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GEODESIC ACCURACY OF RAILWAY NETWORKS UKRAINE IN CONNECTION WITH ACCESSION TO THE EU

ГЕОДЕЗИЧНА ТОЧНІСТЬ ЗАЛІЗНИЧНИХ МЕРЕЖ УКРАЇНИ В ЗВ'ЯЗКУ З ВСТУПОМ ДО ЄВРОСОЮЗУ

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Summary. The operation of international transport corridors is primarily assessed in terms of direct economic efficiency. Profit associated with the transit of transport operations and cargo. However, projects for the creation and development of international transport corridors always entail socio-economic changes. Including: the development of industrial and social infrastructure, the transformation of industrial and economic relations, environmental change, etc. This article discusses the existing problems and the ways of Ukraine's transition to standards (survey, design, construction, operation, modernization stages) and rules operating the railways of the European Union. Taking into account the actual technical condition of the infrastructure of the Ukrainian railway. The parameters limiting the speed of the existing sections of the railway are considered. These include - the radius of the curve, the length of the transition curve, displacement, increase in the external rail, insufficient increase; type of the upper part of the route and its wear; directed translations; artificial constructions; passenger platforms; communication and blocking systems; energy saving systems; rolling stock; train speed and more. Line plan analysis on curves and straight sections of international transport corridors. Calculations using the method of registration of measurement accuracy in high-speed movement confirmed the urgent need to account for the volume of labor costs. The cost of restructuring curves and energy savings to establish rational parameters of the plan in accordance with the specified maximum speed levels.

Keywords: geoinformation systems, arrow method, curve measurement, line layout, radius measurement, international transport corridors, trackwagons and mobile laser scanning, maximum speed.

Introduction. The Association Agreement between Ukraine and the European Union has fully entered into force on September 1, 2017. The need to develop and implement a methodology for assessing the efficiency of regional transport and logistics infrastructure is dictated by circumstances that objectively limit the development of regional economic systems, as well as the modernization of their structure. Namely: high capital intensity of infrastructure, long-term return of large volumes of investment resources; imperfection, instability of the state and regional regulatory framework, greatly increase the level of risks for infrastructure projects; limiting the effect of market competitive mechanisms; inflexible state tariff policy for products and services of the infrastructure industries - monopolists. All of the above factors hinder the achievement of strategic goals of public administration. In the absence of a unified methodology for assessing the effectiveness of state infrastructure and monitoring its impact on the structural dynamics of social and economic parameters of economic systems, implementation of development programs is complicated.

In the established practice of the functioning of international transport corridors, the position of direct economic efficiency related to revenues from transit transport operations is firstly estimated. However, projects of international transport corridors always entail socio-economic changes, including: the development of industrial and social infrastructure, the transformation of production and economic relations, changing the economic situation, etc. At the same time, technologies of integrated assessments of the functioning of international transport corridors have not been worked out so far, which complicates the deliberate decision-making on their creation and development.

Considering international transport corridors as an independent category investment projects, one can distinguish the following characteristic features their implementation, which determine the nature the assessment:

- coordination processes development transport infrastructure in the interests integration international transport systems for the unhindered movement across the borders passengers and goods;
- optimization transport processes that improve the quality transportation, including the reduction of transport costs, lead to an increase in the attractiveness international transport corridors;
- harmonization interconnection between different modes transport in intermodal transport chains;
- assistance in the development a new territories, the development a new international markets for goods and services;

- increasing mobility the population, including the development international tourism and cultural ties, due to increased transport accessibility the regions.

Analysis train speeds, especially passenger traffic, shows that they do not match the requirements international railway lines in their technical condition.

