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Some Issues of the Project Analysis of Options for the Implementation of European Standard Railways in Ukraine

OLEH STRELKO[a], BORYS TOROPOV[a], ANATOLII HORBAN[a], TETIANA HRUSHEVSKA[a], ARTEMII BERNATSKYI[a,b]

a. State University of Infrastructure and Technologies, 9, Kyrylivska str., Kyiv, 04071, Ukraine
b. E.O. Paton Electric Welding Institute of the NAS of Ukraine, 11, Kazymyra Malevycha str., Kyiv, 03150, Ukraine

ABSTRACT: The possibility of more dynamic development of economic, social, and political relations of Ukraine with the countries of Central and Eastern Europe, including with Poland and the countries of the European Union, is the basis of the idea of building railway lines of the European standard. Political and socio-economic circumstances in Ukraine require acceleration of the necessary organizational, technical, technological, and economic research. Implementation of such a large-scale project in Ukraine can be carried out with the participation of foreign partners. The partners' decision to participate in the project will be based on the results of the project analysis. It has been proven that not only the cost of design, search and construction and installation works for a certain infrastructure, but also the method of its calculation will be of great importance for making a reasoned decision. There is a well-founded need to consider the cost of performing works on the station infrastructure complex, both the port economy itself and railway stations in the port's catchment area. The preliminary assessment of the project should begin with its proper identification in the context of a broader investment program due to its impact on the economic, social, and political components of the European Union. There is a well-founded need to determine the geographical area on which the cargo flow can be generated. An essential element of the societal analysis is that the magnitude of the effect decreases significantly as the time interval decreases, and the elasticity results are much higher with national-level data than when using regional-level data. The mentioned provisions are important factors to consider in the project analysis of the introduction of the European track on the railway network of Ukraine in view of making a positive decision for Ukraine regarding the participation of foreign partners in this project and its financing.

KEYWORDS: Railway transport system; European track; Speed and high-speed traffic; Railway infrastructure; Transportation

1. INTRODUCTION

An important component of the quality of life of society is the infrastructure potential of the transport system (Kuşkapan, Çodur, Tortum, Tesoriere, & Campisi, 2022; Ursarova, Mussaliyeva, Mussabayev, Kozachenko, & Vernigora, 2022; Strelko, Solovyova, Berdnychenko, Kyrychenko, & Solovyova, 2023). According to Erhova, Bondarenko, Shibko, & Velmagina, (2018), Strelko, Kyrychenko, Berdnychenko, Isaienko, & Tverdomed, (2019); Németh, Horváth, Movahedi, Németh, & Fischer (2022), this potential should grow (develop) at a faster pace to meet the growing needs of the population and economic sectors. The growing needs are not only an increase in the volume of transportation, but also the quantity and quality of the provided transport services (Aripov, Aliyev, Baratov, & Ametova, 2016; Statyvka, Kyrychenko, Strelko, & Berdnychenko, 2021; Halder et al., 2023).

The priority direction of the social, scientific and technical policy of the transport system of Ukraine in general and railway transport in particular is the achievement of the world level of quality of transport services (Potapov, Vitolberg, Shumyk, Ovcharenko, & Bulgakov, 2018) and the necessary technical (Tverdomed, Tkachenko, Sapronova, Aharkov, & Fedorova, 2019; Romanova et al., 2021; Goolak et al., 2022; Gubarevych, Gerlici, Gorobchenko, Kravchenko, & Zaika, 2023) and technological parameters (Shramenko, N. Y., & Shramenko, V. O., 2018; Shpachuk, Chuprynin, Suprun, & Garbuz, 2018; Soloviova, Strelko, Isaienko, Soloviova, & Berdnychenko, 2020). The integration of Ukrainian railways into the pan-European transport system requires solving a number of issues regarding the compatibility of the technical characteristics of partner railways (Fesovets, Strelko, Berdnychenko, Isaienko, & Pylypchuk, 2019; Ugnenko et al., 2019; Strelko, Yurchenko, Vasilova, Gusar, Rudiuk, 2022). The issue of track width and other related elements of the railway transport infrastructure is brought to the fore: electrification systems, safety (Pitsenko, Muradian, & Myamlin, 2021) and train traffic management (Kurhan, M., & Kurhan, D., 2019), dimensions of approaching buildings and rolling stock (Strelko, Kyrychenko, Berdnychenko, Petrykovets, & Soloviova, 2020), and other components (Fomin, Gorbunov, Gerlici, Vatulia, Lovska, & Kravchenko, 2021; Bernatskyi et al., 2022; Panchenko, et al., 2023).

