Features of Providing Engineering and Infrastructure Objects with Geospatial Information

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Abstract: The urgency of the research is due to the fact that there is a necessity to develop and maintain new mineral deposits for which it is necessary to perform surveying and geodetic works and three-dimensional modeling of the earth's surface. Based on the obtained results the geospatial data are formed. With the help of these data we can design and equip the mineral deposits and determine the geological structures and engineering infrastructure of these deposits. In addition, the geospatial data are the basis and source information of documents during the state cadastral registration and registration of land use rights. On this base, the research has the following scientific and technical task: to analyze the possibilities of using different methods for providing GIS of engineering and infrastructure systems with the geospatial information, and with the data for 3D modeling of the studied objects. Corporate GIS is filled with the data on the state of the engineering infrastructure using the information from space surveying systems with high and medium spatial resolution, as well as survey materials from unmanned aerial vehicles and aerial laser scanning. Monitoring of engineering systems is also carried out using the data of ground geodetic surveys.

The analysis of the possibility of using different methods of providing GIS geospatial information with materials from space surveys with different spatial resolution, data of unmanned aerial vehicles and laser scanning, trigonometric leveling is conducted. The results of the research showed that the data of remote sensing of the Earth with different resolutions, of unmanned aerial vehicles, make it possible to form arrays of geospatial data necessary for organizations engaged in the operation of engineering systems that provide reference data for planning. Also, they allow to obtain data with sufficient accuracy when creating high-level geodetic justification, when it is necessary to increase the accuracy to III and IV classes. It was established that instead of labor-intensive geometric leveling, it is advisable to supplement the data with information obtained by the method of trigonometric leveling using high-precision electronic tacheometers.

Keywords: Geospatial data, Decoding of aerospace images, Geoinformation technologies, Unmanned aerial vehicles, Aerial laser scanning, Three-dimensional model of the earth's surface, Trigonometric leveling, High-precision electronic tacheometer.

INTRODUCTION

At present one of the key areas of development of Ukraine's economy, especially its digital component, is the creation of three-dimensional models of engineering and infrastructure facilities of the developing mineral deposits. This problem formulation is due to the need for spatial location of construction and operation of engineering facilities, planning their future use, preparation of relevant legal documents, and introduction cadastral information into the unified state register of real estate (USR of RE).

One of the most common types of modern geodetic equipment is high-precision and accurate electronic tacheometers, which allow to obtain geospatial information about the terrain and anthropogenic objects both according to the plan and to the height. The height component is determined by performing trigonometric leveling. The application of the trigonometric leveling method is especially relevant when working in rough terrain and adverse conditions, which is characteristic for the areas of eastern Ukraine where the minerals exploration is carried out. Spatial 3D modeling allows to present the developing deposits in the form of a digital model of the area, which reflects the terrain relief, geological structure and infrastructure objects [1, 2].

Development of corporate geographic information systems (GIS) for geological exploration enterprises causes the need for the information about the state of the main networks and their geometric characteristics. Decoding the materials of remote sounding of production facilities of existing prospecting complexes allows to recognize the sites of the main engineering networks, to determine their overall dimensions and some characteristics of the equipment located within them, as well as to draw up the results in the form of graphical diagrams. At the same time, in many cases the result of activity intensification is an increase in the burden on the environment, violation of ecological balance, soil pollution, depletion of land resources, and deterioration of their useful properties [3].

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Table 1. Spatial resolution of Imaging Systems.

No.	Type of Aerospace Survey	Spatial Resolution,m/Pixels	Survey Systems
1	Aerial photography fromUAV ZALA	0,05–0,08	MSC Z-16AGRO1
2	Ultra-high-resolution Spacesurvey (SS) (0,3–1 m/pix)	0,31	WorldView 3,4
3	High-resolution SS(1–5 m/pix)	2,5	SPOT 5
		3,5	PlanetScope
4	Medium-resolution SS(5–30 m/pix)	10,0	Sentinel-2A, 2B
		15,0	Landsat 8
5	Low-resolution SS(>30 m/pix)	250,0	Terra (Modis)

Source: formed by the [12].

