need for the correct diagnosis of sustainable transport development in particular European Union countries.*
The main aim of the paper is to attempt the assessment of sustainable transport development level in European Union countries and identify the underdeveloped spatial areas as the base of implementation for the support policy. In the scope of dealing with research problem, both classic and order, chosen multivariate statistical measures were implemented into the research process.
Moreover, the order taxonomic method with Weber median were introduced which allowed to take into account interactions (directly unobservable relationships) in the set of diagnostic variables and made the analysis immune to skewness of particular diagnostic variables.

Keywords: *sustainable transport; orders, greenhouse gas emission; climate change; taxonomic analysis; synthetic measure construction; spatial assessment.*

1. Introduction

Transport policy of European Union is considered as one of the basic factors of sustainable development. This is due to the fact, that mobility has a significant impact on European Union and its environment [Gratiela, 2013]. It should be noted that each transport activity generates both positive and negative external effects. On one hand, positives include achieving economic goals like production of goods and delivering them onto the market. As a result, transport stimulates economic growth, enables job creation and improves the quality of life. On the other hand, transport brings a wide range of problems such as greenhouse gases emission, global warming, accidents, etc., which affect human's well-being and quality of life. All in all, it should be mentioned that transport has already been identified as the fastest growing source of greenhouse gas emission. Nevertheless, transport is still considered to be the basic factor of development, both on macro and microeconomic scale. All of these put a lot of pressure to implement policies in order to reduce pollution, noise emission, oil consumption or the number of accident victims.

The area of European Union is diversified taking into account both its socio-economic development and natural environment pollution. Consequently, all activities should be balanced in order not to destabilize the economy of particular countries, help society and protect the natural environment. Therefore, sustainable mobility system, allowing citizens and goods to move freely and safety with respect to the environment, is crucial for quality of life and the health of the economy [Persia *et al*., 2016]. All in all, transport should be considered as a system of interrelated components where mutual relationships play a key role. There is a need for the correct diagnosis of sustainable transport development in the area of European Union. Moreover, this kind of analysis can be considered as the basis for implementation of the support policy delivered from European Union institutions.

The main aim of the paper is to attempt the assessment of sustainable transport development level in European Union countries with taxonomic tools and identify the underdeveloped spatial areas as the base of implementation for the support policy. The source of information for the research was data drawn from the Eurostat Data Base.

2. Methodology

The area of transportation is considered as a very sophisticated system. Furthermore, requirement of sustainability in this area increases its complexity. The literature research proved that sustainable development can be measured in terms of the integrated order i.e. a positive target state of development changes combining the constituent orders such as environmental, social and economic in coherent and consistent manner [Borys, 2011]. However, the complexity and multidimensionality of transport phenomenon brings a lot of difficulties in the process of evaluation of spatial objects which are described with a number of diagnostic variables.

Nevertheless, the literature study showed that the research in this field can be run by implementing two approaches [Figura, 2013]. On one hand, one dimension analysis can be carried out where the level of transport development should be evaluated separately according to particular variables included into research process. On the other hand, taxonomic tools, which create possibilities to support logistic policy by the procedures of ordering and classification of research objects which are described many variables, can be implemented.

Although the literature suggests that transport sustainability has already been put many times under the scientific investigation [Janic, 2006; Cheba & Saniuk, 2016; Ahmad & Puppim de Oliveira, 2016; Malasek, 2016; Markova *et al.*, 2017] but much less attention was devoted to investigate mutual but not directly observable relationships (interactions) in the area of sustainable transport development. However, it should be mentioned that the empirical assessment of spatial transport development with implementation of taxonomic methods (classic and order) has already been carried out in literature [Hajduk, 2016; Czech & Lewczuk, 2016, 2017; Fanni *et al*., 2017; Czech *et al.* 2018] but it did not include interactions in the area of transport sustainability. However, the literature study proved that taking into account interactions in the transport researches is very important [Erwing & Cervero, 2001; Vörös, 2015; Matteis *et al.*, 2016].