The relevance of the study lies in the fact that the currently existing political and socio-economic circumstances require the acceleration of urgent research in the organizational, technical, technological, economic direction regarding the introduction of a European standard railway track in Ukraine, in particular, the choice of track width, route parameters and track structure, characteristics of rolling stock, the concept of infrastructure construction, etc. In turn, there is a need to adequately evaluate a significant number of possible technical and technological options for solving the given problem.

2. ANALYSIS OF THE RECENT RESEARCH

At one time, Ukrainian scientists and specialists dealt with issues of increasing traffic speeds in Ukraine: A.A. Bosov, I.P. Korzhenevych, and A.P. Zubko (Bosov, Korzhenevych, Kurhan, & Zubko, 2005), Yu.S. Barash (Barash, Bobyl, Charkina, Bozhok, & Chornovil, 2018), V.L. Dykan (Dykan, Obruch, & Dmytriiev, 2023), H.M. Kirpa (Kirpa, Bosov, & Korzhenevych, 2004), O.H. Kirdina (Kirdina, 2010), M.B. Kurgan and D.M. Kurgan (Kurhan, M., & Kurhan, D., 2019), V. K. Myronenko and V.M. Samsonkin (Myronenko, Samsonkin, Yurchenko, & Pozdniakov, 2022) and others; the Research and Design Research Institute of Transport Construction "Kyivdiprotrans", the Design Institute "Dniprodiprotrans" and the Institute of Technical Mechanics.

In work of Dykan, Obruch, & Dmytriiev (2023), based on a systemic approach and analysis of world experience, theoretical provisions were developed, methodological approaches and practical recommendations were proposed for determining the parameters of the technical possibilities of introducing high-speed traffic on the railway network of Ukraine. The paper (Barash, Bobyl, Charkina, Bozhok, & Chornovil, 2018) provides theoretical provisions for evaluating and justifying the choice of methods of transporting goods by railways with different standards, taking into account volumes, prospects for changes in volumes and sizes of transportation; stages and sizes of investments in the project, income generation, as necessary components of the project analysis. In the work by Novikova, Yurchenko, & Rudyuk (2017), a mathematical model is presented, which includes the determination of the cost of the station infrastructure as the sum of its components; possible variants of the Odesa – Kyiv – Lviv high-speed railway route were considered (new route, reconstruction of the existing line for different speed parameters), an experiment was carried out to evaluate variants of the choice of rolling stock. In the work by Myronenko, Samsonkin, Yurchenko, & Pozdniakov (2022), an improved methodology of project analysis is presented and an approach to establish the socio-economic feasibility of implementing high-speed passenger train traffic on the railway network of Ukraine is proposed.

Interoperability consists in the system's ability to interact with other systems: in this case, the possibility of joint technical and technological functioning of railway networks. The railway transport system of Ukraine is not interoperable with the railway systems of the countries of the European Union due to the presence of a track width of 1520 mm.

The integration of Ukrainian railways into the pan-European transport system requires the implementation in practice of relevant requirements regarding delivery times, speed of movement, comfortable travel conditions for passengers, etc. This problem was investigated by Strelko, Yurchenko, Vasilova, Gusar, Rudiuk (2022) in the context of bringing international transport corridors within the borders of Ukraine to the required standards, priority sections and reconstructions were determined and substantiated, which will contribute to the increase of route speeds in freight and passenger traffic and will add strong arguments for the interest of foreign partners in implementation of transit transportation through Ukraine.