The main sources of information to solve most problems that require the geospatial information are aerospace images obtained in the optimum diapason of the wavelength range [4]. At the same time, to solve certain problems the data from space radio-locating surveying (determination of the earth's surface dynamics, and objects of engineering highways in the areas of difficult climatic conditions), thermal survey, and airborne laser scanning (ALS) materials (construction of main highways and further analysis of their changes) may be required [5]. The most important trends in foreign publications related to using the data of the Earth remote sounding in order to obtain the geospatial information and electronic resources are: quantitative increase in the projects implementing the concept of data presentation, increasing the opportunities for services personification, integration of own data into the existing services, resources globalization and their role in everyday life [6, 7, 8]. However, for the effective use of the satellite data in practice, the potential users must understand the information capabilities of modern remote sounding data in order to update the cartographic materials, transport infrastructure tasks (pipelines and engineering facilities), agriculture, land cadaster, forestry, etc. This topic is also highlighted in domestic publications [9, 10, 11, 19]. However, we think that such topical issues need deeper scientific research.

METHODOLOGY

The analysis of the possibility to use different methods of providing geospatial information with GIS systems has been done. These systems are: space surveys with different spatial resolution, data of unmanned aerial vehicles and laser scanning, trigonometric leveling of classes III and IV obtained using the high-precision electronic tacheometers when forming the arrays of geospatial data of linear infrastructure system objects monitoring. In this research, the excess between the points is determined by the measured angle of inclination and the distance to the object of sighting. Using the method of trigonometric leveling to determine excesses with high-precision electronic tacheometers eliminates a series of difficulties (strict compliance with the equality of the arms when installing the level, the minimum height of the sighting beam above the surface), which significantly increases labor productivity in mountainous and marshlands. Increasing the length of the sighting beam to 200-300 m ensures a double increase in work productivity.

To create a height base, it is proposed choosing the leveling class based on the category of land on which the corresponding object is located. For the formation of a 3D models, it is recommended using leveling of the III class on the lands of populated areas, and leveling of the IV class on the lands of other categories. To clarify and detail the basic cartographic basis along the corridor of a linear object, the ultra-high-resolution space survey data (<1 m/pixels) can be used along with other methods of instrumental remote survey (laser scanning, etc.). Methods of decoding the aerospace images, experimental research in the field conditions with the materials of space surveys, the data of unmanned aerial vehicles, use of high-precision levels and electronic total stations for trigonometric leveling, and geoinformation technologies were used.

RESULTS AND DISCUSSION

To form the basic multiscale spatial basis of GIS, the following data sets of the Earth remote sensing (ERS) are mainly used:

- space survey of mean resolution from 5–30 m (visual coverage with space survey), the data must be presented on the whole territory of Ukraine;
- high-resolution space survey (1–5 m) (basic coverage with space survey of the linear part and adjacent territories of infrastructure objects (not less than 10 km from the axis of the infrastructure object);
- ultra-high resolution space survey (<1 m) is used to detail the basic spatial basis along the axis of the infrastructure object.

To clarify and detail the basic cartographic basis along the corridor of a linear object, the ultra-high-resolution space survey data (<1 m) can be used along with other methods of instrumental remote survey (laser scanning, etc.) (Table **1**).

The materials of space survey and operational documentation are not always sufficient sources to fully reflect the objects or their characteristics in graphical diagrams. For example, the information about underground communications, type of