The presented research focused on the evaluation of sustainable transport development based on synthetic measure construction in two basic ways. The former implements classic statistical measures such as arithmetic mean and standard deviation. The value of synthetic measure is calculated according to the following formula [Hellwig, 1968]:

$$MK_i = 1 - \frac{d_i}{\overline{D} + 2 * S_D} \tag{1}$$

where: $\overline{D}$ – mean of distance vector,

S_D – standard deviation of distance vector.

The latter way of the synthetic measure construction is based on multidimensional median vector as well as *mad* (median absolute deviation). It is worth noting that this kind of the method was implemented into the research process by a Polish statistician and is called the order method [Lira *et al.*, 2002]. The set of diagnostic variables is put under normalisation according to the following equation [Młodak, 2006]:

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

Particular values of are considered as the elements of multidimensional median vector i.e. border or Weber. It should be mentioned the Weber median is calculated in the minimalization process of the following formula:

$$T(\Theta, R^m) = \arg\min_{\Theta \in R^m} \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{m} \left(x_{ij} - \theta_j \right)^2 \right]^{1/2} \right\} \tag{3}$$

It should be noted that this kind of multidimensional median vector makes both the analysis immune to skewness and takes into account interactions in the whole set of diagnostic variables. It is very important from the point of view of the taxonomic analysis of complex phenomena such as socio-economic development, living standard, spatial cohesion or sustainability of transportation system.

In relation to *mad* (median absolute deviation) it should be noted that its particular values are received with the following equation:

$$mad(X_j) = \underset{i=1,2,\ldots,n}{med} \left| x_{ij} - \theta_j \right| \tag{4}$$

Also, it should be mentioned that there are other normalization methods in the literature. They were successfully implemented into the research process with classic statistical measures [Jajuga & Walesiak, 2000]. Furthermore, a multidimensional median vector (border and Weber) has already been implemented in different ways in normalisation process of the data set [Czech, 2014; Czech *et. al.*, 2016]. Finally, the synthetic measure of normalized variable in the case of order method is estimated with the following formula:

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

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

4. Research results

Construction of synthetic measure should be based on the set of diagnostic variables which are describing the area of investigation in proper way. It should be mentioned that there are two main stages in its construction process. The former is based on the theory of the examined phenomenon and creates the set of potential variables. The latter introduces statistical measures in order to create the final set of diagnostic variables. It should be noted that selecting indicators of sustainable transport is a very difficult task. This is due to the fact that there is a wide range of indicators in the literature which are implemented into the research process [Gratiela & Viorela-Georgiana, 2013]. Moreover, the difficulties are compounded by the number of domestic and strategic documents. Nevertheless, it should be mentioned that system of variables for evaluating the sustainable development of transportation should follow the scientific, objective, systematic and comparable and workable principles [Li *et al.*, 2017].

As the basis of taxonomic analysis in the area of sustainable transport development, a set of diagnostic variables was drawn from Eurostat data base for 2019. Therefore, three main areas of the Integrated Order which generate mutual interactions, were taken into consideration and are presented in the figure 1.

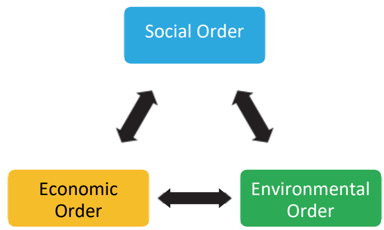

Fig. 1. Interactions in three main areas of Integrated Order
Source: own studies.

The first area i.e. Environmental Order is presented by the following variables: X_1 – average CO2 emissions per one km from new passenger cars (g CO2 per one km), X_2 – exposure in urban areas to air pollution by particulate matter < 10 µm (µg/m3), X_3 – share of renewable energy in final energy consumption (%), X_4 – share of electricity consumption in total energy consumption of transport sector (%), X_5 – share of electrified railway tracks in their total length (%), X_6 – share of natural gas consumption in total energy consumption of transport sector, X_7 – emission of carbon dioxide in the area of transportation and storage (tonnes per capita), X_8 – share of new registered passenger cars in their total number (%), X_9 – emission of nitrous oxide in the area of transportation and storage (grams per capita), X_{10} – emission of methane in the area of transportation and storage (kilograms per capita).