3. AIM

To state and justify the necessity and expediency of using in the project analysis a number of technical, technological, financial and economic indicators of the introduction of a European standard railway track in Ukraine in the context of a common socio-economic space with the countries of the European Union, which will provide the opportunity to obtain the necessary initial data to increase the validity of the adoption of management decisions regarding a positive decision to implement this project for mutual social, economic and political benefit. To prove the need to carry out a feasibility study of this project for all possible alternatives (directions and parameters of route options), the results of which will be the basis for the development of a design analysis.

4. METHODOLOGY

Comprehensive substantiation of the feasibility (or rejection) of introducing a European-standard railway track in Ukraine is a large investment project with the participation of foreign partners, which involves the gradual investment of funds in the design and implementation of construction and installation works. Decision-making in this matter is carried out on the basis of the analysis of a number of project analysis indicators: social efficiency taking into account the benefits of neighboring countries; financial indicators, in particular the net discounted income, which is planned to be received by JSC "Ukrzaliznytsia" jointly with the project partners during its implementation and after its completion. One of the determining elements of the calculation of net discounted income is the cost of construction and installation works, the final conclusion of the project analysis will largely depend on its correct calculation. A significant impact on the technical and economic indicators of the project (construction cost and installation work, operating costs) is exerted by the speed of movement, the value of which must be determined by a feasibility study and approved by the authorized bodies.

5. RESULTS

The geographical position and the developed network of railways of Ukraine provide a significant transit potential for the development of cargo transportation in the Asia-Europe logistics chain. The British Institute for Transport Problems determined the transit ratio of Ukraine in the amount of 3.75, with a maximum value of 5 (for Poland, this indicator is equal to 2.92) (Kharchenko et al., 2019). In this context, the strategic goal of infrastructure projects of rail transport emerges, which consists in maintaining and creating favorable conditions for international trade, facilitating the movement of goods, and ensuring the needs of the population in passenger transportation by rail.

International methodical recommendations calculate such type of efficiency of investment projects as general or social efficiency (social efficiency of the investment project). This approach is due to the fact that the financial (commercial) evaluation of efficiency is aimed at identifying additional profit as a result of the implementation of the project in order to make a decision on its implementation in practice.

As for the general assessment of efficiency, it consists in establishing the degree of influence of the investment project on the national economy of the country and society as a whole. However, it should be noted that the evaluation of the social effectiveness of investment projects is a rather complex and time-consuming process that requires significant efforts from both the government authorities and the project developers.

Preliminary assessment of investments in railway transport projects begins with the proper identification of the project in the context of a broader investment program of a regional, national or European scale, which is the case in this case. Therefore, from a technical point of view, the project must include all engineering elements (lines, networks on the territory of Ukraine) that are necessary for its reliable and safe functioning, such as main tracks, stations (including with tracks and with the necessary equipment for fire and rebuilding trains), locomotive and wagon depots, freight terminals, passenger facilities and other related infrastructure for all farms (energy, automation, telemechanics and communication facilities, rolling stock, etc.). However, in the economic analysis, it is necessary to avoid elements that are not related or are not necessary for the functioning of this project (Berechman, Ozmen, & Ozbay, 2006).

From a technical and technological point of view, the port infrastructure of the Odesa region and the track management of railways with the associated infrastructure are extremely important, namely the track development of berthing fronts, port and near-port stations and other stations where the accumulation of trains for the shipping party can occur. When introducing the track of the European standard, there is a need to reconstruct the named track management and related infrastructure. The volume of construction and installation works will depend on the chosen technical option and the stages of development of the 1435 mm track network. Considering the significant amount of investments in the infrastructure of the Black Sea ports and the accompanying railway component, the implementation of the project analysis should be preceded by the development of technical and economic calculations for each technical option with the determination of the cost of construction and installation works and the terms and stages of their implementation.

The next important element in the evaluation process is to determine the demand for transportation. To do this, it is necessary to analyze the demand for different types of transportation, using data from industry operators or other statistical sources based on reliable estimates based on reasonable assumptions. Quantification of volumes and sizes of traffic "with the project" and "without the project" is important for determining forecasts; it should be noted that the demand analysis should always provide estimates based on the technical-technological and economic characteristics of each specific technical option. Depending on the available data and the resources allocated to carry out this assessment, different methods may be used (regression models, Logit and Probit models, extrapolation of trends, qualitative methods, etc.) and it is highly probable that the results obtained may have differences, including essential ones (Holub, Dmytrychenko, Kulbovskyi, & Sapronova, 2022).

