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PROVIDING THE RAILWAY TRANSIT TRAFFIC UKRAINE–EUROPEAN UNION

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Abstract: 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 net present value indicator net present value of discounted cash flow. The results allows planning measures to accelerate the cargo delivery, both on the territory of Ukraine, and during the transfer of cargoes at border stations, to predict the revenue generation from the implementation of international transportation, which is very important for attracting investments.

Keywords: Railway transit, International transport corridors, Intermodal transportations, Variable gauge, Automatic gauge change system, Prediction models, Evaluation indicators

1. Introduction

The economic development of states depends largely on the operation of the transport system, which has to ensure reliable, safe and efficient operation of cargo transportation both within the country and abroad. The facilitation of borders crossing procedures by the railway transport, the experience of railways in accelerating the passing of borders during international railway transportation in the Eurasian space, and others are discussed in [1].

Railway transport in Ukraine is the main carrier of cargoes, accounting for 65% of all cargo transportations and 81% of cargo turnover (excluding pipeline transport).

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In addition, about 55% of the total volume of international cargo transportations in Ukraine is carried out by railways. In 2017 year, international transportations accounted for about 50% of the total volume of railway cargo transportations. In the structure of international cargo transportations the largest share is export cargoes - 66%, for comparison, import - 23%, transit - 11%.

Further prospects for the integration of Ukrainian railways into the European transport network depend on the following provisions: how successfully the tasks of real development of International Transport Corridors (ITC) [2] will be solved; from the readiness of the railway lines, included in the ITC, to their efficient usage for international transportations; from the availability of rolling stock, which will provide transportation with the governed speeds [3]; from congruity design parameters with the relevant international standards [4], from solving a number of politico-economic, as well as technical and technological problems for the development of the lines connecting Ukraine with Central and Western Europe [5], [6].

The rolling stock used for international transportation is primarily connected with technical and technological support of passengers and cargo transportation by international transport corridors with the passing through the division points of railways, gauge of 1520 mm and 1435 mm.

When crossing through the division points of railways, gauges 1520 mm and 1435 mm, various technologies are used at the border stations: cargo transshipment, replacement of cars with changing the bogies, usage of extensible wheel-sets, etc.

In accordance with the analysis of the process of car traffic volume across the territory of Ukraine, border stations are one of the ‘narrowest’ places in the logistics chain of international railway transportation, as evidenced by considerable trains and cars detention when passing them on interstate transitions.

The main border stations at border crossings with railways of the third countries are shown in *Table 1*.

Today, the existing broad-gauge network of 1520 mm actually ends at the eastern border of the European Union. Some broad-gauge corridors go to the territory of the European Union, significant of them are from Ukraine to Katowice in Poland, to Zahony in Hungary, to Kosice and to Čierna nad Tisou in Slovakia. In order to attract transit railway transportation, European countries create and develop intermodal and container terminals near their borders on the line of ‘New Silk Road’. Ukraine has not yet made global steps, but at the same time has several transshipment complexes located on the border with the EU countries, which are engaged in cargo transshipment from the European gauge to the broad one. For example, ‘Terminal Carpathians’ handles about 50% of cargoes that come from Europe to Ukraine via the railway hub in Chop. Production facilities are located 20 km from the city, Batove. This location allows the terminal to service cargoes from Hungary, Slovakia and Romania.

The purpose of the paper is to study the development of railway transit transportations in international traffic, to identify problematic issues when crossing the borders in the ‘Ukraine-EU’ traffic and ways of their elimination. It will open new opportunities for attracting transit through Ukraine. The authors presented some preliminary results in papers [7], [8].

