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MULTICRITERIA SUSTAINABILITY EVALUATION OF TRANSPORTATION WITHIN EUROPEAN UNION

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Abstract

In recent decades, the growth of passengers and freight mobility has contributed to transport became one of the major source of pollution in environment. For transition countries that are faced with many problems of which depends their future development, the concept of "sustainable development" and "sustainable transportation" are a major challenges. The main purpose of this paper is to application the VIKOR (VIšekriterijumsko KOmpromisno Rangiranje - Multicriteria Compromise Ranking) method to assess the transport sustainability. Authors propose technique to identify according to which transport-sustainability performance needs to be improved in some observed countries.

***Keywords**: Transport,Sustainable, VIKOR,Multicriteria.*

1 INTRODUCTION

Transport plays an important role in the process of globalization of the world economy. Effective and efficient transport contributes to reducing production costs, and, thus, allows the products to be competitive on the world market. It is necessary to bear in mind that transport contributes to the development of national and world economy. Due to intensification of international trade, transport records rapid development, but, accordingly, represents the activity that mostly contributes to environmental degradation. Given the increasingly pronounced conflict between high demand for mobility and strong pressure on environmentcapacities, sustainable development is set as the only possible concept oftransportdevelopment. Since the concept of sustainable development has become one of the top priorities for nations, there has been a growing interest in evaluating the performance of transport systems with respect to sustainability issues [1]. Therefore, the European Union (EU) has for many years invested special efforts to estimate the possible scenarios of sustainable transportdevelopment, as well as the formation and implementation of strategies aimed at reducing the negative impact of transport on the environment.

Based on the criteria and principles of sustainable development, different interpretations of the concept of sustainable transport have developed. The initial focus was to understand the environmental dimension of sustainability, i.e. impact of transport on ecosystems. Modern understanding and interpretation of the concept of sustainable development in transport means that this industry operates in accordance with the principles of economic development, social equality and solidarity, and environmental responsibility. Operational understanding of the concept of sustainable development imposes the need to identify and quantify the complex links between economic development, welfare of mankind, and the environment.

Measuring sustainability is not a new topic. There are numerous approaches in the transport sector, which vary in terms of defining transportsustainability, choice of indicators, and the level of the transport system to which they apply. For an insight into transport sustainability at the macro level, i.e. at the countrylevel, it is necessary to take into account a large number of indicators. One way of comparing countries in terms of transport sustainability is the use of multicriteria methods that allowthe ranking of countries taking into account a large number of sustainable transportindicators. The purpose of this paper is the application of multicriteria method for ranking the European Union member statesaccording to the level of transportsustainability. To apply VIKOR method, it is necessary to determine the value of weight coefficients. The paper applies FANMA method for determining the value of weightcoefficients. The aim is to highlight transport sustainability performance that needs to be improved in some observed countries.

2 LITERATURE REVIEW

There are many definitions of sustainable transport. Sustainable transport is sometimes defined narrowly as simply environmental sustainability, but is increasingly defined more broadly to include other dimensions. The often cited definition is given in the Brundtland Commission's Report: satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs [2].A more comprehensive definitionis given by the Council of the European Union: "A sustainable transport system 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; is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy as well as balanced regional development; limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses nonrenewable resources at or below the rates of development of renewable substitutes while minimizing the impact on land and the generation of noise”[3].On European Conference of Ministers of Transport in 2004th is given the following definition of sustainable transportation: A sustainable transport system is one that is accessible, safe, environmentally-friendly, and affordable [4].

Many experts use the following definition because it is comprehensive and indicates that sustainable transport must balance economic, social and environmental goals: A sustainable transportation system is one that (CST 2005):
1) Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
2) Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy;
3) Limits emissions and waste within the planet’s ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.
In order to quantify the progress towards the objectives of sustainable transportation, it is crucial to define the proper indicators [5]. These indicators can be defined as selected, targeted, and compressed variables that reflect public concerns and are of use to the decision makers [6].
Most indicator sets are traditionally organised around three fundamental sustainability dimensions, thus reflecting transport performance in relation to economic, social and environmental issues. There are also additional dimensions mentioned in some studies such as technical, operational or institutional [7], [8], [9]. Alternatively, the indicators can be classified based on the transportation goals and objectives as in the TERM project [10] or the STPI project [11] or the JRC Well-to-Wheels study [12].