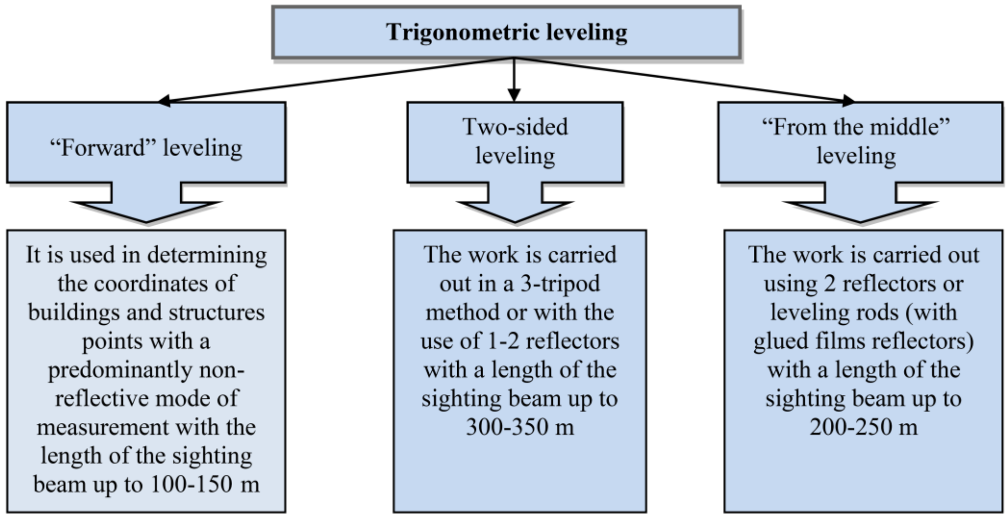

Fig. (1). Methods of trigonometric leveling.
Source: formed by the authors

vegetation, and buildings destination can be obtained as a result of field decoding and field surveying.

To ensure high-precision spatial modeling, it is necessary to create a digital substantiation in the form of a three-dimensional coordinate system (x, y, H). Until recently, the height component was determined by geometric leveling using the optical and digital levels. According to the current instructions on state leveling of classes I, II, III and IV in order to determine the third coordinate H in this system, only the method of geometric leveling is used. Therefore, in the conditions of hilly and marshy terrain, the implementation of geometric leveling is associated with a number of complex technological features, such as strict compliance with the equality of the arms when installing the level, the minimum height of the sighting beam above the surface, which, as a consequence, significantly increases the complexity of this process [13].

Due to the widespread introduction of the high-precision electronic tacheometers in geodetic production, it is possible to replace labor-intensive geometric leveling with high-tech trigonometric leveling (TL). In this case, the excess between the points is determined by the measured angle of inclination and the distance to the object of sighting. This method of determining the excesses eliminates the above-mentioned difficulties, which significantly increases labor productivity [4, 14].

The creation of spatial models is an important step not only for the formation of geospatial information GIS of the linear engineering systems when the formation of such models makes it possible to control the construction of the relevant engineering structures and also to solve various scientific, technical and operational problems.

At present, when determining the plane rectangular coordinates (x, y) of the points of the earth's surface for the construction of 2D models, the following basic methods of geodetic measurements are used (independently or in combination): tacheometric survey, satellite measurements, laser scanning (ground, air, and mobile for the linear objects), aerial photography and the use of unmanned aerial systems (UAS). In the formation of 3D models, the method of polar coordinates, part of which is a trigonometric leveling, can be considered the most accessible and accurate. The use of laser scanning and UAS is very promising [15].

It should be noted that the use of 4D modeling requires determining the coordinates x, y, H at certain intervals t. The urgency of this direction is due to the necessity to monitor the condition of the earth's surface, where the infrastructure facilities are located.

There are the following methods of trigonometric leveling: one-sided (forward), two-sided and from the middle (Fig. **1**). One-sided leveling is used to determine the height of an object (a building or a structure), as well as the marks of the picket points when conducting the tacheometric survey. When conducting one-sided leveling, the errors appearing due to the influence of vertical refraction and curvature of the Earth are not excluded, however at length of a sighingt beam to 150-200 m these errors, as a rule, are neglected.

The essence of two-sided trigonometric leveling (TSTL) is to double measuring the excess between points 1 and 2: first - in the forward direction, and then, after rearranging the tacheometer and the object of sight - in the backward direction (Fig. **2a**). The mean value of the two excesses obtained is freed from the influence of the curvature of the Earth, and the influence of refraction is more compensated [16]. The shorter the time interval between the measurements in the forward and backward directions, the more reliably the refractive error is excluded from the leveling results. We recommend that the specified time interval should not exceed half an hour.