As for freight transportation, as a first step, it is necessary to correctly define the geographical area that can be included in the area of attraction of this project, and on which the freight flow can be generated. It is known that the zone of influence of infrastructure on the volumes and directions of cargo flows goes beyond the territory where the project is directly physically implemented, that is, it is necessary to determine and consider benefits for other economic objects and society for other countries of the European Union, which is of significant importance for definition of social efficiency (social efficiency of the investment project).

In order for the implementation of the European standard track project on the railway network of Ukraine to be successful, it is necessary to attract transit cargo, in particular containers from the ports of Odesa, and implement measures to increase the attractiveness of passenger transportation. The issue of transportation of promising transit volumes of containers through the ports of Odesa was investigated in papers (Alieksieiev, Dovhan, & Alieksieiev, 2018; Myronenko, & Hrushevska, 2018; Ugnenko et al., 2019; Kyrychenko, Strelko, & Berdnychenko, 2021), in which the main parameters of the technical and technological nature of the route of the high-speed railway line from the ports of Odesa to the Western border as an element of the Silk Road were also determined.

A comfortable travel time for a passenger is 2-3 hours, in addition to the distance, it depends on the route and the maximum speed. Table 1 shows possible values of the design speeds of passenger trains, the implementation of which should be determined by feasibility studies and derived values of route speeds and travel time. By the State Construction Regulations "SCR V.2.3-19-2018 Transport facilities. Railways with 1520 mm gauge. Design Standards" regulated speed standards for passenger trains up to 200 km/h in the corresponding categories of railways.

Feasibility studies must be developed considering European design standards, in particular such as requirements for traffic safety, track design, electrification and power supply, automation, telemechanics and communications and other elements of engineering. In principle, the feasibility study of the project should contain sections covering social policy issues and macroeconomic issues, which are important factors in such a large-scale project of European significance. Financial backing of this feasibility study and further consideration of its results must be carried out with the participation of foreign partners.

Route	Distance, km	Speed	Passenger travel time, hours		
			2.0	**2.5**	**3.0**
Odesa – Kyiv	492	Average route	246.0	196.8	164.0
		Maximum running speed	300.0	250.0	200.0
Kyiv – Lviv	553	Average route	276.5	221.2	184.33
		Maximum running speed	300.0	250.0	200,0

Table 1. Values of route and design speeds of trains and their corresponding travel time.

It is assumed that the volume of freight and passenger transportation will increase in the future. There is a need to ensure the required throughput and carrying capacity of the line with passenger and freight traffic for various speed parameters.

The speed of passenger trains is higher than that of freight trains, including accelerated ones, which leads to the "taking over" of freight trains by passenger trains. When performing the project analysis, it is necessary to solve the question: what should be the speed of freight trains to realize the required (set) dimensions of the movement of passenger and freight trains. To get an answer to the question, we will use the following dependence (Novikova, Yurchenko, & Rudyuk, 2017):

(1) $$V_{fr}^{ex} \geq \frac{l_{max} N_{pas} \gamma_V}{24 - \left(N_{pas} + N_{fr}\right) \frac{\Delta t_{fr}^{d}}{60}} ,$$

where l_{max} – the length of the "limiting" run, which has the longest length and train travel time, km;
N_{pas} – the number of high-speed passenger trains on the section per day;
N_{fr} – the number of freight trains with increased speeds on the section per day;
$0 < \gamma_V < 1$ – the coefficient that takes into account the reduction of the average route speed compared to the design speed, which can be taken as 0.9;
Δt_{fr}^{d} – the interval between consecutive freight train departures, which must satisfy the condition

(2) $$t_{min} \leq \Delta t_{fr}^{d} < \frac{24 \cdot 60}{N_{pas} + N_{fr}} ;$$

t_{min} – the minimum permissible interval between consecutive departures of freight trains, which is determined under the condition of compliance with traffic safety (for example, 6 minutes).