Table I

Border stations and destination countries

Main stations at border crossings	Major destination countries
Dyakove - Khalmeu	Romania, Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Macedonia, Montenegro, Bulgaria
Uzhhorod - Matevtse	Slovakia, Czech Republic, Austria, Serbia, Montenegro
Chop - Čierna nad Tisou	Slovakia, Czech Republic, Austria, Germany, Switzerland, Poland, Hungary, Serbia
Chop - Zakhon	Hungary, Italy, Austria, Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Macedonia, Montenegro, Germany, France, Switzerland
Batevo - Epereshke	Hungary, Italy, Austria, Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Macedonia, Montenegro, Germany, France, Switzerland
Izow-Hrubieszow	Poland, Germany
Yagodin - Dorohusk	Poland, Germany
Mostyska II - Medica	Poland, Germany. Czech Republic
Rava-Ruska-Verkhart	Poland, Germany
Vadul-Siret - Vikshany	Romania, Bulgaria, Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Macedonia, Montenegro

2. Consideration of options

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:

1. Cargo transshipment, including in containers from rolling stock, gauge of 1520 mm on a rolling stock, gauge of 1435 mm;
2. Replacement of bogies at the Gauge-Changing Areas (GCA) when crossing rail joints of a different standard;
3. Application of a special rolling stock equipped with bogies with Extensible Wheel-Sets (EWS);
4. Continuation (use of the existing) broad gauge of 1520 mm from the borders of Ukraine to the territory of Europe;

The longest section of the railway with a gauge of 1520 mm is used in Poland - about 395 km (Izow-Hrubieszow-Slavkov) and in Slovakia - about 90 km (Uzhgorod-Kosice). In the direction of Hrubieszow there is an export, and in Slavkov there is an import. More than 50% of cargoes transported to Slavkov are iron ore. Coke and coal mainly are transported back to the east. There is a promising international project for the construction of the Kosice-Bratislava-Vienna broad-gauge railway line (the Eurasian Railway Corridor). Ukraine takes part in it. The project envisages both the construction of a new railway and the reconstruction of the existing railway infrastructure in direction Lviv-Chop Cretan ITC No. 5 (Triest-Ljubljana-Budapest-Bratislava-

Uzhhorod-Lviv). The commissioning of a gauge of 1520 mm to Vienna will significantly increase the flow of cargo transit through the territory of Ukraine. According to railway track calculations, traffic volumes will be at least 30-40 million tons per year. Also, this gauge will make it possible to reduce the cost of transit cargo transportation by railway, so the costs for cargo loading and unloading in the border area are excluded.

5. Continuation of European gauge of 1435 mm from the borders of Europe to the territory of Ukraine;

Continuation of European gauge of 1435 mm from the borders of Europe to the territory of Ukraine can take place in the case of constant mass volumes of traffic during reloading-free technologies by entering the railway track of the importing state into the territory of the exporting state. In Ukraine, there is already experience of using the European gauge. Thus, trains from Slovakia to Romania pass through the European gauge on the Ukrainian territory (Chop, Batevo, Korolevo, Dyakove) without changing the wheelsets. The longest railroad section, gauge of 1435 mm, used on the territory of Ukraine - 112 km (Chop-Dyakovo). Ukraine and Hungary are considering the possibility of putting on the Mukachevo-Budapest train on the European gauge, which will save a lot of time for tourists.

6. Use of the dual gauge 1435/1520 mm.

At Lviv railway, the total length of the dual railway track (1520 and 1435 mm) is about 150 km. This gauge is laid on the railway line sections: the State Border - Mostiska-1, the State Border - Chop-Batevo, the State Border - Yagodin - Kovel, etc. These sections are included in the international transport corridors (Cretan No. 3, No. 5 and Gdansk-Odesa). The main disadvantage of the dual gauge is that it requires junctions and bypasses of separate points due to the need to lay off the turnouts for normal 1520 mm gauge and European 1435 mm one, and as the result a significant decrease in the speed of the trains when crossing separate points.

3. Methods for evaluating the effectiveness of options

Each of the options for organizing regular transportation requires some costs, as well as it has both advantages and disadvantages. The following major principles are base in the evaluating the effectiveness of the project: consideration of the option (project) throughout the calculation period, positivity and maximum effect, time factor record, the inflation impact, uncertainty, risks [9], and suchlike. It is recommended that the beginning of the calculation period should be taken as the date of allocation of funds for the project work. The basis for the preliminary assessment is the methodology developed by the United Nations Industrial Development Organization (UNIDO).

The evaluation can be carried out according to the following indicators:

– Net Present Value (NPV) of discounted cash flow - is the difference between total income and all types of costs, taking into account the time factor.