The coordinates of the characteristic points of the objects of the increased responsibility should be determined with a mean-square error (MSE) of not more than 0,1 m. The survey base in this case is created by methods of satellite measurements or polygonometry of the 4th class of the 1st and 2nd grades. The choice of geodetic constructions method depends on the distance of the real estate object or the land plot

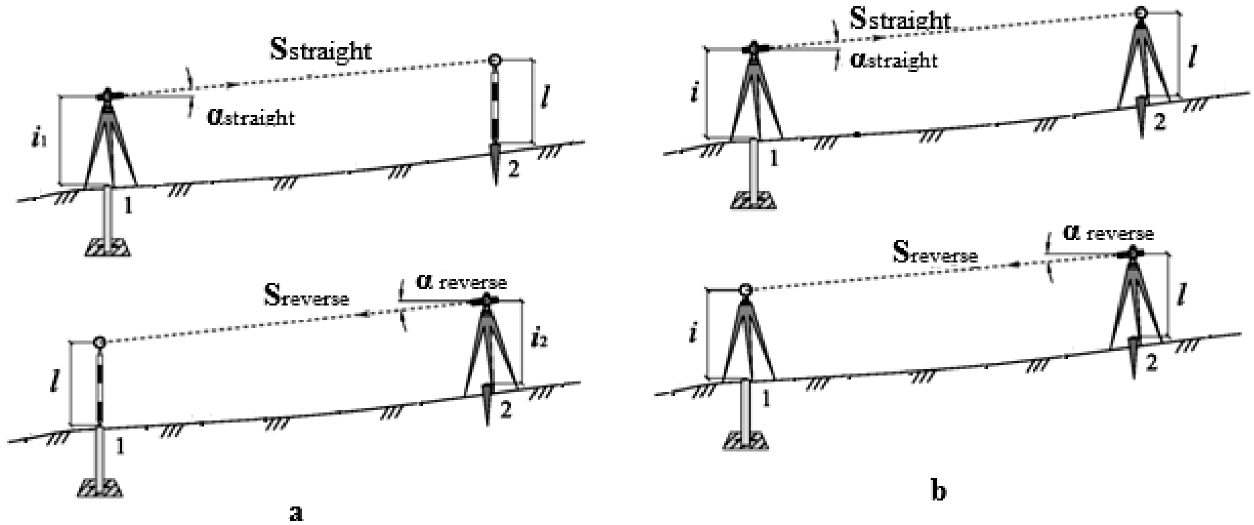

Fig. (2). Two-sided leveling when using the reflector (**a**) and a three-tripod method (**b**).
Source: formed by the authors

from the starting points. When laying polygonometry traverse with an accuracy of grades 1 or 2 (MSE of measuring horizontal angles m_β = 5" and m_β = 10" mβ = 5 ", respectively) a prismatic reflector on the axis, which is held at the point by the assistant with his hands or props is used as a sighting target (Fig. **2a**).

The excess h_{bl} from the two-sided leveling between point 1 (benchmark) and point 2, fixed on the ground with a peg (Fig. **2a**), is calculated by the formula:

$$h_{bl} = \frac{S_{str}\sin\alpha_{str} - S_{rev}\sin\alpha_{rev}}{2} + \frac{i_1 - i_2}{2} \qquad (1)$$

where S_{str} and S_{rev} are the inclined distances, measured in the forward and backward directions, respectively; α_{str} and α_{rev} are the angles of inclination; i_1 and i_2 are the height of the instrument at points 1 and 2, respectively.

According to formula (1), the height of the reflector l can be omitted if it is constant when measuring the excesses in the forward and backward directions, this rule should be followed to reduce the source of errors.

The polygonometry traverses of the 4th class (MSE of horizontal angles measurement m_β = 2") is laid in a three-tripod way. In this case, the reflectors are mounted above the points with the help of the tripods. When moving the tacheometer from the benchmark 1 to the first point of the traverse 2, and the reflector, respectively, to point 1, the position of the tripods does not change: the tacheometer and the reflector are removed from the trigger and change the places. This allows to ensure the invariability of the heights *i* and *l*, as well as the equality of the inclined distances S_{str} and S_{rev} (Fig. **2b**). However, after the tacheometer and the reflector change the places, we recommend to measure their heights above points 1 and 2 one more time to perform the control. The peculiarity of the three-tripod method is that the errors of measuring the heights of the tacheometer and the reflector above the points of the traverse affect only the determination of the marks of the actual transition points, but do not affect the transmission of the mark in the travers itself [16].