Materials and Methods. A large number speed restrictions on the Ukrainian railways is associated with the parameters the plan and the state the railroad. To increase speed the train along the curve, it is necessary to determine the optimal parameters and put the curve in the correct, projected position. Calculations show that when designing rail repairs it is possible to achieve a significant increase in the time train movement only due to the requirements the CP-113 (p.2.3.2-2.3.4 – correction of curves in terms of restoration of design radii) [1, 6, 8,], that is, to make tracks during capital repairs in the project position. Work on the restructuring curves performed on the railways Ukraine is an inaccurate model in which it is believed that three adjacent points the curve lie in a circle. On this principle, the work the dressing-finishing machine, is constructed - the method smoothing. The absolute majority of modern methods curve correction calculations are based on the determination the displacements at separate points the track due to the difference in the length the involutes for the existing and design variants (the involutes model). With long curves, large values landslides and significant variations in the curvature an existing track, an involutes model can produce significant errors. More precisely, the shifts can be determined in the coordinate system by geometric representation the design variant and finding the distance from the starting point to its design position (coordinate model). As the speed increase brings higher requirements for design quality, correction and current curvature, new approaches to filming, calculations and execution work are required. Of course, this will increase the cost a filming and designing such sites, but this is a compulsory step, without which it will be practically impossible to implement a qualitative increase in speed. What weakly influenced the trains' performance at speeds 90–120 km / h, is becoming important at speeds 160–250 km / h. In order to determine how the outline information on the plan line affects the determination the rational parameters the curves and the permissible speed the trains, an analysis the methods filming was conducted, fig.1.

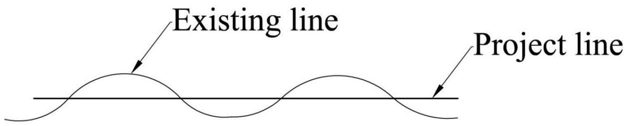

Figure 1 – Geodetic survey accuracy
Рисунок 1 – Точність геодезичної зйомки

Train speed may be limited:

1. Parameters the plan: the radius curve, the length transition curve, diversion bias, increase the external rail, insufficient increase;
2. Type the upper structure the track and its wear;
3. Shift transfers;
4. Artificial structures;
5. Passenger platforms;
6. Communication and locking systems;
7. Energy saving systems;
8. Rolling stock and so on.

The speed limitations are permanent and temporary nature.

Removal permanent restrictions is possible as a result reconstruction the section track, temporary - in accordance with the plan performance travel works.

If there are several restrictions in one place, the minimum limit is taken

By the condition the track, the following restrictions on the speed trains are possible:
1. Under the terms profile;
2. Upper structure the track;
3. Shift transfers;
4. Artificial structures;
5. Disease the earth's canvas;
6. On the elements road plan.

The appearance the restriction the speed trains is affected by many operational factors:
1. Quantity goods transported;
2. Wear elements the track;
3. Depreciation street transfers;
4. Contamination the ballast layer;
5. Untimely performance the travel works;
6. Inconsistency the top structure the track with the conditions operation and other.

Restrictions on the speed passenger and freight trains along the longitudinal profile are possible on the brakes on the slopes and on the implementation the power locomotives on the ascent.

According to the established norms DBN V.2.3.-19-2008 at 120 km / h, the slope the profile should not be more than 15 ‰.

The maximum speed the passenger and freight trains on the slopes is determined by traction calculations or according to the brakes specified in [6].

For all-metal passenger carriages, equipped with electropneumatic brakes on slopes up to 14 ‰ permitted speed 140 km / h.

By the power the locomotive VL82, which is currently used for passenger and freight trains, the construction speed 110 km / h. For freight trains on the driving slope – 51 km / h.

When switching to a passenger locomotive BS2 or BS7 speed restrictions will not be. The gain in time can be determined by the formula:

$$t = 60Z\left(\frac{1}{V_1} - \frac{1}{V_2}\right) \quad (1)$$

where Z – length section;

V_1 – maximum speed with existing locomotive;

V_2 – maximum speed at the design locomotive.

If the turnout is in a curve radius $R > 788\,m$ the speed motion is determined by the formula:

$$V_{\max} = 8{,}6\sqrt[3]{R} \quad (2)$$

at the radius the curve $R < 788\,m$ the speed movement is determined by the formula:

$$V_{\max} = 2{,}83\sqrt{R}\,. \quad (3)$$

On bridges with riding on a ballast, the stability the rail-sleeper lattice should be ensured. For this, the shoulder width the ballast prism should be at least 35 cm, or filled with ballast troughs. The boom the rails on the metal bridges in the extreme spans should be in the range 1/2500 ÷ 1/3000, and in medium spans – 1/5000 ÷ 1/6000 the estimated span.