Discounting of monetary expenses is carried out by multiplying them on the discount factor;

- Internal Rate of Return (IRR) is defined as the annual coefficient of capital investments, which ensures that the costs and incomes for the 'life' term of the investment are equal to zero. The project is considered to be effective if the IRR is not lower than stable bank rates;
- Pay-Back Period (PBP) of capital investments represents the payback period, during which the income minus operating costs (functional and administrative) reimburses the basic capital investments;
- maximum Cash Outflow (CO) - this is the most positive net present value.

There is a large number of researches of domestic and foreign authors concerning the practical aspects in choosing the certain indicators of the investment projects efficiency [10], [11]. For example, in paper [12] it has been shown that in American companies, the main indicators of the investment projects efficiency were the IRR criterion (76%) and the NPV evaluation method (75%). In the UK, the difference in the popularity of the IRR and NPV criteria for assessing the investment attractiveness of the project was also 1% (81% and 80% respectively). In the Netherlands, according to research results, the NPV criterion is the most popular method for assessing the investment projects efficiency; the criteria for IRR and PBP are used by Dutch companies to be approximately equally (89% and 84% respectively). In Canada, the most popular criterion used in Canadian companies was NPV, followed by the IRR and the PBP. In Australia, research has shown that the most popular criterion for determining the projects efficiency is the NPV criterion. Widely used method of determining the payback period is: the percentage of NPV usage was 94%, a simple payback period was 90%.

In China, the most popular evaluation methods are the IRR criterion and the method for determining the payback period of the project. Less than half of Chinese companies use the NPV criterion.

Numerous results of research confirm the hypothesis that large organizations abroad prefer to use more advanced and complex from the point of view of calculation criteria for investment justification, - NPV and IRR.

4. Model for predicting and evaluating the effectiveness of options

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, which is the difference between total income (D_t) and all types of expenses taking into account the time factor (K_t - investments, costs in $ZLoc_t$ - locomotive fleet, $Zcar_t$ - car fleet, C_t - current operating costs, and S_t - costs, depending on the type of technological operations and the time of freight cars presence at the station splicing of different gauges (according to options 1-6):

$$NVP(t)=\sum_{t=0}^{T_p}\left(D_t-K_t-ZLoc_t-ZCar_t-C_t-S_t\right)\eta_t\,. \tag{1}$$

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 [13].

The tariff is determined depending on the distance of transportation, and, the highest growth rate of the fee (by an average of 10% for every 100 km) is observed at distances up to 1000 km and only 0.5% - at greater distances. This, as it will be shown below, has a significant effect on the eventual outcome.

The description of the model is given in the *Table II*, and *Table III*.

Table II

Simulation of the cost for cargo transportation and transshipment at station splicing of different gauges (Distance 1500 km, gross train weight 1200 tons, number of cars 40)

1	Years, t		1	2	3	…	13	14	15	Totaly:
2	G, million tons		5	5.5	6		11	11.5	12	
3	Number	n, day	13	14	15		28	29	30	
4	of trains	N, year	4745	5110	5475		10220	10585	10950	
5	Loc, pcs.		57	61	65		122	126	131	
6	$ZLoc$, million €		228	16	16		36	16	20	524
7	Car, pcs.		2264	2438	2613		4877	5051	5225	
8	$ZCar$, million €		452.8	34.8	35		69.8	34.8	34.8	1045
9	K, million €		30	0	0		0	0	0	30
10	D, million €		323	348	373		696	721	745	7976
11	C, million €		120.7	130	139.3		260.1	269.4	278.6	2981.4
12	S, million €		7.47	8.05	8.62		16.1	16.67	17.25	184.5
13	η		0.926	0.857	0.794		0.368	0.34	0.315	
14	NPV, million €		-477.8	136.4	138.2		115.5	130.8	124.3	1384.2
15	Progressive		-478	-341	-203		1129	1260	1384	

Analogically, tariffs are formed in many countries, for example, on US railways, in the conveyance in low-priced bulk or in destinations where there is competition from other modes of transport, in other words, there is a tariff lower than that for cargo transportation, which can only be transported by railway. The transportation distance is conditionally divided into zones of economic efficiency of cargo delivery. The better the state of highways and modern trucks, the higher will be the zone of economic efficiency under other equal conditions. The above applies with regard to railway transport. On the other hand, it is also evident that the zone of economic efficiency of the cargo delivery decreases with the increase in the costs of consignors.

