The Advisability of Using Dual Gauge for Expansion of the International Traffic

M. Kurhan[1], D. Kurhan[2], M. Husak[3], N. Hmelevska[4]

[1]*Dnipro National University of Railway Transport named after academician V. Lazaryana, ac. Lazaryana str, 2, 49010, Dnipro, Ukraine, E-mail: kunibor@gmail.com*
[2]*Dnipro National University of Railway Transport named after academician V. Lazaryana, ac. Lazaryana str, 2, 49010, Dnipro, Ukraine, E-mail: kurhan.d@gmail.com*
[3]*Dnipro National University of Railway Transport named after academician V. Lazaryana, ac. Lazaryana str, 2, 49010, Dnipro, Ukraine, E-mail: marka2410@gmail.com*
[4]*Dnipro National University of Railway Transport named after academician V. Lazaryana, ac. Lazaryana str, 2, 49010, Dnipro, Ukraine, E-mail: hmelevnela@gmail.com*

Abstract

The possibilities of railway transport for the organization of transportation between the countries are not used to the full extent, since there are a number of technical reasons. The usage of dual gauge (1435/1520 mm) is one of the solutions. As an example of using dual gauge is the international project "Rail Baltica", Lviv railway and etc.
KEY WORDS: *Rail Baltica, transport corridors, dual gauge, railway*

1. Introduction

Track gauge on railway transport is one of the most important parameters of the track infrastructure. There are several standards of track gauge in the world, and when there are sections with a different track gauge, special measures must be taken – either to perform a bogie exchange or to reload cargo or transfer passengers to cars with the appropriate track gauge. This problem can be also solved by combining both tracks into a combined (dual) gauge. Dual gauge, unlike the standard one, consists of three (Fig. 1) or four rails (Fig. 2).

Three rails can be used in a situation when the width difference of two tracks is sufficient to install a rail of the smaller track into the larger track, using one of the rails as a common one [1]. For example, 1668 and 1435 mm in Spain [2], 1435 and 1067 mm in Australia and Japan, 1520 and 1067 mm on Sakhalin, 1676 and 1000 mm in Bangladesh.

To combine tracks that differ little from each other, only a design that uses four rails is possible. This is exactly the situation, in particular, on most of the western borders of Ukraine: the difference between 1435 and 1520 mm is only 85 mm.

On the Lviv Railway (Ukraine), the total length of dual gauge (1520 and 1435 mm) is about 150 km. The Main Department of Track Facilities together with the Scientific and Design Technology Bureau of Track Facilities of Ukrzaliznytsia, factories-manufacturers and specialists of Lviv Railway track services developed and introduced into production new dual rail gauge of 1520 and 1435 mm with reinforced concrete sleepers and intermediate elastic fastening. The experimental section of such a track is located from Chop and Diakovo stations to the state border of Ukraine (Fig. 2).

Fig. 1 Three-rail track near the station

Fig. 2 Section of dual rail gauge 1520 mm and 1435 mm

In contemporary conditions, a project to connect at least two sections of dual gauge with the subsequent establishment of an intermodal hub could be attractive. The combination of Mukachevo and Mostyska stations with a European track (distance almost 300 km) is an appealing option, to build a large transshipping hub in Lviv. Undoubtedly, such projects require foreign investments [3].

A vivid example of such a hub is the Slovak terminal “Dobra”, which plays a key role in the development of container traffic on the V European Corridor (Italy – Slovenia – Hungary – Slovakia – Ukraine – Russia) [4].

Back in 1998, the Karpaty terminal was constructed in Ukraine, the production facilities of which are located near the Batovo hub station (near the Chop city). However, it clearly loses to its Slovak competitor and requires further development.

In addition, Ukraine and Poland could join efforts in constructing a general intermodal cargo transshipment terminal and thus provide their dual rail lines by the reliable cargo traffic [5, 6].

One of Europe's priority rail projects with dual gauge is the “Rail Baltica” railway, which is a part of the North Sea-Baltic railway corridor connecting Finland, Estonia, Latvia, Lithuania, Poland, Germany, the Netherlands, Belgium, and Luxembourg. [7-10]. The length of the "North Sea–Baltic" corridor is 3200 kilometers.

