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Analysis of Feasibility for Implementing European Standard Railway Tracks in Ukraine

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Abstract

The contemporary challenge at hand pertains to the development of theoretical, methodological frameworks, and practical guidelines for establishing railway mainlines in Ukraine aligned with European standards. The objective of this research involves scrutinizing diverse scenarios and, based on this analysis, evaluating the prospects of constructing European standard railway tracks within Ukraine. The introduction of a 1435 mm gauge railway network on a new route within Ukraine necessitates substantial investments in transport infrastructure construction and procurement of rolling stock. An unbiased assessment and definitive determination of prospective directions demand an examination of key criteria characterizing rail-oriented agglomeration tendencies and the volume of transit transportation for both passengers and freight. Additionally, the analysis takes into account the techno-economic potential of these directions.
KEY WORDS: *railway, Net Present Value, transport corridor, track gauge, dual gauge*

1. Introduction

Providing unhindered train mobility, primarily from European Union countries, remains a pressing task for Ukraine. The European Commission and the European Investment Bank have devised a strategy for integrating railway networks of Ukraine, Moldova, and the European Union [1]. The European gauge for high-speed transport is planned to be constructed from the Poland-Ukraine border at Mostyska and Rava-Ruska to Lviv. The envisioned new mainline railway network with a gauge of 1435 mm will operate in parallel with the existing 1520 mm gauge. The new track will serve international passenger trains, Intercity connections, and container or platform-based freight transport. The existing track will cater to local and regional passenger trains and heavy freight. A potential expansion of the 1435 mm gauge railway network to major Ukrainian cities.

Ukraine has already gained experience with European gauge utilization. Trains traveling from Slovakia to Romania pass through Ukrainian territory (Chop, Batovo, Korolevo, Dyakove) on European gauge tracks without the need for wheel pair replacement. The longest stretch of 1435 mm gauge railway utilized within Ukraine is the Chop-Dyakove route (112 km) [2, 3].

The Baltic countries serve as an example of European gauge implementation within their territories. One of Europe's priority railway projects, "Rail Baltica," is part of the "North Sea – Baltic" railway corridor, connecting Finland, Estonia, Latvia, Lithuania, Poland, Germany, the Netherlands, Belgium, and Luxembourg. The "North Sea – Baltic" corridor spans 3200 kilometers and aims to restore direct connectivity between Baltic countries and the European railway network, fostering regional integration [4].

The realization of the ambitious Rail Baltica 1435 mm gauge railway line project, linking Baltic capitals through Poland to the European railway network, will foster the development of both freight and passenger connections in the region. Integrating the railways of Estonia, Latvia, and Lithuania into the European Union's transport system will accelerate train speeds and augment passenger and freight flows and revenues [5].

The current task at hand is the development of theoretical, methodological approaches, and practical recommendations for determining the technical feasibility of establishing railway mainlines in Ukraine according to European standards. While the full transition to European gauge is a long-term perspective, it stands as a necessary step. Therefore, it should be prioritized, with efforts directed towards engaging foreign investors, particularly the European Union, which increasingly demonstrates interest in integrating Ukraine into its economy and logistical infrastructure. The possibilities and pathways for the "European gauge" project are being explored by the ministry over several years; however, its practical realization mandates preliminary studies on freight and passenger flows and the development of techno-economic substantiation.

2. Statement of the Problem

Presently, an agreement exists between the Polish company "Centralny Port Komunikacyjny" (CPK) and

Ukrainian Railways, aimed at the development of new transborder connections using the European gauge of 1435 mm, including the construction of a high-speed railway (HSR) [6]. The document envisions joint preparation of the technical and economic substantiation for the planned new European standard railway line between Poland and Ukraine.

In reference to [7], it is noted that in parallel with the Baltic countries' initiative in 2008, an international project for the new HSR line "Rail Baltica" was born, intended to link Tallinn, Riga, Kaunas through Białystok and Warsaw to Berlin. The project includes additional techno-economic substantiation for maximum passenger train speeds in three variants: 160, 200 and 250 km/h, with work scheduled until 2027. The Rail Baltica line will be adapted for freight traffic with a maximum speed of 120 km/h. It is anticipated that immediately upon the launch of transport on the entire Rail Baltica line, cargo transportation across the Polish border in the southwest direction could reach 12–18 million tons, gradually increasing in subsequent years. Substantial difficulties in executing these projects are linked to the fact that modernizing sections for speeds exceeding 160 km/h necessitates additional investments.

