

Problems of providing international railway transport

*Mykola Kurhan*¹, and *Dmytro Kurhan*^{2,*}

¹Department of Roads Design and Construction, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan St., 2, Dnipro, Ukraine

²Department of Track and Track Facilities, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan St., 2, Dnipro, Ukraine

Abstract. Due to its geographic location and developed transport infrastructure, Ukraine has a significant potential in the development of cargo transportation, primarily in international traffic, in particular as a transitor country in the logistics chain of trade between Asia and Europe. The possibilities of railway transport for the organization of transportation between the countries of the European Union and Ukraine are not used to the full extent, since there is a number of technical reasons of the transport systems incompatibility between Ukraine and European countries. In the course of the research, methods of analysis and synthesis were used to study prospects of the European and domestic system of international railway transportations, the experience of creating, operating and optimizing these systems. To compare the above mentioned options, the authors developed a model for predicting and assessing the efficiency of railway transport from the border of one state to the border of the other one.

Introduction

Due to its geographic location and developed transport infrastructure, Ukraine has a significant potential in the development of cargo transportation, primarily in international traffic, in particular as a transitor country in the logistics chain of trade between Asia and Europe.

Ukraine's economy is dependent on the efficient shipment of bulk commodities such as coal, iron ore, steel, and grains – commodities that travel most economically over long distances by rail. The successful reform and restructuring of Ukrzaliznytsia will be a crucial part of Ukrainian economic reforms going forward [1].

According to the British Institute for Transport Studies, the transit rate of Ukraine is 3.75 (at a maximum of 5); it is the best indicator among European countries (for comparison, in Poland, which is second best, this figure is 2.92). Five international transport corridors pass through Ukraine; the expanded length of these routes is about 6.500 ths km, of which 3.500 are railways. In 2016, Ukraine joined the Coordinating Council for

* Corresponding author: kurhan.d@gmail.com

the Trans-Caspian International Transport Route (TITR) to China through Georgia, Azerbaijan and Kazakhstan.

The possibilities of railway transport for the organization of transportation between the countries of the European Union and Ukraine are not used to the full extent, since there is a number of technical reasons of the transport systems incompatibility between Ukraine and European countries, namely: different wheel gauge, characteristics of rolling stock, type of SSB, voltage in the contact network, dimensions, etc.

Future prospects for the integration of Ukraine's railways into the European transport network will depend on how successfully the tasks on the actual development of international transport corridors (ITC) will be solved [2, 3], on the availability of rolling stock ready to provide transport with governed speeds [4, 5], on political-economic and technical-technological problems of passenger turnover [6] and truck turn-around between Ukraine and Europe.

The basic part

Globalization of the economy and the development of modern supply chains contribute to the creating a transport product that would combine services of various transport modes in the most efficient and convenient way for consignors as well as it would be formed, first of all, on the basis of cargo interests, rather than individual participants in the process of transportation. Multimodal transportations have become such product, which are domestic or international transportation of products using several transport modes.

The object for the transfer in multimodal transportations, in principle, may be any cargo - bulk, unitized cargo. However, the most widespread are multimodal transportations using the so-called ITU (Intermodal Transport .Units, ITU) - containers, controllers, swap bodies. The cargo in ITU is all along the whole route, and all transport and cargo operations are not with heterogeneous packages, but with standard ITU (so-called reloading-free transport technology), which significantly speeds up and cheapens the technological processes, increases safety of cargoes and provides a wide range of other advantages.

The choice of the optimal transportation solution includes the rationale for the most profitable routes, the choice of rolling stock in accordance with the type of cargoes, the mode of cargo transportation (in which various modes of transport are used in stages), border stations technology, etc. [7].

Due to the intensive development of the integration processes of the Ukraine's railway transport into the European transport system, the following issues are of great importance: the functioning of the international transport corridors (ITC), the introduction of specialized rolling stock, which would allow operation both on the gauges of 1435 mm, and on 1520 mm ones, that is, application of European ASCS-technologies, based on 1520/1435 mm automatic gauge change systems [8]. This is development of "East-West" cars for direct cargo transportation by railways of various standards.

The study of international transportation technology can be summarized as following blocks: international transport corridors, rolling stock and operation of border stations (see Fig. 1).