2. Priority Projects of Dual Gauge in Ukraine

Currently, the deepening of the European gauge on the Ukrainian territory is in three border regions. The largest segment of dual gauge (1520 mm + 1435 mm) is located in Transcarpathia between the Chop – Batovo – Mukachevo stations (about 40 km, electrified) and Batovo – Korolevo – Diakovo (about 80 km) [11]. In the Volyn region, the European gauge is laid from the Polish border to Kovel (64 km), and in Lviv: Varlamova Volia – Mostyska – State Border (7 km of 1435 mm track and 11.8 km of dual gauge); Khyriv – Starzhava – State Border and Khyriv – Nyzhankovychi (12.9 km of 1435 mm track and 25.7 km of dual gauge); Rava Ruska – Hrebenne (7.1 km of 1435 mm track). The indicated sections are included in the international transport corridors (Crete No. 3, No. 5 and Hdank–Odesa).

Ukraine has offered Slovakia and Romania to transport goods from one country to another through the Transcarpathian region, simultaneously using the combined railway Khalmeu/Diakove – Batovo – Korolevo – Chop/Chyierna-nad-Tysou.

Ensuring the mobile movement of passenger trains, primarily from Poland to Ukraine is relevant for Ukraine. It is impossible to change the Ukrainian gauge to the European one because of the need for intensive investments. Therefore, options for the reconstruction of domestic destinations are offered [11, 12]. By implementing the uncongested railway traffic between Lviv and Warsaw, it is possible to transport goods and realize journeys of Ukrainian passengers to any of the EU countries, the Balkans, or the Baltics.

2.1. Infrastructure Project Eurogauge “Mostyska-Lviv”

One of the most important directions connecting Germany (and through it other countries of Western Europe) with Ukraine is the Crete transport corridor No. 3. One of the priorities may be the infrastructure project proposed by the Ministry of Infrastructure of Ukraine "Eurogauge "Dry Port". The project envisages the development of railway infrastructure for the construction of dual gauge1435/1520 mm on the Mostyska-1 – Rodatychi section, Lviv region. The estimated cost is 11 million euros, the estimated implementation period is until 2022. The Mostyska-1 – Lviv railway section is a part of the Crete International Transport Corridor No. 3 (Berlin – Wrocław – Lviv– Kyiv). This section is double-track, with a track gauge of 1520 mm, the double track is combined with a track of 1435 mm, until the ‘90s to the station Rodatychi (length 42 km), at this time – to the station. Mostyska-1 (Fig. 3).

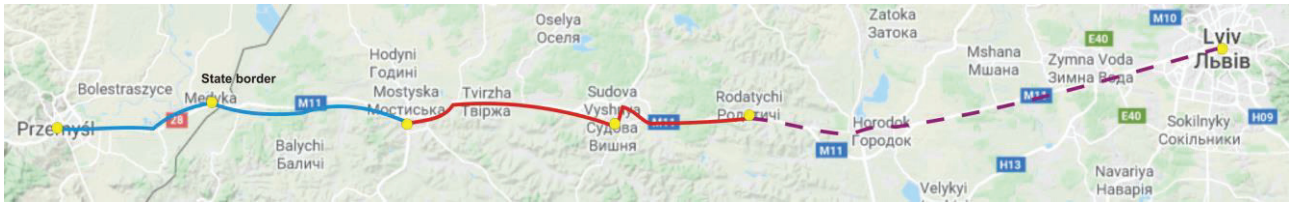

Fig. 3 The project of a section for the State border – Rodatichi dual gauge with a promising way to Lviv (via Google Maps)

The Lviv-Mostyska section is electrified with direct current. Electric locomotives CHS7 in passenger movement and VL10 in freight one are used in service for trains. There are eleven stations in this area. The maximum speed for passenger trains is 120 km/h, for freight trains is 80 km/h.