For a detailed description of the model, the authors consider the NPV calculation example. The results of calculations for one of the numerical options in application of a special rolling stock equipped with bogies with Extensible Wheel-Sets (EWS) are given in *Table II* and in *Fig. 1-Fig. 3*.

Table III

Calculated values that are included in the mathematical model

Row Tabl. 2	Value	Explanation of appropriate values
1	2	3
1, 2	t, G_t	The number of target year $t = 0, 1, 2, ..., T$ (T -accounting period) and appropriate cargo traffic G_t. It allows investigating the impact of cargo traffic G_t and the rate of its growth ΔG on the transportation process: $G_t = G_0 + \Delta G t^a$, $a \in (0.8; 1.2)$, approximation result.
3, 4	n_t, N_t	The number of trains passing per diem n_t and year N_t, depends on the mass of the freight train net weight Q_{net} with the known cargo traffic G_t and the annual coefficient of irregularity of transport γ: $n_t = G_t \gamma 10^6 / 345 Q_{net}$
5, 6	Loc_t, $ZLoc_t$	Inventory locomotive fleet Loc_t and predictive annual investments for the purchasing of locomotives $ZLoc_t$, which, in turn, depend on the number of trains per diem, the transportation distance and the sector speed.
7, 8	Car_t, $ZCar_t$	Inventory locomotive fleet Car_t and predictive annual investments for the purchasing of cars $ZCar_t$, which, in turn, depend on the number of trains per diem, the number of platforms, the transportation distance and the sector speed
9	K_t	Predictive investments K_t for the reconstruction of the railway infrastructure and border station, providing transportation and technological operations with cargo
10	D_t	Predictive annual revenues D_t, which will be received as the transfer fee in international railway traffic. For gauge changing of loaded cars or containers from cars, a charge is calculated for the transportation across the border by the consignee
11	C_t	Predictive annual operating costs C_t for transportation. They were accepted according to the statistics of costs on Ukrainian railways, based on the cost of 1 train-km and 1 train-hour [14].

Table III (*Continued*)

Calculated values that are included in the mathematical model

Row Tabl. 2	Value	Explanation of appropriate values
1	2	3
13	η_t	$\eta_t = 1/(1+E)^t$ discount coefficient of the different-time expenditures. Socio-economic discount rate E, which is included in the formula, characterizes the minimum requirements of the society to the socio-economic efficiency of projects. The research adopted the norm E=0.08.
14	NPV_t	Net present value - formula (1)
15	$\sum_{t=1}^{T} NPV_t$	Progressive total of net present value

Calculated formulas for determining the cost of rolling stock:

– the cost of the inventory fleet in t-th year for locomotive fleet:

$$ZLok_t = P_{lok} Lok_t \,, \tag{2}$$

where $Lok_t = \left(\frac{2L}{V} + t_1 + t_2 + \sum_{i=1}^{m} t_i \right) \frac{1}{24} n_{car\ t} k_{car-inv}$;

– the cost of the inventory fleet in t-th year for car fleet:

$$ZCar_t = P_{car} Car_t \,, \tag{3}$$

where $Car_t = \left(\frac{2L}{V} + \sum_{i=1}^{k} t_3 + \sum_{i=1}^{r} t_4 \right) \frac{1}{24} n_{car\ t} k_{car-inv}$.

In the formulas (2), (3) P_{lok}, P_{car} are the locomotive price and car price; L is the length of the traction service area, km; V is the average local speed of train movement, km/h; t_1, t_2 are the locomotive's locating time in the main and reverse depot, respectively (equipment, technical inspection, etc.); $\sum_{i=1}^{m} t_i$ is the locomotive's locating time on $m-1$ stations of change of brigades, hours; $k_{car-inv}$ is the coefficient of transition from worker to inventory fleet (taking into account locomotives under repair and reserves); $\sum_{i=1}^{k} t_3$ is the ineffective time of cars at a station with technical operations, hour; $\sum_{i=1}^{r} t_4$ is the ineffective time of cars at stations of loading and unloading, hour; k,

r are the number of stations where the technical operations with cars, loading and unloading of cars respectively are performed.