MSE of excess m_{hbl} from the two-sided leveling, and then MSE of the excess measurement per one kilometer of the traverse can be calculated by the following formulas:

$$m_{h_{bl}} = \sqrt{sin^2 \alpha m_S^2 + \frac{S^2 m_\alpha^2}{2\rho^2}}, \quad m_{h_{km}} = m_{h_{bl}}\sqrt{n}, \quad (2)$$

where m_s is MSE of the measured inclined distance; m_α is MSE of measuring the inclination angle in one full step; ρ = 206265 is the number of seconds in a radian; *n* is the number of stations in the traverse of 1 km long. The results of the accuracy calculation according to formula (2) when m_s = 2,0 mm, and α = 6 (for the rough terrain), are given in Table **2**.

Table 2. Mean-Square Errors of TSTL at Different Lengths of Sighting.

m_α,sec	MSE of excess M_{hbl}, mm, at Different length of Lines (m)			MSE of excess M_{hkm} Per1 km of Traverse, mm, at Different Length of Lines (m)			Normative MSE Per 1 km of Traverse for a Class	
	100	200	300	100	200	300	III	IV
1″	0,4	0,7	1,1	1,3	1,6	1,9	5 mm	10 mm
2″	0,7	1,4	2,1	2,3	3,1	3,8		
3″	1,1	2,1	3,1	3,3	4,6	5,6		
4″	1,4	2,8	4,1	4,4	6,1	7,5		
5″	1,7	3,4	5,2	5,5	7,7	9,4		
7″	2,4	4,8	7,2	7,6	10,7	13,1		

Source: formed and counted by the authors

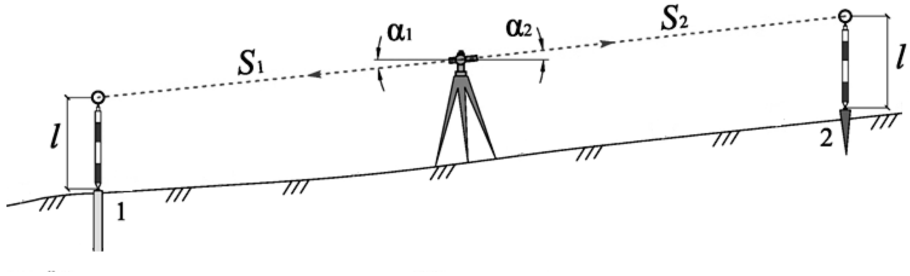

Fig. (3). Trigonometric leveling by the method "from the middle".
Source: formed and counted by the authors.

Table 3. Mean-Square Errors of TSTL Considering the Error of Measuring the Height of the Instrument at Different Lengths of Sighting.

m_α,sec	MSE of Excess m_{hbl}, mm, at Different Length of Line (m)			MSE of Excess m_{hkm} per 1 km of Traverse, mm, at Different Length of line (m)		
	100	200	300	100	200	300
1″	2,0	2,1	2,3	6,4	4,8	4,1
2″	2,1	2,4	2,9	6,7	5,4	5,2
3″	2,3	2,9	3,7	7,1	6,4	6,7
4″	2,5	3,4	4,6	7,7	7,6	7,6
5″	2,7	4,0	5,5	8,4	8,9	10,1
7″	3,1	5,2	7,5	9,9	11,6	13,6

Source: formed and counted by the authors.

From the analysis of the obtained results it follows that the normative accuracy of class III is achieved by the two-sided trigonometric leveling under the condition of measuring the inclination angles with an error of not more than 3" and the length of the sighting line should be up to 200 m. Respectively, the accuracy of class IV is achieved by using the electronic tacheometer with the instrumental MSE of measuring the vertical angle 5" and the length of the sighting line up to 300 m. These statements are true if the travers is laid by a 3-tripod method, because only in this case the errors when measuring the height of the traverse (reflector) are not accumulated.

