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Rationale of Priority Areas of Rail Operation in North-Eastern Europe

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Abstract

The methodology for assessing the importance of railway routes by generalized ratings reduced to the geometric a criterion has been further developed. The results were obtained for the countries of Eastern Europe, including the extension of the Rail Baltica line. The geometric average of the relative criteria was applied as a composite index for assessing the routes.
KEY WORDS: *Rail Baltica, transport corridors, logistics*

1. Introduction

The main factor determining the economic development of the country is the availability of transport networks that provide fast and uninterrupted movement of passenger and freight trains. These networks must be integrated into the transport system of the European Union [1-3].

Today, most railway transportation (especially freight) in the Baltic States comes from the Russian direction using the existing track gauge of 1520 mm. This complicates and increases the traffic cost between northern European countries and the rest of the European Union via Poland.

Analysis of current publications shows that research concerning the preferred priority directions for international transportation include a wide range of studies, the main ones are:

1) reasoning of transportation mode;
2) rationale for the logistic schemes of transportation;
3) choosing the technology of cargo transfer at points when changing the standard of track gauge.

Among the numerous studies of the first and second directions, one should single out a scientific paper [4], which presents the theoretical foundations and empirical results of the analysis and simulation of transport networks on the example of Poland using structured networks.

The simulation model proposed in [5] reflects the features of the Polish transport network, impact of demand for passenger and freight transport, the distribution mechanism of freight and passenger flows in the network. The issue of compatibility of transport systems remains difficult. The main aspects of the systematic approach to this problem are presented in [6]. The main directions of the railway system operation which depend on introduction of interoperability are covered in the article.

As for the scientific works of the third direction, we can cite a monograph [7], which compares such options as transhipment of cargo; replacement of bogies at the gauge-changing areas (GCA); the use of special rolling stock equipped with adjustable-gauge bogies (AGB); extension or use of the existing broad gauge track of 1520 mm from Ukraine's borders to the territory of Europe; extension of the European track of 1435 mm from the borders of Europe to the territory of Ukraine and using the dual track of 1435/1520 mm.

In [8], decision-making models for assessing efficiency of the Europe – Asia transport system are proposed. The technology of rolling stock transition when track gauge changeover of 1435/1520 and vice versa at the crossroads of Medica – Mostyska (Poland – Ukraine) was studied. It is shown that technical and economic analysis, life cycle cost analysis and analytical network process can be used in assessing the technology efficiency.

Baltic states are an example of using the Stephenson (Europe) gauge on their territory. One of Europe's priority rail projects is «Rail Baltica», which is a part of «North Sea – Baltic» rail corridor with a length of 3 200 kilometers.

The Rail Baltica project involves the construction of a high-speed international railway from Tallinn via Riga to the Lithuanian border with Poland. Implementation of the Rail Baltica railway line for the track of 1435 mm will allow connecting the Baltic capitals via Poland with the European rail network [2, 9]. According to the plan, in Latvia the length of Rail Baltica should be 265 km, in Estonia is about 200 km, and in Lithuania is 392 km (Fig. 1). The project included the train speed of up to 240 km/h, but initially it was set at 160 km/h.

This project envisages that the unified standards system of rail transport has to function in the EU common railway transport networks, which maximally meets the needs of EU countries and its citizens [11].

Paper [12] is devoted to the research for extension priorities of «Rail Baltica». It presents a methodology for assessing efficiency of the extension of the passenger railway route from Warsaw in the western and southern directions. It is known that development of a country and its importance in relation to other countries of the region are determined by its area, number of inhabitants and gross domestic product. Having estimated indexes by the method of concluding ratings, it was found that the project is the most important for Estonia, in second place by value for Lithuania, third in Latvia, in fourth place is in Poland. At the same time, Polish researchers believed that the Rail Baltica railway should be evaluated not only on the section from Tallinn to Warsaw, but also considering the possible links between the Baltic states with Berlin and Hamburg.