The second area i.e. Social Order as a part of Integrated one includes the following variables: X_{11} – number of passenger cars per 1 000 citizens, X_{12} – number of killed in road accidents per 100 000 citizens, X_{13} – motor coaches, buses and trolley buses per 1 000 citizens, X_{14} – number of killed in rail accidents per 1 million citizens, X_{15} – share of trains in all passenger transport (%), X_{16} – share of population living in households considering that they suffer from noise (%), X_{17} – exposure in urban areas to air pollution by particulate matter < 2.5 µm (µg/m3), X_{18} – share of motor coaches, buses and trolley buses in all passenger transport (%), X_{19} – number of airline passengers per one citizen, X_{20} – number of killed in commercial air transport per 1 million passengers.

The third one is the Economic Order and the following variables are included: X_{21} – goods transported by rail in million tonne-kilometre, X_{22} – length of railway lines per 1 000 km2, X_{23} – share of environmental taxes in total tax revenues (%), X_{24} – air transport of goods in tonnes per 1 000 citizens, X_{25} – share of renewable energy in transport sector (%), X_{26} – length of motorways per 100 km2, X_{27} – number of lorries and road tractors per 1 000 citizens, X_{28} – share of rail freight transport in all inland fright transport (%), X_{29} – share of road freight transport in all inland fright transport (%), X_{30} – share of two or more railway tracks in their total length (%).

The wide range of potential set of diagnostic variables caused that three member countries of European Union were not taken into investigation. This is due to the fact that there are countries such as Cyprus and Malta which do not have railway transport. It is worth mentioning that this kind of transportation system is considered as one of the most environmentally friendly and should not be omitted in this kind of research. Furthermore, it was not possible to make the analysis for Belgium because of significant incomplete data.

In order not to exclude from analysis some member states, the missing data was completed by time-series extrapolation (only in a few cases).

Every set of potential diagnostic variables should be put under statistical investigation before taxonomic measure construction i.e. variation and correlation analysis. Hence, in order to carry out the first stage of statistical investigation, basic statistical measures were calculated for potential variables separate for particular orders. The results of this kind of analysis are presented in table 1.

