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Digital models and the effect of error when shooting terrain for high-speed traffic

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Abstract. The article discusses general information about Ukraine and the possibility of introducing high-speed traffic using modern technologies for surveying the area. This step makes it possible to work out more detailed options in the design. Surveying using electronic total stations and GPS devices allows you to accurately determine the spatial position of the site, but because of errors in determining the coordinates of individual points, it does not give a real ratio of the curvature of neighboring track points when they are close. Railways require constant and accurate monitoring of the structural state of objects this data can be obtained using mobile laser scanning, which allows you to collect a high-resolution three-dimensional survey of all objects in the visibility range of the scanning system in a short period of time. Having an extensive transport infrastructure and at the crossroads of the most important areas of world trade between Europe and Asia, Ukraine has all the prerequisites for the development of the transport industry within the framework of a balanced state policy. Today, all countries are faced with the task of further expanding the space of non-power scenarios for the transformation of the financial and economic order in the world.

1. Introduction

France is the first European country to introduce high-speed lines. The total length of 3345 km, of which 3220 km in operation (at the end of 2018). Based on the successful experience of operating a high-speed rail in France, other European countries such as Germany and Italy have developed their own railways. The indicated national high-speed railways have various technical features and, in general, do not have the ability to interact. The European community is promoting the development of a trans-European network of high-speed railways [1]. Therefore, it is necessary to guarantee the possibility of interaction between individual railways and their individual systems.

Based on the tasks of creating a high-speed rail network, the total population and economic situation in Ukraine, as well as based on the basic principles of high-speed rail, in Ukraine it is proposed to create the following system of high-speed rail.

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General information about Ukraine was analyzed in terms of geographical location, administrative regions, urban population and economic situation. New lines are intended exclusively for passenger traffic. This makes it possible to reduce the distance between destinations. And at the destinations, joint operation with the existing network of railways is provided, this will allow you to penetrate the city centers, creating extensive access to the new network throughout the territory.

With the existing technology, surveying of tracks and roads, as a rule, is carried out in the following sequence: design, construction and consolidation of the geodetic base; breakdown of the picket in the direction of shooting and for all individual sections and sites; survey of curves, determination of turnout centers and their measurement; survey of track development, artificial structures, drainage devices, underground, ground and air communications; measurement of overall distances from the axes of the path to the nearest buildings and structures; longitudinal leveling all the way; shooting of the territory along the highway, including shooting of all cargo fronts [2]. Based on the data obtained, a plan is drawn up that shows the location of all tracks and turnouts, the location of buildings and structures.

2. The basic part

To solve this problem, it is necessary to create a digital model of both existing railway lines and sections of the construction of high-speed passenger lines. Digital models of the terrain and geological structure of the area are formed on the basis of the use of materials from ground and aerospace surveys. It is advisable to use those methods of topographic surveys that provide information about the area in electronic form, which allows you to automate the process of preparing topographic plans and a digital terrain model.

Tacheometric surveys are especially effective if they are performed using electronic total stations or computer geodetic stations with real-time recording of recorded information on magnetic media or its subsequent entry into the memory of the base computer.

Phototheodolite shooting. It is advisable to process the results of phototheodolite surveys on universal stereophotogrammetric instruments with automatic registration of the measured coordinates of terrain points or to perform systematic computer processing of photographs using automated systems such as Fotomodxr for this purpose.

Aerial photography. It is advisable to determine the coordinates of terrain points when processing stereopairs using universal stereophotogrammetric instruments with automatic recording of measured coordinates on magnetic media or to perform system computer processing by preliminary scanning stereopairs or using electronic photographs for this purpose.

Terrestrial and satellite imagery using GPS satellite navigation systems is best suited for creating a digital model, since it provides information about the terrain directly in electronic form on magnetic media, which allows you to automate the process of model preparation as much as possible [3].

Engineering and geological surveys are carried out comprehensively using traditional engineering and geological exploration methods (mechanical drilling, punching, clearing devices, etc.), airborne geological exploration (color, spectrozonal, thermal aerial surveys) and ground-based geophysics methods with automatic recording of magnetic measurements carriers (vertical electrical sounding, electrical profiling, seismic exploration, static and dynamic sounding, etc.). The use of automation and computer processing of engineering-geological survey data is absolutely mandatory.

Digital and mathematical models, presented in geodetic rectangular coordinates without distortion of scale, can nevertheless be characterized by different accuracy and degree of detail of the relief elements, situation and geological structure of the area, which is associated with the category of relief, situational features of the approximated area, the scales used to construct digital models of topographic plans and aerial survey materials.

The necessary accuracy of the model must necessarily be linked to the required accuracy of engineering problems solved by it.

When using traditional topographic surveys to build a digital model of materials, the accuracy of situational contours is taken in accordance with the accuracy of the performed topographic surveys equal to 1 mm in the scale of the plan. The accuracy of the representation of the relief should not go beyond the horizontal section height in flat terrain, section height in rugged terrain and 1 section height in mountainous. The accuracy of the digital model using topographic surveys made using electronic tacheometers or GPS receivers, taking into account that information is recorded accurately on magnetic media, depends mainly on the accuracy of the instruments used [4].

When constructing digital models according to existing topographic plans and maps, the characteristic points of the area are taken with an accuracy assumed to be: 0.5 mm - to display situational features of the area and 0.2, 0.3 and 0.5 section heights - to display respectively flat, rugged and mountainous reliefs.