From the analysis of the profile and plan of the Lviv-Mostyska section, it was found that the largest number of curves has a radius from 700 to 1200 m, their specific gravity is 12.1%. The specific gravity of curved radii up to 700 m is 4.9%. A large number of restrictions on the parameters of curves are characteristic of plan of the line. The ruling gradient is 8‰.

Superstructure: rails type P65, a continuous welded rail. Fasteners and sleepers are new or used combined with new ones. Sleeper density: in straight lines and curves – 1840 pcs/km, except for wooden sleepers on a ribbon track in curves with a radius up to 1200 m – 2000 pcs/km. The ballast is crushed stone, 30 cm thick under sleepers.

The total number of artificial structures on the site is eighty-one pieces, of which sixteen are reinforced concrete bridges, eight are stone pipes, eight are reinforced concrete pipes, and four are metal bridges.

The time of freight train from Lviv to Mostyska (excluding standing at stations) is about 70 minutes, and passenger one is about an hour at an average speed of 70-75 km/h.

According to the forecasts, Ukrzaliznytsia plans to build 1520/1435 mm dual gauge from Mostyska to Lviv, which will open new opportunities for passengers, Ukrainians will have a direct high-speed service from Lviv to Krakow, Prague, Vienna.

Dual gauge will allow trains to depart from Europe, without wasting time for changing bogies, to travel to Sknyliv railway station, located 5.5 km from Lviv. This destination point was chosen to avoid overloading the Lviv station, through which actually all domestic trains run. And Sknyliv can become an international railway hub, switching part of the passenger traffic in Przemyśl. In addition, for the comfort of passengers, Ukrzaliznytsia plans to launch an express train between Sknyliv, the airport and the city's central railway station.

Transportation will be carried out by European operators, as there is no appropriate rolling stock in Ukraine. In the overall scope of works, it is necessary to lay 69.8 km of the 1435/1520 mm dual gauge, to build 3.1 km of the 1435 mm track, to perform 58.2 km of expansion for the main platform of a roadbed, to carry out comprehensive and recreational repair of 9.5 km of the existing dual gauge and reconstruction of eight stations, to perform reconstruction and modernization of the power supply infrastructure, to build the infrastructure for the railway station at the Sknyliv station for the 1435 mm gauge.

2.2. Infrastructure Project "Eurorail Lviv-Rava-Rusk-Warsaw"

The target of the "Eurorail Warsaw–Lviv" project is establishing an effective international railway service between Poland, other EU countries, and Ukraine under conditions of actively growing political, economic and social relationships. Laying dual gauge would allow trains to travel non-stop from Lviv to European cities.

For the construction of new dual gauge, in particular on the Rava–Ruska–Lviv section to the railway station Briukhovychi near Lviv (Fig. 4), it is necessary to perform a set of works: to lay 58 km of new dual railway gauge; to reconstruct five stations; to equip nine crossings with automation; reconstruct eighteen artificial structures and enlarge the major site of the roadbed with a length of 59.1 km.

The choice of Briukhovychi as the destination point of the European gauge is not accidental. Despite the developed broad-gauge infrastructure around the Lviv railway station, its rebuilding requires significant investments. Therefore, it is easier and cheaper to lay the European gauge to Briukhovychi station on the outskirts of Lviv, from which one can reach the city center by motor-vehicle transport in 10 minutes.

The total cost of the main works for the development of railway infrastructure and for the construction of dual gauge on the Rava–Ruska–Lviv section to the railway station Briukhovychi, according to preliminary estimates, is 50 million euros (excluding funds for the development of designing estimates and other works).

The Lviv-Rava-Ruska section, single-track, is served by diesel traction, belongs to the low railway category both in terms of traffic size and maximum speed.