The maximum speeds the trains on the bridges must be determined experimentally on the basis dynamic tests.

The earth saw should be strong, stable, protected from natural and other factors and comply with applicable design standards.

The suitability an earthwork for passage passenger trains at a speed 200 km / h, is determined by a soil laboratory based on engineering geological, engineering-geodesic, engineering-hydrometeorological and hydrological surveys. If necessary, the engineering seismic and other types refinement, as well as the actual determination the deformation properties soils, should be performed additionally. There is a diagnostic mobile complex "Era" and "Integral" for studying the condition the earth's canvas.

The restriction the speed trains on passenger platforms depends on their width, type and location and is determined by the design standards DBN V.2.3-19-2008 section 15 "Passenger".
According to the plan, the speed limitation line depends on the following factors:

1. $V_{passenger}$ – the given speed a passenger train;
2. V_c – weighted average train speed;
3. $V_{maxcargo}$ – maximum speed a freight trains;
4. $V_{mincargo}$ – the minimum speed a freight trains;
5. f – speed lifting wheel on a rail;
6. $a_{passenger}$ – unsuppressioned acceleration the passenger train;
7. $a_{maxcargo}$ – unsuppressioned acceleration the freight train at $V_{maxcargo}$;
8. $a_{mincargo}$ – unsuppressioned acceleration the freight train at $V_{mincargo}$;
9. ψ – the rate growth a unearned accelerations.

Depending on these parameters, it is necessary to determine:

1. R – the radius the curve;
2. h – increase the curve;
3. l – the length the transition curve;
4. i – deviation slope increase external rail.

Due to the fact that the relationship between values is nonlinear, the problem relates to multivariate and is executed on the basis existing programs computer technology and modeling in the design railways on the main criteria for driving comfort given in tabl.1

Table 1 – Criteria for driving comfort
Таблиця 1 – Критерії комфортності їзди

Country	$a_{passenger}$, m/c^2	ψ, m/c^2	$f, mm/c$	h, mm
Japan	0,50	0,14	45	180
England	0,65	0,25	38 – 57	150
Italy	0,85	0,15 – 0,33	56	160
France	0,85 – 1	0,30 – 0,85	50	180(200)
Germany	0,65 – 0,85	0,30 – 0,70	28 – 31	150
Poland	0,60	0,30 – 0,70	28 – 35	150
Russia	0,40 – 0,70	0,30 – 0,70	24 – 45	150
USA	0,50	0,30	32	140

Method of arrows. The method allows a fairly accurate estimate the curvature two adjacent points, but gives an error in determining the angle of rotation, which is calculated as the sum the arrows. Random measurement errors the arrows are distributed according to the normal law with the parameters: the mathematical expectation the arrow difference is zero, the mean square deviation is 1.2 mm.

Filming a track-measuring car. The asymmetry the measuring circuit, the large error measurement the traversed path does not allow to obtain reliable parameters the line plan based on the results the races the track-measuring vehicle.

Filming with straightening machines with the system "Navigator", "Arrow". Accurate system measuring the distance traveled; small asymmetry, high accuracy bending arrows.

Method Gonikberg. When measuring Goniberga's method, the empirical error distribution curve was approximated by the normal distribution curve, with the parameters the mathematical expectation the difference in arrows equal to zero, the mean-square deviation is equal to 3.3 mm.

Coordinate filming with the help electronic spacers allows to accurately determine the spatial position the track section, but because the errors coordinates individual points (up to 20 mm) does not give a real correlation the curvature, the neighboring points, the track at their close location.

Using GPS devices. Accuracy at the level an electronic tacheometers, such receivers give only with a differential scheme and parking at each point for a sufficiently long period time, which prevents such filming directly on the track in the "window".

The use modern equipment and innovative technologies opens up new opportunities for solving various problems faced by engineers - designers, builders and railwaymen. It is important to get data in full details when filming not only simple but also multi-level complex objects such as a contact network at large railway stations (it is extremely difficult to determine their characteristics with the required accuracy).