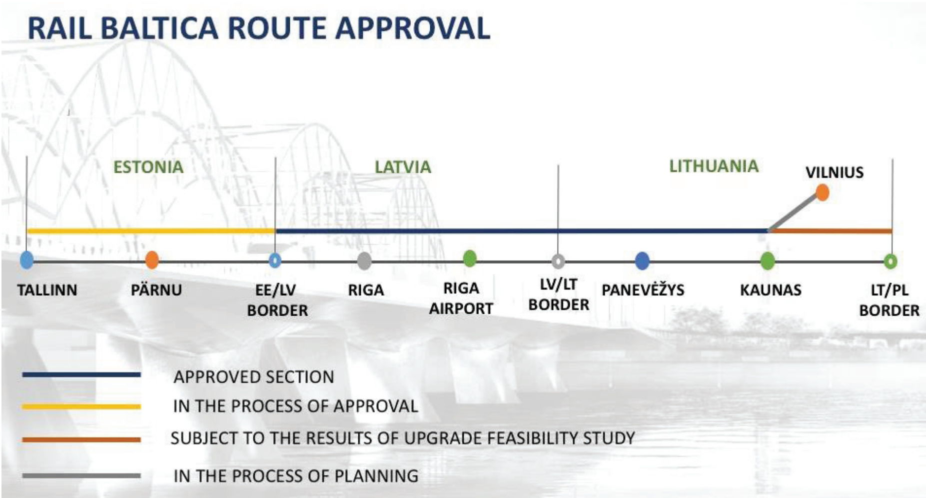

Fig. 1 “Rail Baltica” route [10]

2. Methodology

The purpose of this research is the introduction of European methods to justify the priority areas for the development of railway connection. Based on the methodology proposed in [12], which resolve into assessing the importance of routes by the geometric average criterion of several relative criteria

$$R_i = \sqrt[n]{\prod_{j=1}^{n} R_{ij}} \,, \tag{1}$$

where R_i – the value of the generalized rating of the i-th route; n – number of criteria; R_{ij} the value of the j-th relative criterion of the i-th route, which is defined by formula

$$R_{ij} = \frac{X_{ij}}{\sum_{j=1}^{k} X_{ij}} \,, \tag{2}$$

where X_{ij} – the j-th criterion for the i-th route, in paper [12] three criteria were proposed ($n = 3$): the ratio of the country area, the number of inhabitants in the country and the gross domestic product (GDP) to the time when the train is travelling within the country; k – number of routes.

If the area of the territory can be considered as constant value, the number of inhabitants and GDP can vary, and the denominator – that is, the train movement time is also not constant, because it depends on the state of the railway infrastructure, type of rolling stock, traffic schedule and so on. For further research, the authors of this study propose certain changes regarding the formation of these criteria.

Thus, in [13], unlike the known mathematical models, cities and regions that gravitate towards the highway are selected as objects of analysis. Such indexes as population in agglomeration, size of passenger traffic in international connection, the gross regional product (GRP) in agglomeration, transport mobility of population are considered. Indexes characterizing the technical and economic potential of the directions are the length, time of the passenger's journey, cost for reconstruction of the existing railway, tariffs for transportation, regularity and frequency of movement.

One of the important principles which is allocated in the assessing the transportation distribution options is the formation of passenger flows and the speed of passenger movement, not rolling stock. Let us review how these issues were addressed when considering ways to further developing the trans-European high-speed rail network. One of these projects, the Next Generation Train (NGT), was developed by eight institutes of the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt) – DLR [14]. The main idea of NGT is to determine the range of the high-speed network (HSN) in Europe, designed for the movement of new generation trains (NGT) at a speed of 400 km/h. The main nodes and criteria of the model included economic centers (cities), direct rail connections, train speed and travel time. In doing so, the volume of transportation and population of cities were calculated, regional preferences of passengers by transport modes were taken into account and so on. The obtained transport model has allowed forming the recommended testing ground for the network of new railway lines, proving the feasibility of the HSN construction at a speed of 400 km/h in the central part of Europe.

In assessing the importance of the route according to formulas (1), (2), in our opinion, it would be more reasonable to take into account not the total number of residents, but the volume of passenger traffic. For this target it is proposed to use the methodology presented in [15] to calculate the projected volumes of passenger traffic, which factoring in both transit flows of passengers through the territory of a country and the population in cities covered by the corresponding route. The annual number of passengers carried between two cities N_1 and N_2 according to the forecast:

$$P_{N_1-N_2} = k_{\text{mod}} \frac{(C_1+T_1)(C_2+T_2)}{C_1+C_2+T_1+T_2} k_m k_t k_s \,, \tag{3}$$