In the selection of sustainable transportindicators, the work relies on the three dimensions. In order to analyze the sustainable transport of the European Union member states on the basis of sustainable transport indicators, one of the multicriteria methods will be applied, ie VIKOR method.

A cross-country transport-sustainability evaluation has been performed using a multicriteria approach based on the concept of outranking, formulated by Roy[13].The best-known methods of multicriteria decision-making are ELECTRE (ELimination and Et Choice translating REality), PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation), AHP(Analytical Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions) and VIKOR (Multicriteria Compromise Ranking) [14]. Awasthi et al. investigate four multicriteria decision making (MCDM) techniques namely TOPSIS, VIKOR, SAW and GRA for sustainability evaluation of urban transportation projects [15].TOPSIS and VIKOR are compared and applied to determine the best compromise alternative fuel mode. The result shows that the hybrid electric bus is the most suitable substitute bus for Taiwan urban areas in the short and median term [16].
Kolak et al.have applied TOPSIS metod and MACBETH (The Measuring Attractiveness by a Categorical Based Evaluation TecHnique)to evaluate the sustainability of transport networks of selected European countries [5]. Bojkovic et al. introduce a MCDM outranking approach, namely the ELECTRE method for evaluating the transport sustainability at the macro level [17].Alsoauthors have appliedthe modified ELECTRE (ELimination Et Choix Traduisant la REalité; Elimination And Choice Corresponding to Reality) method for the evaluation of transport sustainability at the macro level [17].Jeon et al. evaluate three transport and land-use scenarios at the urban level using the simple weighted average method in conjunction with composite sustainability indices and a range of performance measures [18].

3 MULTICRITERIA ANALYSIS OF SUSTAINABILITY MODES OF TRANSPORT

To perform the ranking of modes of transport from the perspective of sustainability in below we will define alternatives and criteria in order to apply the FANMA and VIKOR methods. Criteria that will be used to rank alternatives are the indicators of transport sustainability on the example of the European Union (Table 1).

Table 1 Details about the indicators selected to evaluate the transport mode sustainability

Dimension	Indicator	Description	Measurement Unit	Source
Economical	CEC1	Employment of mode by transport	Number (In thousands)	Eurostat
	CEC2	Turnover by mode of transport	million eur	Eurostat
	CEC3	Final energy consumption by mode of transport	mtoe	Eurostat
Environmental	CEN1	Greenhouse gas emissions from transport by mode of transport	Thousand tonnes of CO_2 equivalent	Eurostat
	CEN2	Number of people exposed to noise from major roads outside agglomerations (> 59 Lden)	%	European Commission – DG Mobility and Transport
Social	CSC1	Road Fatalities	number	Eurostat
	CSC2	Railway Fatalities	number	Eurostat

Table 2 The initial decision table

	CEC1 max	CEC2 max	CEC3 min	CEN1 min	CEN2 min	CSC1 min	CSC2 min	Q V=0.5	Rank
w	0.0308	0.0305	0.2014	0.1858	0.3073	0.1328	0.1113	-	-
BE	215.0	48 182	10028.4	47.0	514 600.0	727	0	0.12730	17
BG	155.5	5 728	3107.2	9.3	500.0	661	2	0.17267	18
CZ	262.9	21 077	6219.1	18.0	391 000.0	688	2	0.20414	21
DK	147.3	49 764	4915.8	17.1	83 100.0	182	0	0.02922	10
DE	2 062.4	268 368	63466.6	192.4	968 400.0	3 377	0	0.71791	26
EE	37.8	5 118	780.4	3.4	0.0	78	1	0.05041	14
IE	79.9	17 223	4474.5	14.0	43 100.0	193	0	0.02965	11
EL	166.6	11 478	6467.1	26.7	0.0	795	0	0.06297	16
ES	824.6	94 770	31980.4	118.6	1085 200.0	1 688	3	0.49617	24
FR	1 378.5	205 926	49535.5	153.8	4021 700.0	3 384	0	0.89212	27
HR	77.2	3 612	2015.2	6.0	0.0	308	0	0.02088	7
IT	1 059.7	147 723	40085.6	118.9	2784 600.0	3 381	1	0.68554	25
CY	17.9	2 332	842.9	3.3	34 800.0	45	-	0.01107	2
LV	74.9	5 286	1093.5	4.1	400.0	212	0	0.01365	3
LT	108.7	7 614	1739.9	5.3	3 300.0	267	0	0.01701	5
LU	19.8	4 886	2490	7.4	3 200.0	35	0	0.01617	4
HU	216.3	15 220	3992.4	11.7	111 100.0	626	3	0.27469	22
MT	9.9	1 149	294.5	5.0	14 500.0	10	-	0.00932	1
NL	409.0	75 579	13914.8	83.5	58 800.0	477	0	0.19747	20
AT	206.8	40 735	8725.7	24.2	314 500.0	430	0	0.06152	15
PL	720.8	41 833	16369.6	46.4	225 700.0	3 202	2	0.42557	23
PT	147.8	17 520	6472.3	20.8	5 000.0	638	0	0.04912	13
RO	337.5	12 837	5473	16.5	44 100.0	1 818	1	0.18490	19
SI	43.4	4 726	1823.6	5.6	58 900.0	108	0	0.01721	6
SK	121.9	7 847	2211.6	6.6	101 600.0	291	0	0.02443	8
FI	148.0	22 946	4759	13.3	38 900.0	229	0	0.02755	9
SE	270.0	49 090	8524.4	26.2	175 800.0	0	0	0.03940	12
UK	1 205.1	185 328	51133.3	156.2	5034 500.0	0	0	0.95634	28