5. Research results

Cargo transshipment, and changing bogies at the points of changing the wheel gauge of various standard - these are measures that are widely used at the border stations of Ukraine. Taking into account the limited format of material presentation, in this article the accents are made on the application conditions of the special rolling stock equipped with bogies with extensible wheel-sets (adjustable-gauge bogies) (option 3).

At present, on the order of Ukrzaliznytsia (state-owned enterprise of rail transport in Ukraine), the research project 'Scientific and technical support for the sustainable development of railway transportations in the international traffic Ukraine-EU is executed within the framework of which, among other things, it is planned to introduce rolling stock with Ukrainian extensible wheel-sets.

The model developed by the authors allows obtaining the solution of the inverse problem - determining the sphere of effective application for the chosen transportation option.

During the simulation, 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.

With stable flows of cargo $G_t = 5.0$ million tons/year the term for the appearance of net present value $\sum_{t=1}^{15} NPV_t$ is: at length of haul up to 1000 km - about three years (*Fig. 1*), at length of 1800 km - the 7th year, 2000 km - the 9th year, (*Fig. 2*).

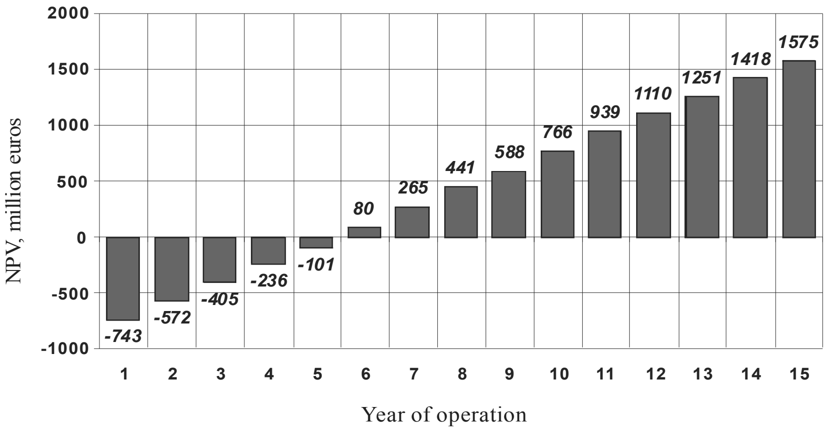

Fig. 1. Diagram of NPV distribution by years

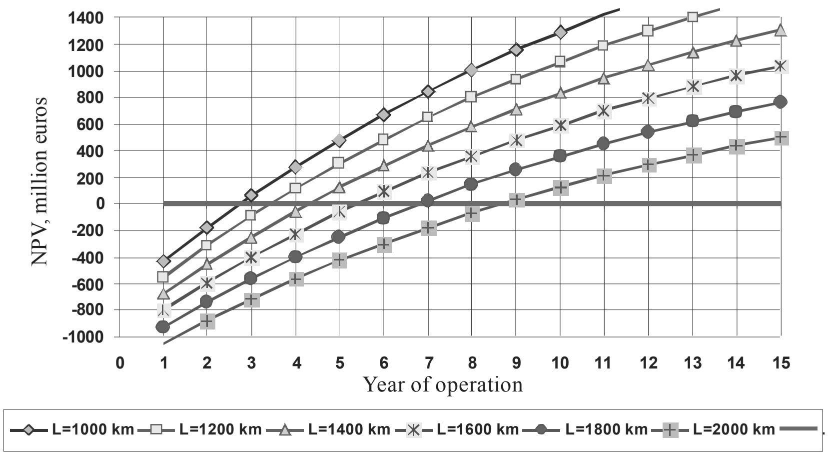

Fig. 2. Dependence of NPV on the length of haul more than 1000 km

With the source data, considering in the example, with a distance of 1700 km and more investments in a locomotive and car fleets, current operating costs and costs, depending on the type of technological operations and the time of freight cars presence at the station splicing of different gauges exceeds the income received by Ukrzaliznytsia. It follows that costs vary according to the linear law and their growth rate depends on length of haul and, as it will be shown below, - on the traffic volumes. Annual revenues and losses depend on the type of cargo, means of transportation and other factors affecting the transportation fee.