When creating a digital terrain model based on aerial photographs or photo-theodolite surveys, the accuracy of displaying situational features of the terrain and terrain is determined by the accuracy of reading the photogrammetric coordinates, which provides one or another used stereophotogrammetric device [5].

To ensure the necessary accuracy of approximation of the terrain, the density of the initial array of points (average distance from each other) for regular and irregular (statistical) models accept:

- in the flat terrain - 20-30 m;
- in rough terrain - 10-15 m;
- in the mountains - 5-7 m.

The combined effect of the curvature of the earth and refraction on the accuracy of determining the excess is found by the formula:

$$f = \frac{d^2}{2R} \approx \frac{kd^2}{2R}, \qquad (1)$$

where R - earth radius;

k - coefficient of the refraction curve, taken equal to 0.16.

Based on (1) the refractive index

$$k = \frac{d^2 - 2Rf}{d^2} = 1 - \frac{2Rf}{d^2}. \qquad (2)$$

The absolute error in the position of the curve point is determined by the formula:

$$m_{xy} = m_x\sqrt{2}. \qquad (3)$$

Using the well-known formulas from the theory of mathematical error of geodetic measurements, we calculate the influence of rounding of arguments from a given sample of measurements taking into account the absolute error and we obtain the following dependence in Figure 1.

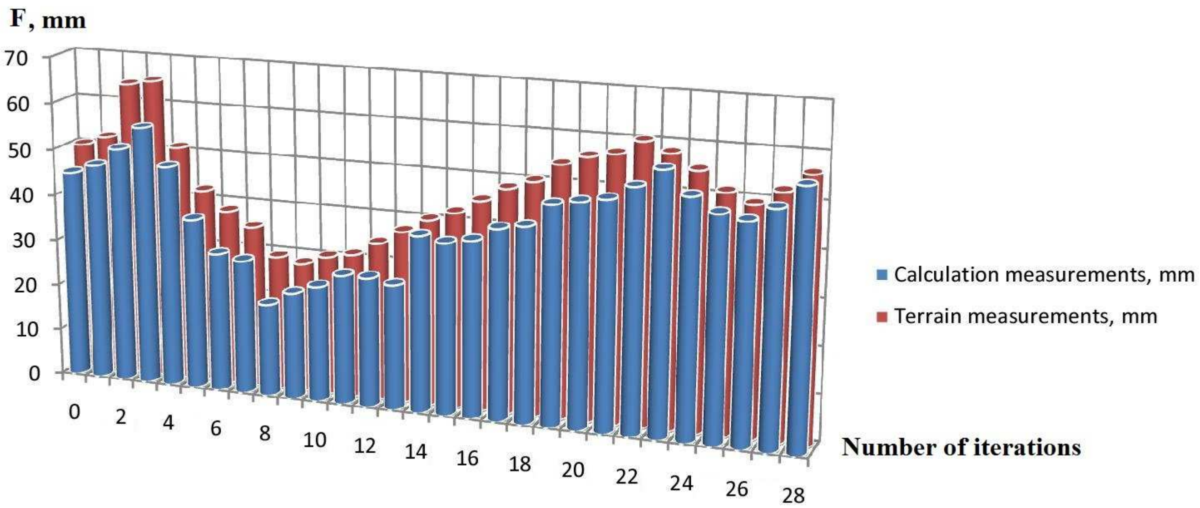

Figure 1. The relationship between the standard deviation of the calculated and field measurements

After analyzing the results and taking into account that the permissible values of the differences range from 4 mm to 12 mm, the maximum error in determining the coordinates should not exceed 2–7 mm, respectively [7].

Since modern tacheometers provide this accuracy, the use of this calculation apparatus is very effective for controlling the smoothness of curves at the current content of railway lines and highways [8, 9].

A significant effect when working with an electronic total station is achieved by using the pick-up-free method of filming. In the case-free shooting method, a limited number of points characterizing the situation and relief are typed and determined [10-12]. Given that there are constant signs on the railway track (picket, kilometers, traffic lights, various signs), their position can be used to fix the leveling points. On the territory of the enterprise, corners of buildings and other permanent objects can be used as such points.

3. Conclusions

Surveying using electronic tacheometers and GPS devices allows you to accurately determine the spatial position of the site, but because of errors in determining the coordinates of individual points, it does not give a real ratio of the curvature of neighboring track points when they are close. The mobile laser scanning method is especially effective for the rapid receipt, processing and updating of a large amount of high-precision data. Railways require constant and accurate monitoring of the structural state of objects these data can be obtained using mobile laser scanning, which allows you to collect a highly detailed three-dimensional survey of all objects in the visibility range of the scanning system in a short period of time. At a shooting speed of 60 kilometers per hour, it is possible to achieve accuracy at the level of several centimeters (about 3000 points per square meter) [3-5].

Having an extensive transport infrastructure and at the crossroads of the most important areas of world trade between Europe and Asia, Ukraine has all the prerequisites for the development of the transport industry within the framework of a balanced state policy. At the same time, the formation of international transport corridors is a complex process that requires political, social, economic, organizational and technical innovations and transformations. Today, all countries are faced with the task of further expanding the space of non-power scenarios for the transformation of the financial and economic order in the world.

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