The errors in measuring the height of the instrument or reflector above the benchmarks can be ignored. Let's evaluate the effect of the error of measuring the height of the instrument m_i on the accuracy of the two-sided leveling when laying a traverse with a reflector on the axis. If you measure the height of the instrument with a tape with an error of m_i = 2 mm, then the MSE of the second item in formula (1) will also be 2 mm. Then the error of excess between the points of the traverse $m'_{h_{bl}}$, considering m_i, can be calculated by the formula:

$$m'_{h_{bl}} = \sqrt{m^2_{h_{bl}} + m^2_i}. \quad (3)$$

The result of the calculation accuracy of the two-sided leveling, considering the error of measuring the height of the tacheometer, obtained by formula (3) are given in Table **3**.

From the analysis of data given in Table **3** it follows that when measuring the height of the tacheometer with an error of 2 mm when using the reflector on the sighting axis, the accuracy of class III leveling can be achieved only when the value of errors value of the angles measured does not exceed 1", which is difficult to achieve under the influence of the environmental factors. At the same time, the accuracy of class IV is confidently ensured when measuring the angles with an error 2-3".

Let's consider the third method of trigonometric leveling – "from the middle". In this case the tacheometer is installed between two points (Fig. **3**).

When leveling by the method "from the middle", like in the case of the two-sided leveling, there is the compensation for the influence of the Earth's curvature and refraction [16-17]. An important advantage of leveling "from the middle" is the absence of the necessity to measure the height of the instrument. This method is also more productive: at a distance of 200 meters from the tacheometer to the reflector, the mark is transmitted by 400 m at once, while at the two-sided leveling it would be necessary to divide this distance into two parts (accurate sighting at 400 m at once is difficult to conduct).

The formula for calculating the excess when leveling "from the middle" under the same number of heights of the backward and forward sighting targets above the points of the traverse looks like

$$h_a = S_2 \sin\alpha_2 - S_1 \sin\alpha_1 - \frac{S^2}{2R}(k_2 - k_1). \quad (4)$$

where k_1 and k_2 are the coefficients for refraction when sighting at points 1 and 2 respectively; R is the average radius of the Earth (6371 km). The third component in the formula (4) is due to the inequality of the refractive coefficients when at sighting points 1 and 2. In general, the difference between the refractive indices Δk is an unknown value. Under the homogeneity of sighting relief at the backward and forward points it is possible to neglect a difference of refraction coefficients; in that case the accuracy of leveling can be estimated by the formula:

$$m_{h_a} = \sqrt{(2\sin^2\alpha)m_S^2 + \frac{2S^2 m_\alpha^2}{\rho^2}}. \quad (5)$$

The mean-square errors of the excess measurement under the trigonometric leveling "from the middle" for α = 6° are given in Table **4**.

Table 4. Mean-square Errors of Trigonometric Leveling by "from the Middle" Method at Different Lengths of Sighting.

m_α,sec	MSE of excess m_{ha}, mm, at different length of sighting (m)			MSE of excess m_{hkm} per 1 km of traverse, mm, at different length of sighting (m)		
	100	**200**	**300**	**100**	**200**	**300**
1″	0,8	1,4	2,1	1,7	2,2	2,7
2″	1,4	2,8	4,1	3,1	4,4	5,3
3″	2,1	4,1	6,2	4,7	6,5	8,1
4″	2,8	5,5	8,2	6,2	8,7	10,7
5″	3,5	6,9	10,3	7,8	10,9	13,3
7″	4,8	9,6	14,4	10,9	15,2	18,6

Source: formed and counted by the authors.

The analysis of data from Table **4** showed that to perform leveling with the accuracy of class III, the measurement of the inclination angles should be performed with an error of not more than 2", and the length of the sighting should be reduced to S <200 m. The trigonometric leveling with an accuracy that can be attributed to class IV, should be performed with the tachymeter with MSE of measuring the inclination angle less than 3" and the length of sighting – not more than 200 – 300 m [17].