The corridor begins at the port of Helsinki, proceeding south through three Baltic countries and northeastern Poland to Warsaw. From there, it follows the traditional east-west corridor through Łodź to Poznan and then to Berlin, reaching major ports on the western coast of the North Sea (Hamburg, Bremen, Bremerhaven, Amsterdam, Rotterdam, and Antwerp).

Among numerous studies devoted to selecting priority international transport directions, the work in [8] stands out, presenting theoretical foundations and empirical results of analysis and modeling of transport networks in Poland using structured networks.

Numerous challenges arise on both European and Ukrainian railways due to mixed train operations [2, 9]. The study in [9] pertains to decision-making problems encountered by railway infrastructure managers in networks with segregated tracks and corridors of shared usage, where the same tracks serve both passenger and freight trains.

The article [10] presents the specifics of an emulation model enabling computational experiments and drawing conclusions regarding the distribution of transportation modes within the national transport system. Various elements of the model are characterized, including the passenger and freight demand model, mechanisms for allocating material and passenger flows within the network. Descriptions of infrastructure, transport vehicles, and other parameters are provided.

In the work [11], research methods and solutions addressing pertinent transport issues discussed during the International Scientific Conference "Transport of the 21st Century" held from June 9 to June 12, 2019, are outlined. Contemporary technologies and solutions employed for transportation planning, management, and operation are specifically highlighted.

The EU's transport infrastructure strategy, as defined in the TEN-T Core Network Principles [12], centers on enhancing the quality of transport infrastructure through new investments and efficient utilization of existing infrastructure to improve accessibility, mobility, and safety. The corresponding investment priorities are outlined within the thematic objective of "Promoting sustainable transport and removing bottlenecks in key network infrastructures." Apart from the aforementioned works, studies addressing the enhancement of throughput and carrying capacity are also of interest. For instance, in the article [13], the impact of train type heterogeneity on the throughput capacity of single-track railways is investigated, while work [14] examines the carrying capacity of freight railway corridors in the Slovak Republic. This article focuses on the characteristics of operation in freight railway corridors and their carrying capacity when accommodating mixed passenger and freight traffic. Given the drawbacks of mixed train operations on shared tracks, the proposition of segregating freight traffic from passenger traffic onto parallel tracks becomes intriguing.

The application of design norms for a different track gauge necessitates the resolution of numerous related challenges associated with maintaining designated speed limits [3, 7, 15-17], ensuring safety conditions [18], organizing infrastructure components, including electrification and signaling [19-21], etc.

Based on the results of the aforementioned analysis, this article presents research findings concentrated on comparing various scenarios for constructing a railway track according to European standards within the territory of Ukraine. The implementation of European gauge railway tracks in Ukraine aims to elevate the domestic transportation system to global standards in terms of technical parameters and service quality. The current article is devoted to addressing specific aspects of this issue.

The purpose of this study is to analyze different scenarios and, based on this analysis, assess the feasibility of constructing a European standard railway track within the territory of Ukraine. The research is grounded in an analysis of scientific developments related to the design and construction of railways with varying track gauges.

3. Methods and Results

The most notable scenarios are as follows:

1. The existing double-track section is reconstructed into two single-track sections with gauges of 1435 mm and 1520 mm.
2. A mixed-gauge track (1435/1520 mm) is laid on the main line.
3. A European standard railway track is designed on a new route.

Let us delve further into the first two scenarios using the example of the directions Warsaw-Kovel-Korosten-Kyiv, Warsaw-Lviv-Shepetivka-Kyiv, Warsaw-Lviv-Zhmerynka-Kyiv, Fig. 1 and Table.