where $P_{N_1-N_2}$ – forecast of annual number of passengers carried between two cities N_1 and N_2, ths people; C_1, C_2 – city population N_1 and N_2 correspondingly, ths people; T_1, T_2 – transit passenger traffic at station N_1 and back from the station N_2, ths people; k_{mod} – the model factor is assumed to be equal 2; k_m – factor which accounts the mobility of the population; it needs to be clarified as the mobility of the population in different regions is different. For example, in Ukraine the overall ratio is 10.58, and for the long distance is 1.47 [7]; k_t –factor that accounts the period for the travel of passengers on a given section according to the average travel time of 4 hours, which ranges from 0.75 to 1.25; k_s – factor that accounts additionally the frequency passengers travels at a given section (business trip, change on a plane, rest, tourism), which ranges from 0.75 to 0.9 for cities with population up to 600 ths people; 0.9 – 1.1 for cities with a population of 600-1000 ths people and 1.3 - 1.5 for cities with a population of more than 1 million people.

Or taking into account the intermediate stations N_r between cities N_1 and N_m:

$$P_{N_1-N_m} = \frac{1}{\sum_{r=1}^{m} \frac{1}{P_{Nr}}} \,. \tag{4}$$

Another important parameter of methodology (1) – (2), which affects all the criteria, is the train travel time, which can be designated by the speed. Activities to reconstruct the railway sections, update their condition, modernize the infrastructure, etc. lead to changes in the route speed, usually in the direction of increasing.

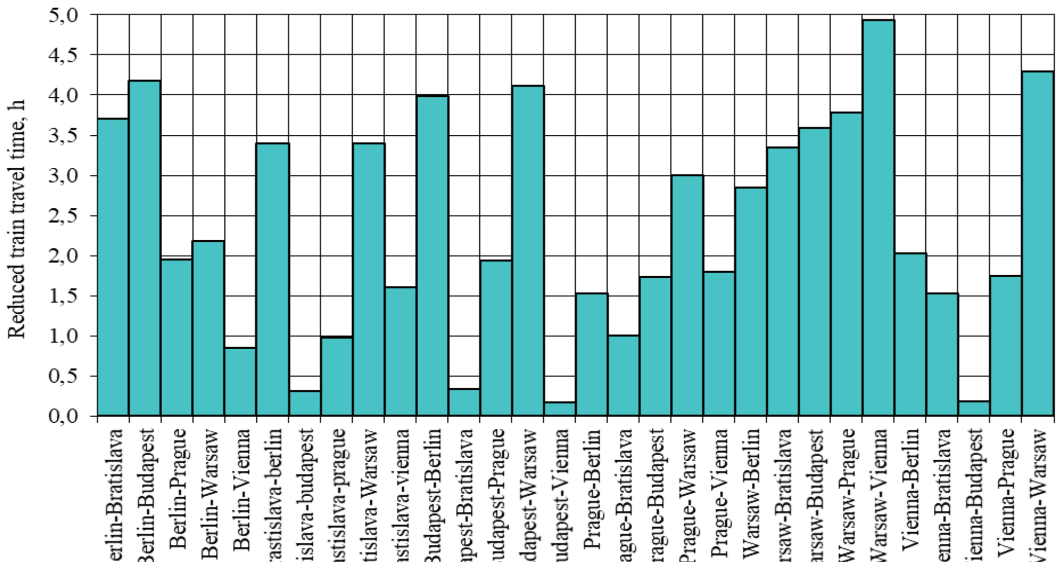

Fig. 2 Reduced train travel time in 2017 compared to 1990

On the basis of the data given in [16] and others, the status and prospects of development of international rail passenger traffic in Central and Eastern Europe have been analyzed. Fig. 2 shows a graph of the change in the time of movement of passenger trains, which showed that since 1990 to 2017, the travel time decreased from 0.2 and 0.3 hours respectively on Budapest-Vienna (261 km) and Bratislava-Budapest (215 km) short routes, up to 4.2 hours to Berlin-Budapest (993 km) and 4.9 hours in the direction of Warsaw-Vienna (672 km).

In addition to the significant impact of driving time on the ratings under consideration, it should be noted that such a characteristic as route speed may be considered as an additional (fourth) rating. And more importance should be given to a route with a lower route speed, such that after the appropriate reconstruction has the potential to increase its rating indexes.

3. Calculations

The testing ground of railway routes for further calculations by the above method is shown in Fig. 3.

Fig. 3 The testing ground of international railway routes

Fig. 4 shows the main characteristics of the sections, such as number of inhabitants, length and time of the movement. To improve visual perception, geographic distances and the number of inhabitants for key cities are scaled. When creating the image the material of free access from Google Map was used.