Equality does not contradict condition (2).

(3) $$\Delta t_{fr}^{d} = \frac{24 \cdot 60}{N_{pas} + N_{fr}} \cdot \frac{t_{min}}{\Delta t_{fr}^{d}} ,$$

From where, after substituting the intermediate result

$\Delta t_{fr}^{d} = \sqrt{\frac{24 \cdot 60}{N_{pas} + N_{fr}}}$ в (1), let's obtain

(4) $$V_{fr}^{ex} \geq \frac{l_{max} N_{pas} \gamma_V}{24 - \sqrt{24\left(N_{pas} + N_{fr}\right) \frac{t_{min}}{60}}} .$$

N_{pas}, passenger trains per day	N_{fr}, freight trains per day								
	4	8	12	16	20	24	28	32	36
4	31.7	33.4	35.0	36.5	38.0	39.4	40.9	42.4	43.9
6	48.9	51.3	53.6	55.8	58.0	60.2	62.4	64.6	66.9
8	66.8	70.0	73.0	75.9	78.8	81.8	84.7	87.7	90.8
10	85.5	89.3	93.0	96.7	100.4	104.0	107.7	111.5	115.4
12	104.9	109.4	113.9	118.2	122.6	127.1	131.6	136.1	140.8
14	125.1	130.3	135.4	140.5	145.6	150.8	156.1	161.6	167.1
16	145.9	151.8	157.6	163.5	169.4	175.4	181.5	187.8	194.2
18	167.5	174.1	180.6	187.3	193.9	200.8	207.7	214.8	222.1
20	189.8	197.1	204.4	211.8	219.3	226.9	234.7	242.7	251.0
22	212.7	220.8	228.9	237.0	245.4	253.9	262.6	271.5	280.7

Table 2. Average route speed of freight trains for different traffic volumes of passenger and freight trains.

Taking, in accordance with (Novikova, Yurchenko, & Rudyuk, 2017), l_{max} = 173 and γ_V = 0.9 and t_{min} = 6 min., Table 2 shows the results of the calculation according to formula (4).

6. DISCUSSIONS

Comment regarding the use of the given results: assuming a prospective volume of transportation of 1 million 20-foot containers per year (1 million TEU – twenty-foot equivalent) (Abourraja et al., 2018). If they are transported in express trains of 50 cars, 2 TEU per each, this corresponds to an average daily volume of traffic of 27.4 trains in each direction (27-28 pairs of trains per day). Passenger high-speed trains in the future will depart, for example, from 6:00 a.m. to 10:00 p.m. every hour, a higher frequency is difficult for Ukraine imagine. That is, the maximum volume of passenger traffic will be 17 trains per day. Their average route speed will be 270 km/h, the maximum 300 km/h. The route speed of express cargo trains will ensure such volumes of traffic, about 195 km/h, and the maximum – 217 km /h. But this speed must be approached gradually (in stages that correspond to the "darkened" "diagonal" cells of Table 2). It is clear that during the day from 6:00 a.m. to 10:00 p.m. priority is given to passenger trains, and in freight trains will pass between them. Freight traffic is mainly carried out at night.

Different indicators are used to characterize the financial efficiency of railway transport investment projects. One of the most widespread is the net discounted income NPV – integral effect, financial net carried value - Net Present Value, the accumulated discounted income for the entire calculation period is defined as the difference between the discounted value of cash receipts from the investment project and discounted costs according to the following formula:

$$(5) \quad NPV = \sum_{t=0}^{T_{ep}} \frac{B_t - C_t}{(1+r)^t} \ ,$$

where B_t – the results of the investment project (amount of income from the project);
C_t – current costs (operating and capital costs);
t – the year in which the corresponding results and current costs were obtained,
r – the discount rate.