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

Variable	Order	A_S	Mean	M_B	M_W	S_X	Mad (B)	Mad (W)	V_S	V_B	V_W	Mdim Stage I	Mdim Stage II
X_1	Environmental	-0,66	122,89	124,00	123,45	9,50	7,90	8,00	7,73	6,37	6,48	-	
X_2		0,09	20,25	20,25	20,36	5,73	3,95	3,95	28,28	19,51	19,40	1,66	-
X_3		0,68	34,90	33,80	33,44	18,78	13,43	13,08	53,81	39,74	39,10	1,32	-
X_4		0,72	1,40	1,17	1,41	0,87	0,59	0,51	62,35	50,86	35,91	2,86	-
X_5		-0,32	49,89	55,11	51,78	24,01	16,60	18,51	48,12	30,12	35,74	1,98	-
X_6		2,18	1,24	0,65	1,22	1,57	0,55	0,89	127,51	84,50	73,16	2,01	-
X_7		2,49	1,65	0,83	0,99	2,08	0,22	0,36	125,66	27,15	36,40	8,11	-
X_8		0,56	6,30	6,10	6,02	2,54	1,64	1,69	40,35	26,95	28,09	1,77	-
X_9		2,38	54,59	34,06	35,88	58,98	13,55	13,99	108,03	39,78	38,99	6,63	-
X_{10}		3,92	0,57	0,08	0,59	1,46	0,06	0,55	255,18	81,03	94,33	1,85	-
X_{11}	Social	0,15	515,11	513,67	517,66	93,10	59,02	59,58	18,07	11,49	11,51	2,22	-
X_{12}		0,53	5,31	4,93	4,97	1,93	1,42	1,42	36,43	28,73	28,48	7,14	-
X_{13}		0,29	2,16	2,04	1,85	0,89	0,63	0,66	41,03	30,76	35,60	4,91	-
X_{14}		1,15	4,59	4,09	3,33	3,62	2,31	2,02	78,94	56,52	60,62	5,57	-
X_{15}		0,14	6,15	6,00	6,09	3,55	3,30	3,26	57,74	55,00	53,53	2,56	-
X_{16}		0,53	15,31	14,05	16,83	5,45	4,25	3,88	35,59	30,25	23,04	3,29	-
X_{17}		-0,05	12,12	11,90	11,56	3,94	2,50	2,65	32,49	21,01	22,92	4,33	-
X_{18}		0,03	11,71	11,90	9,95	4,28	3,45	2,85	36,56	28,99	28,66	3,81	-
X_{19}		0,58	3,38	2,71	3,97	1,97	1,41	1,49	58,39	52,03	37,45	2,46	-
X_{20}		3,16	0,004	0,00	0,01	0,01	0,00	0,01	300,33	-	100,00	2,09	-
X_{21}	Economic	1,27	6,31	4,86	5,70	6,04	3,48	3,83	95,77	71,56	67,24	16,48	3,31
X_{22}		0,88	54,14	46,37	51,19	30,45	17,80	21,61	56,25	38,39	42,21	2,62	2,46
X_{23}		0,14	7,13	7,03	7,31	1,82	1,61	1,59	25,57	22,83	21,67	2,33	2,18
X_{24}		4,85	77,28	11,65	18,44	280,39	7,71	13,37	362,82	66,20	72,49	2,44	1,99
X_{25}		2,89	9,11	7,87	9,05	5,63	1,20	1,38	61,88	15,23	15,29	2,73	2,66
X_{26}		1,66	2,14	1,81	1,89	1,95	1,27	1,25	90,93	70,26	66,38	2,86	2,24
X_{27}		0,84	5,40	4,84	5,39	3,53	2,55	2,56	65,28	52,66	47,44	2,51	2,51
X_{28}		1,33	23,79	23,40	23,34	18,19	10,95	10,89	76,49	46,79	46,66	29,30	-
X_{29}		-0,59	70,41	71,75	71,79	19,61	14,50	14,50	27,86	20,21	20,20	6,63	3,70
X_{30}		-0,32	49,89	55,11	51,02	24,01	16,60	18,09	48,12	30,12	35,46	2,70	2,61

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

Source: own studies.

As a result of variation analysis only variable X_1 was omitted in the area of Environmental Order. This is due to the fact that classic variation coefficient and both forms of its order version, which are based on border as well as Weber median, were under the value of 10%. Additionally, the statistical measures included in the table prove that some of diagnostic variables have strong asymmetrical distribution. The strong skewness is observed for selected variables in every of the examined orders i.e. environmental, social and economic. Therefore, it is essential to implement order statistics such as median, *mad* and order variation coefficients at the stage of the final set of diagnostic variables selection. Moreover, it should be noted that the order taxonomic method of the synthetic measure construction should be introduced into further assessment process of development level of sustainable transport.

In spite of elimination variables which carry the same information, the method of inverted matrix of Pearson correlation coefficients was implemented [Malina & Zeliaś, 1997]. Therefore, three separate inverted matrixes were calculated in relation to sets of diagnostic variables in the area of particular orders. The investigation process proved that, in the area of both environmental and social order, all values located in the main diagonal of inverted matrixes were under the value of 10. Therefore, it resulted in including the variables from X_2 up to X_{20} in the further analysis. Nevertheless, in the area of economic order the variable X_{28} was removed. Then, Pearson correlation matrix for economic order was inverted again in order to check if other variables can be included for further analysis [Czech & Słaby, 2017]. To sum up, the final set of twenty eight diagnostic variables was a base for synthetic measures construction in the case of particular orders i.e. environmental, social and economic.

Going further, three sets of diagnostic variables were put under the process of standardization, both in the classic and order form with Weber median. Implementation of the normalized three sets of diagnostic variables and the pattern taxonomic development method allowed to construct partial synthetic measures in three analysed orders in the area of sustainable transport. Further, the total measure for integrate order was calculated as well. It should be mentioned that synthetic measures for every of the examined orders were treated as stimulants in the process of the sustainable transport measure construction (integrated order). The values of both classic and order measure with Weber median for sustainable transport development are presented in figure 2.