In order to keep the transit volumes of cargo transportations in the direction of the sea trading ports, Ukraine has proposed to include additionally into ITC network directions leading to the Black Sea ports, Odessa, Nikolaev, and Kherson (Fig. 2).

Among the directions linking Lviv with the countries of Europe and the EU countries, two main ones can be delineated: one of them passes through the Mostyska II station and it is the shortest connection with Poland, Slovakia, the Czech Republic, Germany and other countries of Central Europe, as well as Scandinavia; The second direction passes through Chop and connects Ukraine with Slovakia, Hungary, Bulgaria, Romania and other countries

of Central and Southern Europe. The second direction according to design parameters and the longitudinal profile does not allow to realize high speeds. Particular attention should be paid to the section Lavochno-Mukachevo, where gradients of the longitudinal profile larger than 15 ‰ are about of 28‰, curves with a radius of up to 500 m - 29.3‰, and the speeds do not exceed 60-70 km/h.

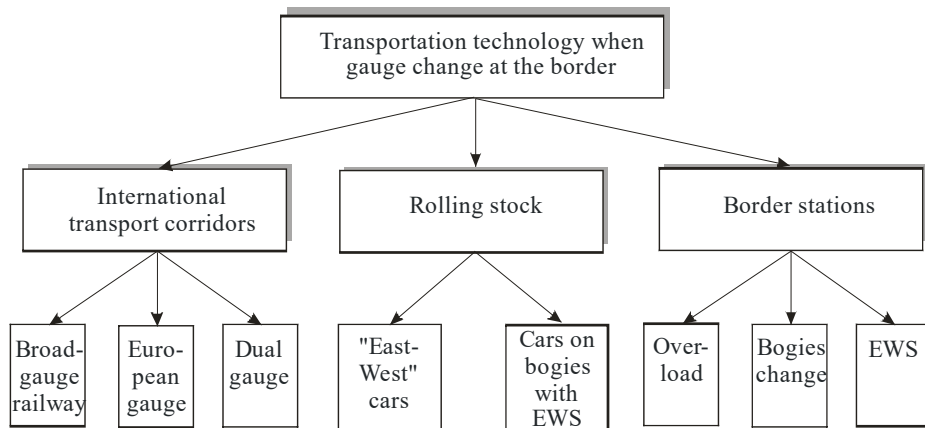


Fig. 1. The outline scheme of transportation technology at crossing the borders



Fig. 2. Passing of ITC to the Baltic Sea - the Black Sea through the territory of Ukraine

A significant obstacle in the ITC modernization No. 5 was the Beskidskiy single-track Tunnel built in 1886. The Beskidskiy Tunnel is of strategic importance, since it transits more than 40% of transit cargo to Western and Central Europe. The new Beskidskiy double-track railway tunnel was constructed at the expense of European Bank of Reconstruction and Development (EBRD) loan and own funds of railways in order to increase the transit potential of Ukraine, bringing to the relevant technical requirements of the International Transport Corridor and ensuring the safety of trains on the strategic

direction of Kyiv-Lviv-Chop. The capacity of the new tunnel is three times larger than the existing one.

The carried out analysis of the technical state and parameters of the Lviv-Chop route showed that main reasons that restrain the increase in speed (except the tunnel) are the plan of the line with insufficient lengths of transition curves and curves of small radii, state of the permanent-way (excessive wear of rails and railroad switches), state of the artificial structures and road bed.

Plan and profile of the line (Table 1), speed limit at stations and a number of other reasons cause the need to reduce the speed with respect to its maximum level.

Issues relating to the poor state of infrastructure are proposed to be solved in the process of reconstruction of the railway. It is more complicated to change parameters of the plan and profile of the line.

Table1. Profile and plan indicators on international transport corridors within Ukraine (in %)

International Transport Corridor	Gradients on the longitudinal profile $i > 8 \%$	Radius curves in plan $R < 700 \text{ m}$
ITC No. 3	7.2	7.8
ITC No. 5	23.0	19.5
ITC Gdansk-Odesa	10.0	2.6

It is obvious that the integration of the transport system of Ukrainian railways is possible only under keeping of interstate requirements regarding maximum speed, time of cargo and passengers delivery, travelling comfort, etc. These challenges can not be solved today without bringing the ITC infrastructure to a proper state. For example, the monograph of H. N. Kirpa [9] presents an analysis of the technical state and infrastructure of international transport corridors within Ukraine. The features of each corridor are marked, the priority areas are identified, their restructuring will accelerate the cargo and passengers delivery, interest European and other countries in transit traffic through Ukraine.