The previous calculations have shown that the traverses of the trigonometric leveling, which are laid using the high-precision tacheometers ($m_\alpha \leq 2"$), can correspond to the accuracy of geometric leveling of classes III or IV. Let's consider the basic requirements of technological character which must be provided when performing the trigonometric leveling with the accuracy used to leveling of classes III and IV:

• the order of readings at the stations;

• the permissible minimum height of sighting;

• the permissible value of the inequality of the axes of sighting at the station and the permissible value of their accumulation in the traverse;

• favorable time for measurements;

• the system of control and tolerances at the station. The proposed technique involves the use of high-precision electronic tacheometers with MSE of measuring the inclination angles of not more than 2", and the distances with MSE – not more than 2-3 mm (including the non-reflective mode) [13, 17, 18].

Obtaining high-precision results of trigonometric leveling directly proportionally affects the quality of geospatial information on land, forest resources and, consequently, financial resources of enterprises (land and forestland taxation systems), based on the system and complexity of management decisions and implementation of engineering and infrastructure systems with stable operation and financial stability in the future [19, 20, 21].

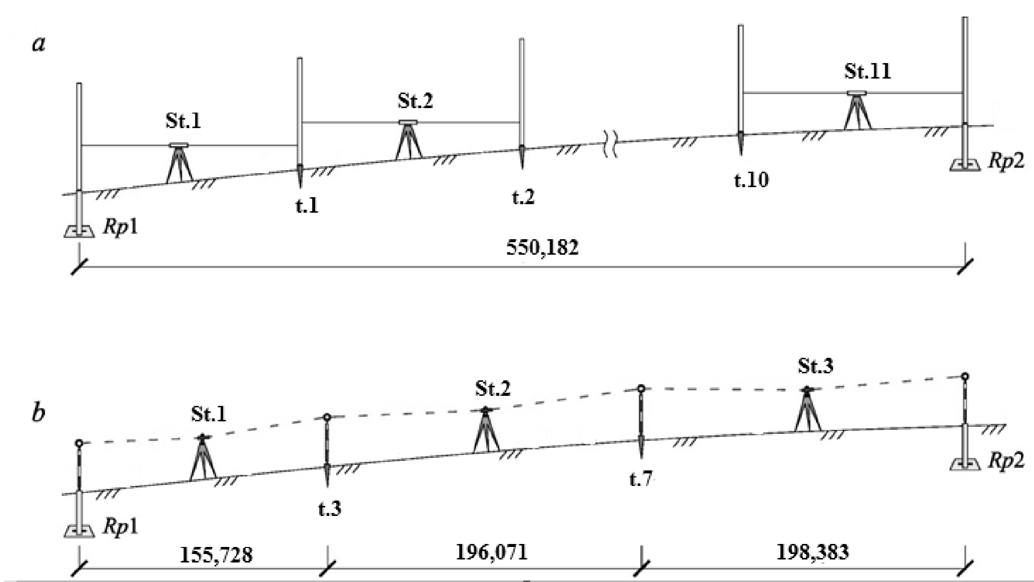

Fig. (4). Scheme of geometric (**a**) and trigonometric leveling by the method "from the middle" (**b**).
Source: formed and counted by the authors.

Table 5. Comparing the Results of Geometric and Trigonometric Leveling.

Traverse Points	Excess, mm, Defined			Deviation Δ from Geometric Leveling			
	Geometric Leveling	Trigonometric		Actual		Permissible	
		III class	IV class	III class	IV class	III class	IV class
Rp_1 – t.3	+252,28	+251,5	+250,7	-0,78	-1,58	±3,95	±7,9
t.3 – t.7	+485,43	+483,11	+490,16	-2,32	+4,73	±4,4	±8,8
t.7 – Rp_2	+302,18	+301,15	+307,61	-1,03	+5,43	±4,5	±9,0
Σ	+1039,89	+1035,76	+1048,47	-4,13	+8,58	±7,4	±14,8

Source: formed and counted by the authors.