The method omobile laser scanning, especially effective for prompt reception, processing and updating a large volume of high-precision data. Project and construction organizations, services exploitation objects strategic importance, railways require constant and accurate monitoring the constructive state objects - these data can be obtained using mobile laser scanning, which allows for a short period time to collect high-dimensional three-dimensional information about all objects that are in the scope the scanning system. At a filming speed 60 kilometers per hour it is possible to achieve precision at the level several centimeters and density – about 3000 points per square meter.

Used scanning system, which was installed on the roof the railway platform. Basic GNSS stations were installed to ensure high accuracy measurements along the passage corridor. They were located every 20 kilometers on pre-installed base points.

Together with the scan, this system allows you to take pictures the territory the object with four wide-angle cameras with a filming frequency up to 20 frames per second. The data from the cameras can significantly improve the perception objects, analyze their characteristics, assign true colors to points and object attributes.

Automatic correction the brightness the image, waterproof system, range scanning provide the ability to perform filming in adverse weather conditions and at any time a day (even at night - with artificial lighting in the area). Due to the compactness the device and the convenient mounting structure, the system mobile laser scanning can be mounted on any vehicle.

The high frequency scanning allows to collect data without significant losses in the density measurements.

After filming and processing mobile laser scanning data, control was carried out, in which reference objects were used, fixed in characteristic points along the railway line. Data control was carried out by combining the cloud laser reflection points (TLOs) with reference objects. The discrepancies data mobile laser scanning on the reference objects: plan and height position which do not exceed 5 cm are received.

As a result mobile laser filming received the following set data: TLO; geotagged photos; trajectory the motion the scanning system; GNSS observation data at base stations.

After data processing is created: 3D-model terrain in the format AutoCAD and ArcGIS с insertion in the database attribute characteristics; digital models railway infrastructure objects; digital terrain models in ESRI GRID and ASCII format; topographic plans scale 1: 1000; classified TCO.

In addition, the latest software developments in the field digital cartography, CAD and GIS from the well-known manufacturers Autodesk, Bentley, TechNet, ESRI, RIEGL, InnovMetric, TerraSolid, are used.

Especially noteworthy is the software product SiRailScan German company TechNet. With its help, the cloud points laser reflection in the automatic mode check the dimensions the railways and formulate detailed reports detected violations. In the long run, such reports can be used in the reconstruction and repair of railways.

By results data processing the following tasks will be solved:

– creation a complex system spatial data ohe infrastructure of railway transport;
– construction longitudinal and transverse profiles;
– planning and calculating the trajectories of railway transport;
– analysis parameters of railway infrastructure objects and comparison with normative values;
– detection areas on a railway canvas and ballast prisms requiring repair or reconstruction;
– definition the dimensions the infrastructure along the railway track and the calculation critically dangerous values (determination the wires the contact network and close-up transmission lines, deformation the infrastructure objects, landslides the earth's canvas);
– inventory of railway infrastructure objects.

Results and Discussion. At present, a single geoinformation system is being created, in which the integration cloud points, 3D models and topoplanes of railways with databases will be implemented. It’s advantage in the bulk picture, which is achieved by working with data in a three-dimensional space. This will enable operative design train schedules and railways reconstruction, planning and conducting inventory works, calculating geometric parameters of railway infrastructure objects, and solving many other tasks.