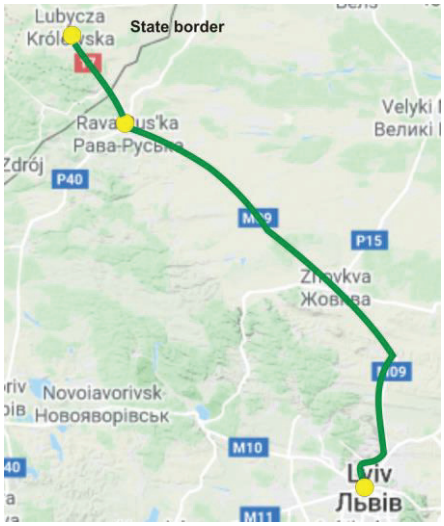

Fig. 4 Plan of the Lviv–Rava–Ruska–Warsaw railway route (via Google Maps)

The development of measures for the reconstruction of railway sections is preceded by an analysis of the technical condition of the line, parameters of the plan, and the longitudinal profile. According to the data of the rail-sleeper-ballast map as of 01.01.2019, the following characteristics of the existing gauge are given. The density of a line is 5 million tons gross/km per year. The passed tonnage of the line ranges from 13 to 24 million tons gross/km. The maximum speed of passenger trains passage along the section is 80 km/h, freight ones are 60 km/h.

In this section there is a ribbon track with rails P65 type, the length is 25 m. Sleeper density varies from 1449 pieces/km to 1904 pieces/km, as the section has curves of small radii from 203 to 300 and more meters.

Depending on the size of the radii, the track is laid on reinforced concrete and wooden sleepers. That is the reason why four types of intermediate fastenings are operated on the section. The total number of artificial structures on the section is eighty-two pieces, of which forty-two are reinforced concrete bridges, five are stone pipes, twenty-eight are reinforced concrete pipes, five are metal bridges, and two are metal pipes.

The longitudinal profile of the Lviv–Rava–Ruska section with a length of 68 km is mainly a descent with gradients from 9 to 16‰, steep gradient 10‰ - 15.2% (Fig. 5).

The plan of a line has a significant impact on the value of the permissible speed limit. The presented histograms show that the specific gravity of curves with a radius of up to 500 is 15.9% (Fig. 6). A large number of restrictions by the parameters of the curves component and adjacent ones are characteristic for the plan at the Lviv–Rava–Ruska section. Due to the complex plan of the line, it is often impossible to increase superelevation of the outer rail in curves, which requires lengthening the transition curve, it is often cannot perform with short straight between two curves. According to the results of traction calculations, it is found out that at the maximum permissible speed up to 80 km/h, the average running speed is about 50 km/h, and the travel time is 80-90 minutes.

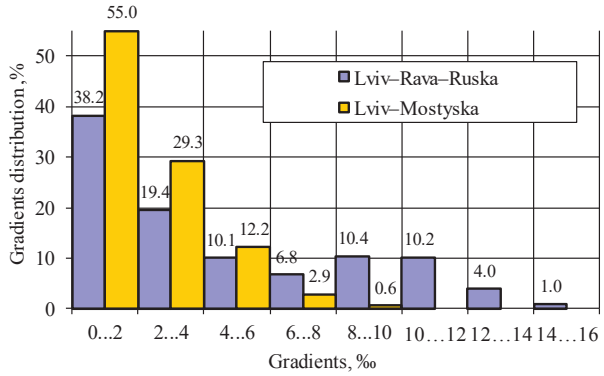

Fig. 5 Histogram of gradients distribution

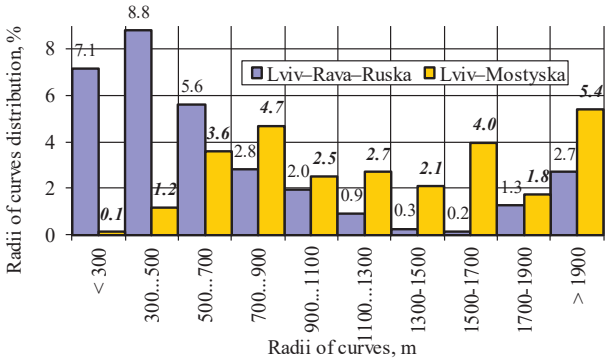

Fig. 6 Histogram for radii of curves distribution

Analysis of histograms (Figs. 5 and 6) shows that both in terms of profile and plan, the Lviv–Mostyska section has significantly better indexes in comparison with the Lviv–Rava–Ruska one. The aforesaid is confirmed by the level of average running speed, which is 1.5 times higher in the first section. In addition, the Lviv–Mostyska section is double-track, which allows at 4-5 times ensuring the higher train-handling capacity.