In paper [10] features of the simulation model of the transport system are presented on the example of Poland. The model reflects those properties of the system that are important from the standpoint of research, namely: features of the transport network, the model of demand for passenger and cargo transport, distribution mechanism of cargo traffic and passenger flows into the network. The model allows performing computational experiments and drawing conclusions with respect to the distribution of vehicles in the national transport system, taking into account emissions from transport activities.

The issue of the compatibility of transport systems remains complicated one. In paper [11], the main aspects of the system approach to the issue of railway transport compatibility are presented. It has been shown that despite the difference in control systems, electricity supply and operation of railways, various standards of track infrastructure, there is a need to solve the problem of integrating the railway transport systems. The article covers the main directions of the railway system operation, which depend on the introduction of interoperability.

The analysis of the ways for organizing the cargo transportation in international traffic with the European Union countries showed that the following options are subject to comparison: cargo transshipment, including in containers from rolling stock, gauge of 1520 mm on a rolling stock, gauge of 1435 mm; replacement of bogies at the gauge-changing areas when crossing rail joints of a different standard; application of a special rolling stock equipped with bogies with extensible wheelsets; continuation (use of the existing) broad gauge of 1520 mm from the borders of Ukraine to the territory of Europe; continuation of European gauge of 1435 mm from the borders of Europe to the territory of Ukraine; Use of the dual gauge 1435/1520 mm.

To compare the above mentioned options, the authors developed a model for predicting

and assessing the efficiency of railway transport from the border of one state to the border of the other one, taking into account all expenditures by the *NPV* indicator (Net Present Value of Discounted Cash Flow), which is the difference between total income (*D*) and all types of expenses taking into account the time factor (K_i – investments, costs in K_l – locomotive fleet, K_c - car fleet, C - current operating costs, and C_s - costs, depending on the type of technological operations and the time of freight cars presence at the station splicing of different gauges:

$$NPV(t) = \sum_{t=0}^{T_p} (D_t - K_{it} - K_l - K_{lt} - K_{ct} - C_t - C_{st}) \eta_t \quad (1)$$

Uncertainty and risks in assessing the effectiveness of options are taken into account through the modified discount rate, which is included in the calculation of discount coefficient of the different-time expenditures (η_t).

To determine the transfer fee, the International Railway Transit Tariff (ITT) was used. It applies for the cargo transportation, as well as for transportation through border and port stations [12].

Conclusions

During the simulation (1), such source data as the initial volumes and the rate of their growth over time, length of haul, the type of cargo and cars for transportation (containers on platforms, tanks, universal cars) varied, the speed of delivery, which depended on the state of the railway infrastructure on the international transport corridors etc.

Let us consider, how the cargo traffic volume (G_t) and the rate of its growth (ΔG) affects the transport process at a various length of cargoes transportations. For example it is accepted: $G_t = 5,0$ million tons/year. The length of transportation varied from 400 up to 2000 km.

At the same time, the largest total revenue is observed at length of haul of 1000 km (Fig. 3). If we set at 100% of the total revenue for the length of haul 400 m, then at a length of 600 km income increases by 26.1%, at a length of 800 and 1000 km, respectively, by 56.1 and 85.6%. At lengths greater than 1000 km the profit decreases and at a length of 1700 km becomes negative. So, short routes of 600-1400 km are desirable.