Fig. 2. Values of classic and order synthetic measure according to integrated order
Source: own studies.

The presented data shows the significant differences in the sustainable transport development level of investigated countries according to both implemented methods of synthetic measure construction.

Further, the values of both method of synthetic measure construction were used to construct the rankings of the development level in the areas of environmental, social and economic orders as well as the whole area of sustainable transport. The location of particular European Union member countries according to both particular orders and two methods of synthetic measure construction are presented in Table 2.

Tab. 2. Positions of countries in the ranking and groups according to particular orders

Country	**Environmental**		**Social**		**Economic**		**Integrated**
	MK	***MP***	***MK***	***MP***	***MK***	***MP***	***MK***
Bulgaria	19	19	22	22	18	18	21
Czechia	14	13	7	7	7	7	8
Denmark	21	23	5	5	15	14	17
Germany	5	8	17	16	3	4	4
Estonia	16	17	1	1	21	21	10
Ireland	18	20	3	2	20	17	15
Greece	24	18	12	9	24	23	23
Spain	10	10	15	13	11	13	12
France	8	7	9	11	12	8	9
Croatia	13	9	19	20	17	16	19
Italy	3	3	23	23	14	12	13
Latvia	23	22	18	18	22	20	22
Lithuania	20	21	10	8	23	22	20
Luxembourg	22	24	6	6	6	24	11
Hungary	6	4	13	15	5	6	5
Netherlands	11	15	14	14	1	2	7
Austria	1	1	8	10	4	5	2
Poland	15	12	16	17	16	15	18
Portugal	7	6	21	21	13	10	14
Romania	17	16	24	24	19	19	24
Slovenia	12	11	20	19	10	11	16
Slovakia	4	5	11	12	9	9	6
Finland	9	14	2	3	8	3	3
Sweden	2	2	4	4	2	1	1

Notation: MK – classical measure, MP - order measure.
Source: own studies.

5. Conclusions

The carried out research with the use of both methods of synthetic measure construction (classic and order) for chosen members of the European Union in terms of the level of sustainable development of transportation system has brought up a number of conclusions. It should be mentioned that they concern both the methods implemented into the research process and the level of transport sustainability in particular countries.

The former proved that potential set of diagnostic variables should be put under statistical investigation with order statistical measures such as median, median absolute deviation and order variation coefficients. This is due to the fact that there are observed variables with very strong skewness of empirical distributions in every data set describing the examined orders i.e. environmental, social and economic. Therefore, variation analysis of the potential set of diagnostic variables with the use of the classical coefficient, should be supported by implementation of its order substitutes. It should be noted that implementation of order variation coefficients, with both border and Weber median, confirmed acceptance or rejection of particular variables for further analysis. Strong skewness and mutual interaction among variables, in three sets of diagnostic variables for every one of the examined orders, proved the need to implement into research process the order method of synthetic measure construction with Weber median.

The latter showed that the level of sustainable transport development should be considered as a complex phenomenon. On one hand, the analysis of constructed ranking, according to classical measure, showed that the leading place in Europe, in the context of transport sustainability (Integrated order), is taken by the so called Old European Union i.e. Sweden, Finland and Austria. The leading positions were confirmed by the values of the order synthetic measure with Weber median. Going further, the analysis showed significant differences in the case of the weakest group according to both methods of synthetic measure construction. It should be noted that only in the case of Latvia both methods confirmed the same position. All in all, detailed analysis of European Union members, in terms of individual orders i.e. environmental, social and economic, showed sensitive areas in the case of individual countries that should be taken into account in the process of allocating support funds.

To sum up, it should be noted that there are significant spatial disproportions in the development level of sustainability of transportation system in analysed countries. They occur in the area of environmental, social and economic order as an important areas of the integrated order. Hence, the results of this study can be treated as a guide for reflection and a base for further analysis.

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