According to the Instruction on laying and maintenance of the dual railway gauge 1520 mm and 1435 mm [13] dual gauge is laid on wooden sleepers in straight and curved sections of a track with a radius not less than 300 m or reinforced concrete sleepers, special type in straight and curved sections with a radius of not less than 350 m. Fig. 6 shows that on the Lviv–Rava–Ruska section, curves less than 300 meters is 7.1%. Therefore, in this case, dual gauge is not laid, and its application requires a widening of the roadbed with the transition to a new track or the restructuring of curves, which will also lead to a shift in the axis of the track.

3. Advantages and Disadvantages of Dual Gauge

Laying dual gauge does not require the structure of a separate roadbed, which can be attributed to the advantages of this method in organizing train traffic. However, the use of dual gauge requires junctions and bypassing of end of block sections due to the need to lay turnouts of standard 1520 mm and European 1435 mm gauges, which leads to a decrease in the speed of trains when passing stations [14].

The solution of this problem, as well as the construction of the second gauge with a width of 1435 mm parallel to the existing line of 1520 mm, leads either to the need to reconstruct the end of block sections on this direction, or the use of curves to bypass them [11]. At this, such constructions as flat crossings, a gauntlet, and combining of 1520 mm gauge and the Western European 1435 mm gauge are used.

According to the definition of The Organization for Cooperation of Railways (OSJD) a gauntlet and combining of tracks (used in constraint environment) this is a part of tracks of the double-track section, where one rail track is mounted on another and laid on common sleepers with the help of two crosspieces without turnouts for gauntlets (Fig. 7) and one crosspiece and one turnout for combination (Fig. 8). In reality, in the areas of gauntlets there are options without changing the motion side and with the change of motion side.

Four hundred twenty-one sets of turnouts for 1435 mm gauge, thirty crosspieces lying separately, forty-two sets of flat crossings are operated within the “Lviv Zaliznytsia” regional branch for combination and crossing of 1435 mm gauge with each other and with standard 1520 mm gauge. Fig. 9 shows a fragment of the tracks gauntlet, where one rail track is move up to the other and laid on its sleepers using a crosspiece without turnouts.

In addition, to ensure the connection of dual gauge with separately located 1435 mm and 1520 mm tracks on the Lviv Railway, individual structures of connection are operated. For example, the combined turnout is operated along the Khust distance of the track at the Berehove and Vynohradove stations, type P50, mark 1/11, left-side, on the wooden bars (Fig. 10).

Fig. 7 Scheme of the tracks gauntlet

Fig. 8 Scheme of the tracks combination

Fig. 9 The tracks gauntlet

Fig. 10 The combined turnout

In Ukraine, a special turnout was developed for the movement of trains with different track gauge as one of the options for design solutions. The dual turnout according to the Dn410 project with rails of the European profile, type UIC60, mark 1/11, 1435 mm gauge on the wooden bars with a crosspiece and with welded rail ends was laid in May 2005 on the first major track of the intermediate railway station Kosyny, regional branch "Lviv Railway" [11]. In September 2017, the turnout according to the Dn410 project was inspected and it was established that the passed tonnage was 8.9 million gross tons, the speed was 60 km/h in the direct route, and 25 km/h in the sideways one. Due to the fact that dual gauge is laid on reinforced concrete sleepers to ensure the equal elasticity of the railway track, it is necessary to start laying such turnouts on reinforced concrete beams.

On dual gauge sections, the same train traffic along a track of each width will hardly be provided. Different cyclicity of loading will lead to asymmetric operation of an under sleeper base. In the presence of improper maintenance in the sleepers and ballast condition, this can provoke an increase in the intensity of the residual strain accumulation.