Together with the results and costs, the planning horizon of the evaluation period T_{ep} appears in the NPV. When it comes to a complex object of railway transport, the planning horizon of the evaluation period goes beyond the perspective (100, 50, 30 years. The earth bed serves 100 years, the service life of the rails depends on the type and volumes of tonnage passed, technological objects serve 10–15 years, etc.). The longer the forecasting horizon, the greater the probability of an error in the demand for transportation. For such a large-scale railway complex project, at appropriate time intervals (10, 15, 30 years), there is a need to replace "outdated" devices, equipment, and equipment with more modern ones, which requires additional investment in their acquisition and the execution of the necessary construction and installation works, and thus increases the residual value of the object.

We will present the values of errors in forecasting the demand for transportation in infrastructure transport projects, which are presented in the source (Berechman, Ozmen, & Ozbay, 2006). In this study, 210 infrastructure projects in 14 countries of the European Union were considered: 27 – investments in railways, and the rest – in highways. The authors concluded that the demand is overestimated in 9 out of 10 railway projects with an average percentage of overestimation of 106 %.

The results indicate the existence of a positive systematic bias in the determination of demand in railway projects. For investment in roads, the forecasts are more balanced, although there are also significant errors. Thus, for half of the considered projects, the difference between forecasted and observed demand exceeds ± 20 %.

There is a high estimated standard deviation, indicating a high degree of uncertainty and risk. The results of the analysis of the projects carried out by the Kyivdiprotrans Research and Design Institute of Transport Construction for the railway network of Ukraine coincide with the conclusions of this study.

In recent decades, there has been a noticeable improvement in the estimation of transport demand in Europe, but forecast errors remain and have not significantly decreased over time (Myronenko, Samsonkin, Yurchenko, & Pozdniakov, 2022). Given that errors in transportation demand forecasting significantly affect the project's defining characteristics, it is important to include uncertainty in the context of its evaluation. In the case of railway infrastructure of this scale, mistakes will have extremely serious consequences, since the investment is practically irreversible.

The conducted studies revealed a positive correlation between investments in railway transport infrastructure and the economic development of regions of different status. These studies used a traditional production function model. Despite the fact that the range of calculated economic growth has significant differences in different studies, the positive elasticity between investment in railway transport infrastructure and economic development is now generally recognized (Grushevska, Notteboom, & Shkliar, 2016; Olkhova, Davidich, Roslavtsev, & Davidich, 2017; Kukhar, Kasyanov, Shuldiner, Maliavin, & Voronkov, 2019).

An essential element in the research is that the magnitude of the measured effect decreases significantly with further refinement of the econometric model, mainly this applies to territories with appropriate economic and social characteristics and considering the time factor. That is, when a time lag between the moment of investment in infrastructure and the moment when economic benefits appear in the econometric model was introduced, the determined elasticity decreases as the lag decreases.

It was found that when performing the specified calculations using the initial data of the national level, the results of elasticity are much higher than when using the data of the region or district level. In the opinion of the authors, the mentioned provisions are extremely important factors to be considered in the project analysis of the introduction of the European track on the railway network of Ukraine in the context of obtaining possible economic benefits by the countries of the European Union in general and the countries neighboring Ukraine, in particular. This thesis is also a significant factor considering the adoption of a positive decision for Ukraine (and not only) regarding the participation of foreign partners in this project and its financing.

7. CONCLUSIONS

The railway network of Ukraine has a significant transit potential for the development of freight transportation in the Asia-Europe logistics chain. The railway transport system of Ukraine is not interoperable with the railway systems of the countries of the European Union due to the presence of a track width of 1520 mm, which is a restraining factor for the development of transport.

The integration of Ukrainian railways into the pan-European transport system requires solving several issues regarding the compatibility of the technical characteristics of partner railways. The political and socio-economic circumstances of today require the acceleration of the research complex; there is a need for an adequate assessment of possible technical and technological options for solving the problem.

The construction of a railway line of the European standard will provide an opportunity for more dynamic development of Ukraine's relations with the countries of the European Union; will have an indirect effect on the countries of the European Union, primarily neighboring states; this component must be taken into account during the analysis of social efficiency, as a factor that is important for the comprehensive assessment of the project and the adoption of a positive decision regarding its implementation.

The presence of a significant number of factors that affect this project of a technical-technological, financial, social, and political nature requires the involvement of specialists in the field of system analysis in order to carry out its comprehensive analysis.

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