Traditional technologies in Ukraine do not allow to solve the problems modernization the line plan at the proper level. If the filming a plan for design reconstruction can be performed by coordinate methods, the accuracy such filming will not be sufficient in the current maintenance and repair the track, since the error the coordinate individual points can reach 10–20 mm. At the same time, filming curves symmetric or asymmetric arrows methods will give an increasing error along the length the curve [4, 6]. During filming and racking a not long curves with bending machines, accuracy is sufficient to provide standards for the content, but the results measurements have a high uncertainty for building a plan and profile sites. This is due to the fact that the angle rotation is practically determined by summing the measured arrows, and the position the trace in space is double summed. Since measurements are performed with an accuracy 0.1 mm at distances less than a meter, the uncertainty the position the end measured area after double summing the arrows is very high. Without additional comparison the results arrival with the measured coordinate’s individual points, this information will also be unreliable [4, 8, 9]. For detailed calculations the line plan in order to increase the speed, it is necessary to accurately coordinate the existing plan two tracks, straighten the plan on the results these calculations and check the performed stratification in accordance with the "Methods for the analysis of accuracy of filming, calculations and correction of rail curves by different types machines / CP-0164". The realization such filming and ensuring the subsequent maintenance the plan track at the proper level is possible only with the creation a single ramp system of Ukrzaliznytsya. Technical and economic indicators project design evaluation, project design efficiency determine the quality the project as a whole and the feasibility its implementation in particular. System indicators describing the quantitative and qualitative characteristics an object is used to select the best project design. The combination these indicators gives an objective assessment the feasibility restructuring the curve and economic efficiency. The savings time observed during the reconstruction the railway plan relate to the most common performance indicators and are widely used in the theory of railway design (time train, time traffic locomotive and carriage, travel time passenger, time intervals). In addition, time is included in the dimension many performance indicators, such as speed, throughput and shipping capacity. Determination the effectiveness the project solution is carried out using indicators overall and comparative efficiency investment costs [5]. The indicators the overall effectiveness design decisions include net discounted income, profitability index, the internal rate discount, the term investment return. Comparative indicators include the comparative integral effect, the construction and operating costs and the payback period additional investments. As you know, investment costs in railway construction are in the form investments.

Conclusions and Recommendations. One the main tasks in organizing high-speed traffic in Ukraine is to ensure high accuracy and maintenance the upper structure the track. The intensity the wear and tear the upper structure the track and the rolling stock, the accident-free and comfortable traffic at high speeds largely depends on the magnitude the deviation the track from the design position in terms profile and height. Foreign experience shows that the most effective way to control the geometry a track based on a stationary reference grid along the track. Measurement this grid allows the most accurate determination the displacement rails.

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ГЕОДЕЗИЧНА ТОЧНІСТЬ ЗАЛІЗНИЧНИХ МЕРЕЖ УКРАЇНИ В ЗВ'ЯЗКУ З ВСТУПОМ ДО ЄВРОСОЮЗУ

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Анотація. Функціонування міжнародних транспортних коридорів в першу чергу оцінюється з позицій прямої економічної ефективності, пов'язаної з прибутками від операцій з транзитного перевезення. Однак проекти створення і розвитку міжнародних транспортних коридорів завжди тягнуть за собою соціально-економічні зміни на мезо рівні, включаючи: розвиток виробничої і соціальної інфраструктури, трансформацію виробничо-економічних відносин, зміна екологічної обстановки і т.д. У даній роботі розглянуті існуючі проблеми та шляхи вирішення переходу України на норми (зйомки, проектування, будівництва, утримання, етапи модернізації) і правила роботи залізниць Європейського союзу з урахуванням реального технічного стану інфраструктури української залізниці. Розглянуто параметри, що обмежують швидкість на існуючих ділянках залізниці. До них відносяться - параметрами плану: радіус кривої, довжина перехідної кривої, ухил відводу, підвищення зовнішньої рейки, недостатнє підвищення; тип верхньої будови колії та її знос; стрілочні переводи; штучні споруди; пасажирські платформи; системи зв'язку та блокування; системи енергозбереження; рухомий склад; інтенсивність руху поїздів та інше. Наведено аналіз плану лінії на кривих і прямих ділянках міжнародних транспортних коридорів, розрахунки за методикою обліку точності вимірювань при швидкісному та високошвидкісному русі, підтверджена нагальна необхідність врахування обсягів робіт, витрат на перебудову кривих і економію енергетичних ресурсів для встановлення раціональних параметрів плану відповідно до заданих рівнів максимальної швидкості.

Ключові слова: геоінформаційні системи, метод стріл, вимірювання кривих, розкладка ліній, вимірювання радіусу, міжнародні транспортні коридори, вагони трасування та мобільне лазерне сканування, максимальні швидкості.

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