Fig. 1 Variants of European gauge in the reconstruction of existing routes

Table

Reconstruction measures for the introduction of "Eurociti" trains

Cost of reconstruction	Required measures	Drawbacks of the variant
Warsaw-Kovel-Korosten-Kyiv (767 km) – 3.56 billion euros	1. Construction of a second track on the Kovel-Sarny-Korosten section (298 km) with a gauge of 1435 mm; 2. Electrification of the Dorohusk-Kovel-Sarny-Korosten railway section (360 km, gauge 1435 mm); 3. Reconstruction of the second track from 1520 mm to 1435 mm gauge on the Korosten-Kyiv section or laying a mixed gauge track on one of the main tracks (156 km).	1. The investments in this option will yield profitability at high transportation volumes; 2. During the reconstruction of the double-track section Korosten-Kyiv into two single-track lines (1520/1435 mm), the throughput capacity decreases by 4-5 times.
Warsaw-Lviv-Shepetivka-Kyiv (914 km) – 2.27 billion euros	1. Replacement of the 1520 mm gauge track with a 1435 mm gauge track on the Rava-Ruska-Lviv section or laying a mixed gauge track (67 km); 2. Reconstruction of the second track from 1520 mm to 1435 mm gauge on the Lviv-Krasne-Zdolbuniv-Shepetivka section or laying a mixed gauge track on one of the main tracks (268 km); 3. Replacement of the 1520 mm gauge track with a 1435 mm gauge track on the Shepetivka-Novohrad-Volynskyi-Korosten section (150 km); 4. Reconstruction of the second track from 1520 mm to 1435 mm gauge on the Korosten-Kyiv section or laying a mixed gauge track on one of the main tracks (156 km).	1. The investments in this option will yield profitability at high transportation volumes. 2. During the reconstruction of the double-track sections Lviv-Krasne-Zdolbuniv-Shepetivka and Korosten-Kyiv into two single-track lines (1520/1435 mm), the throughput capacity decreases by 4-5 times.
Warsaw-Lviv-Zhmerynka-Kyiv (967 km) – 1.735 billion euros	1. Replacement of the 1520 mm gauge track with a 1435 mm gauge track on the Rava-Ruska-Lviv section or laying a mixed gauge track (67 km); 2. Reconstruction of the second track from 1520 mm to 1435 mm gauge on the Lviv-Krasne-Ternopil-Khmelnitsky-Zhmerynka-Kyiv (627 km) section or laying a mixed gauge track on one of the main tracks.	1. The investments in this option will yield profitability at high transportation volumes. 2. During the reconstruction of the double-track sections Lviv-Ternopil-Khmelnytskyi-Zhmerynka-Vinnytsia-Kyiv into two single-track lines (1520/1435 mm), the throughput capacity decreases by 4-5 times.

Laying dual-gauge track does not require the construction of a separate earthwork, which can be considered an advantage of this train operation organization method. However, the implementation of dual-gauge track necessitates solutions and bypasses at junction points due to the requirement of laying switch turnouts between the standard 1520 mm and European 1435 mm gauge tracks, leading to reduced train speeds during station passage. Addressing this challenge, as well as constructing a second 1435 mm gauge track parallel to the existing 1520 mm line, results in either the reconstruction of junction points along the route or the application of curves for their avoidance [7].

The preliminary assessment of investment projects is based on methods [12, 22, 23]. A considerable body of research by domestic and international authors exists, focusing on practical aspects of selecting specific indicators for evaluating the efficiency of investment projects. The authors of this study employ the Present Value of Discounted Cash Flow methodology, namely the Net Present Value (NPV) [3, 7].

The developed model enables the examination and forecasting of revenues that Ukrzaliznytsia, the Ukrainian Railways, would accrue from transport operations under the aforementioned scenarios, considering various levels of forecasts and transport volumes for the perspective.

In the evaluation of variant costs, data were obtained from respective project materials of "Kyivdiprotrans" and "Lvivtransproekt," adjusted with coefficients to account for the transition to 2023 prices: reconstruction of the second track from 1520 mm to 1435 mm gauge – 2.5-3.0 million euros per kilometer, electrification – 3.0-4.0 million euros per kilometer, construction of a second mainline track – 7.0-8.0 million euros per kilometer.

According to the proposals [1], it is envisaged that the new mainline network with a gauge of 1435 mm will be utilized for international passenger trains and for transporting goods in containers or on platforms. The volume of passenger transportation will be determined by the number of train pairs per day – n, and the volume of freight transportation - by the net weight that can be transported annually – G. As the volume forecasts for transportation at this point are unknown, various combinations of passenger (2, 4, ..., 10 train pairs per day) and freight (5, 10, ..., 25 million tons per year) traffic were considered in this study.The cumulative net present value is composed of revenue from both passenger and freight transportation over a calculation period of 15 years.