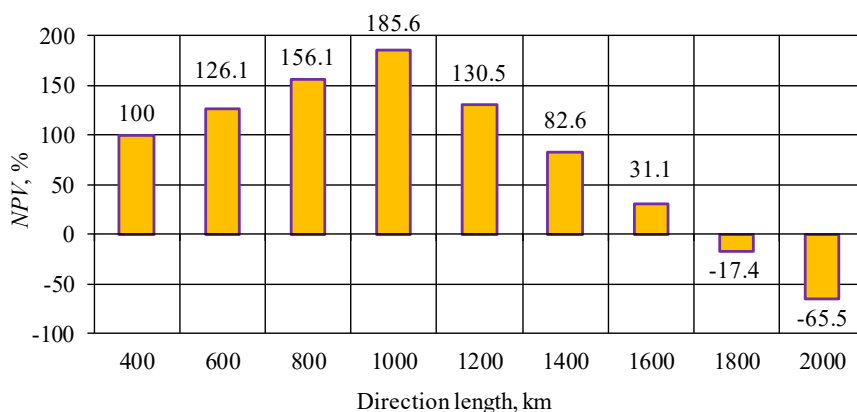


Fig. 3. Change in net present value (%), depending on on length of haul

To study the impact of the sectoral speed value on the final result, calculations are

presented for a length of 1000 km at values of the sectoral speed from 30 to 60 km/h (for further extension) km/h. According to the obtained results, a diagram of the change in net present value $\sum_{t=1}^{15} NPV_t$ was constructed (Fig. 4) in comparison with sectoral speed (V_s) of 30 km/h.

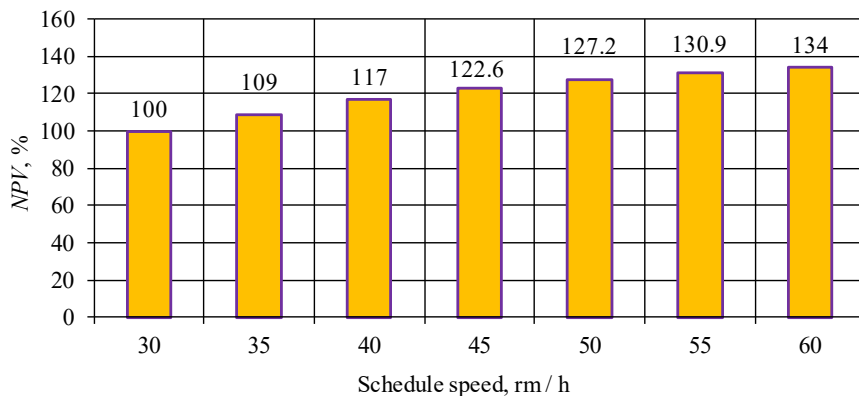


Fig. 4. Change in net present value, depending on the level of sectoral speed

The analysis of the diagram makes it possible to conclude that there is a need for modernization of international transport corridors in order to increase the speed affecting the circulation of rolling stock, the need for them to carry out transportations and, as a result, to obtain revenues from transportations. From analysis, it may be the recommended sequence of events. Thus, an increase V_s from 30 to 40 km/h leads to an NPV increase by 17.0%, with an increase V_s from 40 to 50 km/h - by 10.2%, and from 50 to 60 km/h - by 6.8%.

References

1. R. Pittman, Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, **1(67)**, 34-50 (2017).
2. M. B. Kurhan, D. M. Kurhan, *Theoretical basis for the introduction of high-speed trains in Ukraine*, DNUZT, Dnipro, Ukraine, 283 (2016).
3. F. Horvat, S. Fischer, Közlekedésépítési Szemle, **59 (5)**, 33-37 (2009).
4. Ju. V. Demyan, Ju. V. Vereshhak, Visnik of the Volodymyr Dahl East Ukrainian National University, **5(147)**, 167-172 (2010).
5. S. Fischer, Acta Technica Jaurinensis, **8(3)**, 240-256 (2015).
6. M. B. Kurhan, D. M. Kurhan, Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, **6(72)**, 40-48 (2017).
7. M. B. Kurhan, E. V. Voznaya, Ukraine Railway, **12(18)**, 24-33 (2014).
8. M. Szkoda, Eksploatacja i Niezawodnosc. **16 (3)**, 422-432. (2014).
9. G. M. Kirpa, *Integration of Ukraine's railway transport into the European transport system*, (DNUZT, 2004).
10. M. Jacyna, M. Wasiak, K. Lewczuk, M. Kłodawski, Archives of Transport, **(31)**, 23-35 (2014).
11. J. Szkopiński, Archives of Transport, **(29)**, 65-75 (2014).
12. *International railway transit tariff (Tariff 8100)* (Official Edition of OSJD, 2018).