Based on the above, we propose a sequence of calculations, which is shown in Tables 1 and 2.

Table 1

Indexes that determine the development of countries and their importance in the region

Country	Area of the country, ths km^2	Number of inhabitants, millions of people	Gross domestic product, ths $/person
Germany	357,0	81,454	52,559
Czech Republic	78,9	10,572	37,371
Austria	83,9	8,685	52,137
Hungary	93,0	9,715	31,903
Ukraine	603,7	42,153	9,283
Lithuania	65,3	2,792	34,826
Latvia	64,5	1,920	29,901
Estonia	45,1	1,324	34,096

The ratio of values can be considered as relative criteria given in Table 1, over time (Table 2).

Table 2

Routes classification

Route	Distance, km	Travel time, hour	Estimated volumes of passenger traffic, ths persons
Warsaw-Berlin	563	6,1	741,3
Warsaw-Prague	743	6,7	459,1
Warsaw-Vienna	672	7,5	831,4
Warsaw-Budapest	879	7,3	419,7
Warsaw-Kiev	976	14,2	521,2
Warsaw-Tallinn	977	12,5	153,0
Warsaw-Kaunas	569	7,8	218,1
Vilnius-Kiev	813	14,5	245,3
Warsaw-L'viv	340	9,1	410,0

The results of calculations of the relative criteria are given in Table 3.

Table 3

The relative criteria that determine the importance of the route

Route	The ratio of the area of the country to travel time, ths km^2/h	The ratio of passenger traffic to travel time, thousand people / hour	The ratio of GDP per capita to travel time, ths $/h
	R_{i1}	R_{i2}	R_{i3}
Warsaw-Berlin	58,52	121,52	8,62
Warsaw-Prague	11,78	68,52	5,58
Warsaw-Vienna	11,19	110,85	6,95
Warsaw-Budapest	12,74	57,49	4,37
Warsaw-Kiev	42,51	36,70	0,65
Warsaw-Tallinn	13,99	12,24	7,91
Warsaw-Kaunas	8,37	27,96	4,46
Vilnius-Kiev	41,63	16,92	0,64
Warsaw-L'viv	66,34	45,05	1,02

Based on the data in Table 3, one can applying the multicriteria optimization methods to compare the importance of routes. Each route occupies a specific place according to the value of each relative criterion. Applying this principle, Table4 is drawn up.

Table 4

Priority of routes by relative criteria

Route	Place by ratio			Geometric average criterion, R_i *100	Route priority	Average route speed, km/h
	territories to travel times	volume of transportation to time on the road	GDP to travel time			
Warsaw-Berlin	2	1	1	22,56	1	92
Warsaw-Prague	7	3	4	9,45	3	111
Warsaw-Vienna	8	2	3	11,73	2	90
Warsaw-Budapest	6	4	6	8,43	4	120
Warsaw-Kiev	3	6	8	5,75	8	69
Warsaw- Tallinn	5	9	2	6,33	6	78
Warsaw - Kaunas	9	7	5	5,80	7	73
Vilnius-Kiev	4	8	9	4,39	9	56
Warsaw-L'viv	1	5	7	8,30	5	37

It should be noted that the above-considered task of establishing the priority of directions was solved in a direct formulation. Another solution to the problem is possible. That is, it is possible to define conditions (volumes of traffic, passenger travel time or route speed), under which a particular direction will become more priority (attractive) for international transport.

4. Conclusions

The methodology for assessing the importance of railway routes by generalized ratings reduced to the geometric a criterion has been further developed. The results were obtained for the countries of Eastern Europe, including the extension of the Rail Baltica line. The Warsaw – Berlin route received the highest rating, it coincides with the results given in [12].

In parallel with the results of assessing the priority of the route, Table 4 shows the values of route speed as an index of potential improvement opportunities for the considered criteria. Thus, the sections with the lowest values of the general criterion, such as Warsaw – Kyiv and Warsaw – Kaunas, have low route speed indexes, so they have the opportunity to improve their assessment through technical measures.

The geometric average of the relative criteria was applied as a composite index for assessing the routes. This approach can be considered acceptable for the formation of preliminary proposals. It is necessary to include the relativity of the considered criteria. First, each of them is determined by different technical and economic characteristics, which may not have equal weight for this comparison. Secondly, their values depend not only on the characteristics of the corresponding route, but also on the overall indexes of the test ground under consideration.

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