Analysis of the results revealed that for the reconstruction cost of the Warsaw-Kovel-Korosten-Kyiv railway infrastructure at 3.56 billion euros, the phased reconstruction of the existing track as described in Table may be justified with annual passenger traffic volumes of 6 train pairs per day and freight transport of 5 million tons per year, or with passenger transportation of 2 train pairs per day and freight of 10 million tons per year, see Fig. 2.

Similar calculations were conducted for the Warsaw-Lviv-Shepetivka-Kyiv route, see Fig. 1. Analysis of the results indicated that for the reconstruction cost of the railway infrastructure at 2.27 billion euros, the phased reconstruction of the existing track as described in Table may be justified with annual passenger traffic volumes of 2 train pairs per day and freight transport of 5 million tons per year, see Fig. 3.

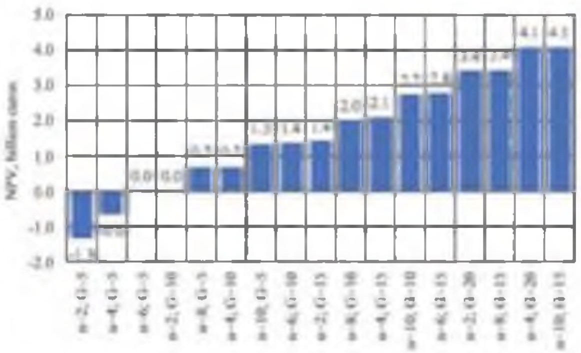

Fig. 2 NPV distribution diagram for the Warsaw-Kovel-Korosten-Kyiv Route

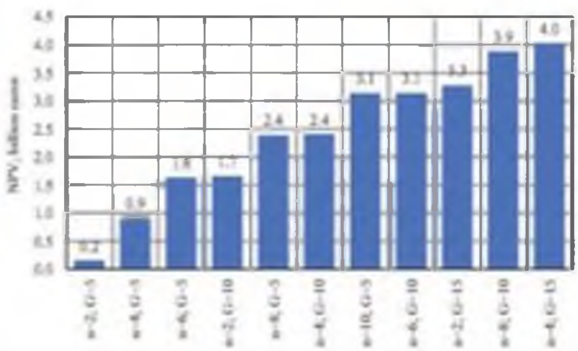

Fig. 3 NPV distribution diagram for the Warsaw-Lviv-Shepetivka-Kyiv Route

The analysis of the results revealed that for the reconstruction cost of the Warsaw-Lviv-Zhmerynka-Kyiv railway infrastructure at 1.735 billion euros, the reconstruction of the second existing track to European standards may be justified with annual passenger traffic volumes of 2 train pairs per day and freight transport of 5 million tons per year, see Fig. 4.

In order to achieve the same economic effect under different scenarios, for instance, 4.0 billion euros, on the Warsaw-Kovel-Korosten-Kyiv route, profit will occur after the 5th year of operation with transportation volumes of 10 train pairs per day and freight movement of 15 million tons per year; on the Warsaw-Lviv-Shepetivka-Kyiv route, profit will occur after the 4th year of operation with transportation volumes of 4 train pairs per day and 15 million tons per year; on the Warsaw-Lviv-Zhmerynka-Kyiv route, profit will occur after the 3rd year of operation with transportation volumes of 2 train pairs per day and 15 million tons per year, see Fig. 5.

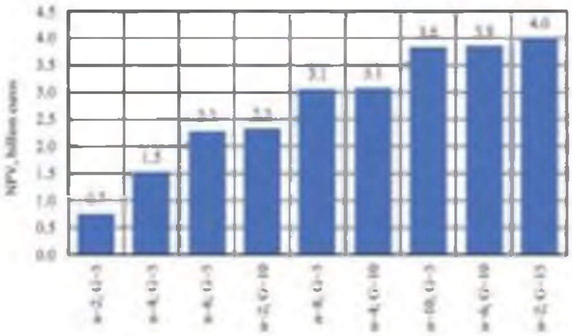

Fig. 4 NPV distribution diagram for the Warsaw-Lviv-Zhmerynka-Kyiv Route

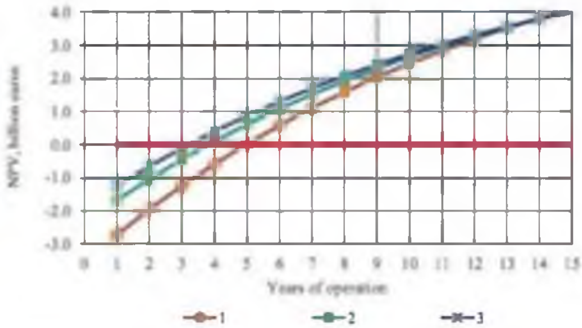

Fig. 5 Distribution of NPV across different movement directions: 1 – via Kovel ($n = 10$; $G = 15$); 2 – via Shepetivka ($n = 4$; $G = 15$); 3 – via Zhytomyr ($n = 2$; $G = 15$)