To verify the theoretical part and the correctness of the performed calculations of the accuracy of the trigonometric leveling in autumn 2021 under a favorable anti-epidemic situation, the field measurements were conducted in the village Dokuchaievske in Kharkiv region. The works were performed at an air temperature of + 18-22 °C and variable cloud. Two ground benchmarks Rp_1 and Rp_2, located at a distance of 0,55 km from each other, were selected on the site. 10 wooden pegs 25-30 cm long were driven into the ground between the benchmarks at a distance of 50 m from each of them. Previously, on the fixed points t.1-t.10, the traverse of geometric leveling was laid (Fig. **4a**). The accuracy of the level used was 0,5 mm/km of the double traverse according to the passport. The traverse was laid in two directions; from the level to the rail it was approximately 25 m. The excess head between the forward and backward traverses was 2,5 mm, which does not exceed the permissible value $f_{per} = 5\,mm\sqrt{0{,}55km} = 3{,}7\,mm$. To compare, the mean values of the excesses from the traverses in two directions were taken as standard excesses between the benchmarks.

Then between the original benchmarks the traverse of trigonometric leveling by the method "from the middle" was laid (Fig. **4b**), first – by the method of leveling according to class III (using a tacheometer Leica TS-06 with the accuracy of m_α = 2"), and then – by the method of class IV leveling using the tacheometer Leica TCR-405 (m_α = 5"). In both cases the measurements were performed in the conditions of variable cloud at an air temperature of +18–22 °C. The standard rounded reflectors fixed on the axes (the height of both was 1,5 m) were used as the sighting targets. The excess at the station was measured by two methods at two positions of the vertical circle. The mean values of the two methods, if their difference did not exceed 5 and 7 mm for III and IV classes respectively, were taken for the calculation (Table **5**).

From the requirements for leveling of classes III and IV it follows that the deviation of the excess under the trigonometric leveling from the standard values are within the tolerances calculated by the formula:

$$f_{per}III = 10mm\sqrt{L_{km}}\ ,\ f_{per}IV = 20mm\sqrt{L_{km}}\ . \quad (6)$$

The inconsistent traverse of trigonometric leveling of class III, laid in two directions, amounted to $f_{111} = -4{,}13$ mm, and the traverse of class IV – f_{1V} = +8,58 mm, which is not exceeding the permissible values.

On the basis of the conducted experiment it is possible to draw a conclusion about the real possibility of performing leveling of classes III and IV by the electronic tacheometers. At present, the high-precision leveling should be used to fill it with the geospatial GIS data on altitude and use them in conjunction with the data from the sighting systems with high and medium resolution, as well as with the materials from the unmanned aerial systems.

CONCLUSION

1. The geospatial databases on linear engineering infrastructure objects must be kept in the relevant state. To solve the problem of inventory making and control of the actual state of these objects, it is advisable to use the data from the space survey of ultra-high resolution (< 1 m), as well as the aerial photography and the materials from the unmanned aerial systems, which provide the necessary accuracy and details to identify the objects and clarify their spatial position, state of objects and of the environment.

2. The complex of the remote sounding data of the Earth for providing the geospatial data for three-dimensional modeling of the Earth's surface and engineering infrastructure involves obtaining three main data sets, which can be relatively divided into three levels:

• Level I. Surveillance coverage with space survey with a mean resolution (5-30 m) of the territory of Ukraine from the open sources (for example, Landsat);

• Level II. Basic coverage with high-resolution space survey (1-5 m) of the linear part of the engineering infrastructure and adjacent areas with the objects in accordance with the needs of the users;

• Level III. Detailed materials of ultra-high resolution of remote sounding (< 1 m), obtained from different types of bearer (space photography, aerial photography, unmanned aerial system photography). They are performed at the request of departments of companies operating and monitoring the critical infrastructure objects.

3. When creating a high geodetic substantiation with an accuracy of classes III and IV, we propose to use the method of trigonometric leveling with the high-precision electronic

tacheometers instead of labor-intensive geometric leveling. The greatest effect from the application of the proposed method of trigonometric leveling is expected in marshy, rough or hilly terrain, which is especially true for the western regions of Ukraine. By increasing the length of the sighting beam to 200-300 m a double increase in productivity is provided.

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