Weight of criteria can be determined on the basis of subjective or objective approach. Weight of criteria can be determined and by using some of the methods of objective approach. The best-known objective methods are: method of Entropy, CRITIC, FANMA and DEA method. In the paper authors apply FANMA method to determine weight coefficients. In each column of Table 2, within each criterion it is necessary to determine the maximum and minimum value, which refers to the observed indicators of transport sustainability.

To adopt an alternative as the best according to VIKOR method, it must be the first in compromise rankings and must meet the two conditions: condition U1 and conditionU2. If the first alternative does not fulfill the U1 condition (or both conditions, U1 and U2), then a set of compromise solutions includes alternativesin compromise rankings to the alternative that fulfills the U1condition, or to the one over which the first alternative has “sufficient advantage” expressed as DQ. Based on the above,the segment below will examine the fulfillment of U1 condition, which reads:

The first alternative in compromise rankings for the value ofv=0.5 must have “sufficient advantage” over the alternative for the next positions. “Advantage” is calculated as the difference between Q_i for the value of v=0.5. Alternative a’ has “sufficient advantage” over the following a” in the rankings, if:

$$Q(a') - Q(a'') \geq DQ \tag{1}$$

$$DQ = \min (0.25; 1/(m-1)) \tag{2}$$

where:

DQ – “sufficient advantage”threshold,

m – number of alternatives,

0.25 – Value of “sufficient advantage” threshold that limits the threshold for cases with a small number of alternatives.

In the present case DQ = min (0.25, 0.037) = 0.037

Based on the U1 condition,the observed countries are rankedbased on transportsustainability indicators. According to the Q value (v=0.5), the best alternative is Malta (a_{18}).

The condition U1 is not fulfilled because:

$$Q(a_{13}) - Q(a_{18}) = 0.01107-0.00932 < 0.037 \tag{3}$$

Given that alternative a_{18} has "sufficient advantage" over alternative a_{13}, alternative $a_{13}$is included ina set of compromise solutions. In the same way it is examined whether alternative a_{18}has sufficient advantage over the following alternatives in the rankings. On the basis of the fulfillment or non-fulfillment of U1 condition, itcan be concluded that the following alternatives, in addition to alternatives$a_{18}$and a_{13}, are to be included in a set of compromise solutions a_{14}, a_{16}, a_{15}, and a_{24}. Based on the foregoing, it can be concluded that Cyprus, Latvia, Luxembourg, Lithuania, and Slovenia record the highest level of transportsustainability. With reference to U1 condition, ranking of other European Union members is carried out (Table 2). The lowest level of transport sustainability is recorded in the United Kingdom (12th position), followed by France (11th position) and Germany (10th position).

4 CONCLUSION

Due to the negative impact on the environment and human health, on the one hand, and the need for sustainable development, on the other hand, transport today is facing a big exam. Although the European Union, especially its developed countries, invest substantial efforts in the creation and implementation of transportdevelopment strategies, which will allow for greater mobility of people and goods and ensure the improvement of environmental conditions, the results of this study show that highly developed countries record the lowest level of transportsustainability. Increased use of alternative energy sources would reduce the consumption of conventional energy sources and the reduction of GHG emissions. This is why there should be a growing interest in the identification and implementation of various technological and economic instruments that can contribute to increasing the level of transport sustainability in developed countries of the European Union.

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