4. Conclusions

With the aim of integrating into the European transport system, Ukraine is actively pursuing the standardization of track gauge to 1435 mm. The primary objective behind transitioning to the European standard gauge is to ensure seamless train movement between the Baltic countries and other European Union member states that utilize this standard. The adoption of the European standard gauge of 1435 mm is widespread across most European nations, allowing for easy connection to the existing European railway network without the need for technical operations such as cargo transshipment or wheelset replacement.

Currently, Ukrainian Railways is engaged in infrastructure modernization efforts to transition to the 1435 mm standard gauge. The construction of railways conforming to the European standard is underway in specific regions of Ukraine, notably on the Lviv-Krakovets route where a new railway crossing with a 1435 mm gauge has already been constructed. Additionally, plans are in place for the modernization of railway mainlines in the eastern and southern parts of Ukraine. While a complete transition to the European gauge represents a long-term perspective, it should nevertheless be a prioritized direction, with a strong emphasis on engaging foreign investors, particularly the European Union, which has shown increasing interest in integrating Ukraine into its economy and logistics infrastructure.

The proposed Strategy by the European Commission and the European Investment Bank outlines key stages, including the construction of the 1435 mm Euro gauge from the Polish border to Lviv, between Lviv and Kyiv, network expansion in western and southern Ukraine, and extending the European gauge from Kyiv to the east. Practical implementation entails conducting preliminary studies on freight and passenger flows, as well as developing theoretical and methodological approaches and practical recommendations for determining the technical feasibility of creating European-standard railway mainlines in Ukraine.

In the construction of the European standard gauge railway in Ukraine, various scenarios are possible, namely: the conversion of existing double-track sections into two single-track lines with gauges of 1435 mm and 1520 mm; the implementation of mixed gauge (1435/1520 mm) on the main line; and the design of European standard gauge railway on a new alignment.

The introduction of a 1435 mm gauge railway network on a new alignment in Ukraine will require significant investments in building transport infrastructure and procuring rolling stock. Numerous issues arise concerning land allocation for new construction, land parcel costs, construction organization, and more. Considering the aforementioned aspects, the study examines three principal approaches for implementing the European gauge along existing routes: Warsaw-Kovel-Korosten-Kyiv (767 km), Warsaw-Lviv-Shepetivka-Kyiv (914 km), and Warsaw-Lviv-Zhmerynka-Kyiv (967 km). The first option proved to be the shortest but 1.5 times costlier than the second and twice costlier than the third. The reconstruction of the existing track in the Warsaw-Kovel-Korosten-Kyiv direction can be justified with annual passenger traffic of 6 train pairs per day and freight transport of 5 million tons per year on the 1435 mm gauge.

To achieve an equivalent economic effect under the considered scenarios, e.g., 4.0 billion euros, on the Warsaw-Kovel-Korosten-Kyiv route, profitability will occur after the 5th year of operation with passenger traffic of 10 train pairs per day and freight movement of 15 million tons per year; on the Warsaw-Lviv-Shepetivka-Kyiv route, profitability will follow the 4th year with passenger transport of 4 train pairs per day and 15 million tons of freight per year; on the Warsaw-Lviv-Zhmerynka-Kyiv route, profitability will emerge after the 3rd year with 2 train pairs per day and 15 million tons of freight per year.

An objective assessment and final decision necessitate an analysis of key criteria for determining promising routes, which can be classified into two groups: the first group characterizes agglomeration inclined towards the railway route and the volume of transit passenger and freight transport; the second group characterizes the technical and economic potential of routes (line length, number of main tracks, traction type, construction complexity, travel time for passengers, required investments). A conclusive decision demands further economic studies and the determination of prospective volumes of freight and passenger transport.

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