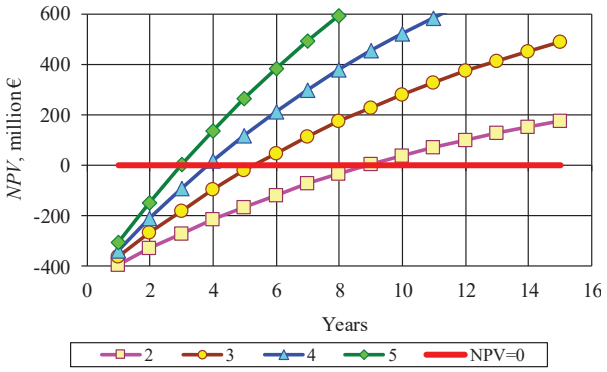

Fig. 11 The progressive total of the net present value depending on the size of passenger traffic (Lviv-Mostyska-Krakow-Warsaw section)

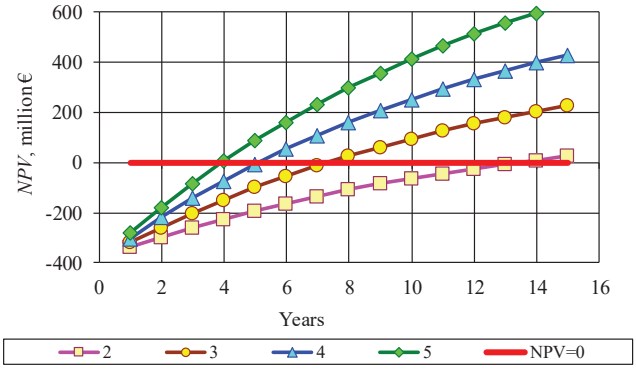

Fig. 12 The progressive total of the net present value depending on the size of passenger traffic (Lviv-Rava-Ruska-Warsaw section)

A further comparison was conducted on such an index as the net present value (*NPV*). The model developed by the authors for forecasting and evaluating the efficiency of railway transportation from the border of one state to the border of another was presented in [11, 15]. The main index (*NPV*) used in the model is the difference between total income and all types of costs, with consideration to the time factor. The list of recorded expenses includes investments, locomotive fleet, car fleet, current operating costs, costs that depend on the type of technological operations, and the stay period of freight cars at the break-of-gauge points.

The transportation fee was set in accordance with the order of the Ministry of Infrastructure of Ukraine "On Amendments to the Tariffs for the Carriage of Passengers, Luggage and Cargo-Luggage by Rail in International Transport", No. 208 March 25, 2019.

Options of passing passenger trains in the amount of two to five pairs per day were considered as forecast data. It is established that the net present value depending on the size of passenger traffic was previously observed in the Lviv-Mostyska-Krakow-Warsaw option (Fig. 11) in comparison with the Lviv-Rava-Ruska-Warsaw option (Fig. 12).

4. Conclusions

Analyzing the options considered, we can conclude that the construction of dual gauge would facilitate a non-stop quick and comfortable trip from Lviv to European cities. The driving time for the longer version is shorter and is 5.7 hours, compared to 6.2 hours in the second case. Operating costs for passenger train mileage is 6.0/6.5 euros/train-km against 8.0/8.5 euros/train-km in the second case.

According to the Lviv–Mostyska–Warsaw project, the length of the option is 1.6 times higher and its forecasted cost is 120 million euros against 50 million euros: the cost of the Lviv–Warsaw project via Rawa-Ruska, ie the difference is 58%. The authors do not share such a valuation, considering it to be understated, and therefore the study assumed a unit cost of 5 to 10 million euros per 1 km.

At the quantity of two pairs of passenger trains a day in the first case the positive effect comes at $t = 9$ years, in the second option at $t = 13$ years. With a doubled traffic volume, the income appears in the 4th and 5th years, respectively. It should also be noted that in the first version $NPV = 306$ million euros against 132 million euros in the second one at the cost of dual gauge construction 5 million euros/km (177 million euros total) against 7 million euros/km (25 million euros total) respectively.

The final decision on the advisability of using dual gauge for expansion of the international traffic should be made after clarifying the volume of round-trip traffic between Lviv and Warsaw, taking into account, as it was noted above, the complexity of the longitudinal profile and plan of options, technical equipment, and operating standards.

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