This way, short routes of 600-1400 km are desirable. In addition, as mentioned above, technical problems related to the design and manufacture production of EWS should be solved, and their cost should be reduced by at least 20%, as it is confirmed by the study [15].

Based on charts in *Fig. 2* an explanation can be provided regarding the optimum period for the emergence of net present value at the length of 1000 km (*Fig. 3*).

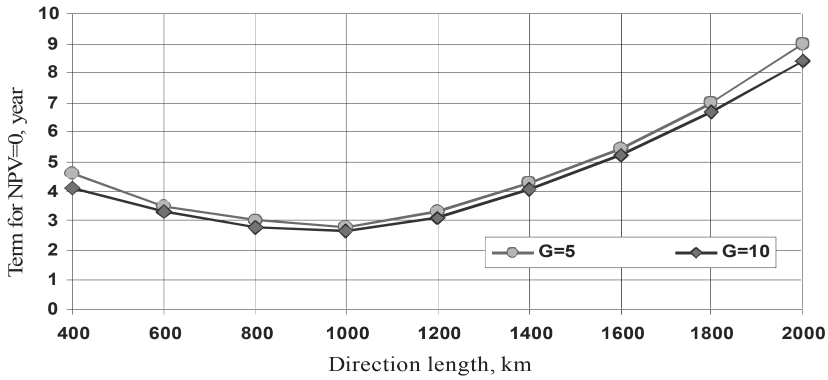

Fig. 3. The term when net present value comes depending on length of haul

The conducted research have shown that parameters and state of the international transport corridors affect the efficiency of the use of one or another option of cargo transportation (1-6) under other equal conditions. The sectorial speed V and, as a result, the required number of rolling stock for transportation depends on these parameters (see Eqs. (2) and (3)).

As the analysis showed, the average sectorial speed on the Ukrainian railways is 38 km/h and ranges from 28-33 km/h on the Donetsk and Lviv railways to 42-47 km/h on the South and Southwest Railways.

6. Conclusions

Having researched various ways of cargo transportation by international transport corridors and various options of the transition of rolling stock across the border (cargoes transshipment, changing the car bogies, application of rolling stock equipped with EWS, using the broad-gauge railway of 1520 mm from the borders of Ukraine to the territory of Europe, continuation of the European gauge of 1435 mm from the borders of Europe on the territory of Ukraine, the use of a dual gauge 1435/1520 mm, it is possible to draw the following conclusions: in option 3 (application of EWS), it is most expedient to use cars equipped with extensible wheel in directions with stable cargo traffic, that form short routes at the length of 600-1200 km. In this case, technical problems related to the design and manufacture of the EWS should be solved, and their cost should be reduced by at least 20%. Wide using the EWS technology for cargo transportation is problematic, but it has the advantage over others when transporting valuable and dangerous goods. The type of cargo and the delivery time factor can be decisive.

Taking into account the significant volumes of transportation in the East-West direction, as well as the favorable geographical position of Ukraine, it can be argued that creating efficient modes for organizing the cargo transportation in international traffic with the EU countries will allow attracting the additional volumes of transit cargo traffic. The positive experience, first of all in the European Union countries, has shown that if there is an efficient transport network and an advanced system for the cargo transfer at the points of changing railway infrastructure standards, both domestic and transit cargo traffic increase significantly, which makes it possible to increase the attractiveness of the country in the international transport system. The results obtained in the authors' research allow us to conclude that international transportation carried out through the territory of Ukraine has certain special characteristics. Changing railway gauge standards at the border with European countries are forcing to look for the most rational routes for cargo transportation (taking into account the length, technical state and parameters of the ITC, delivery speed, etc.) and rational technologies for the reloading-free transfer of cargoes at the border points, which will lead these transportations to an innovative way of development. The obtained results allow bringing the scientific basis for the creation and further development of the modern national system of intermodal transportations, as well as optimization of parameters of its individual units for further integration into the European transport system.

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