Geodesic provision for cadastral works: development prospects

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Abstract. The article analyzes the geodesic provision development when performing a cadastral survey. It has been established that improvement will be manifested in the use of modern geodetic technologies - three-dimensional laser scanning. The analysis of literary sources showed that there is a significant number of scientific works on the use of laser scanning for obtaining cadastral data and creating a three-dimensional cadaster. Methods for performing cadastral surveys, criteria for choosing a measuring instrument, methods for assessing the accuracy of coordinates, algorithms for processing the scan data, building models have been developed. However, the issues of further use of three-dimensional information for the cadastral documentation preparation are practically not covered, while the cadastral documentation is the basis for introducing the information into the real estate cadaster. The article presents the results of performing the ground-based laser scanning of a linear object. Additional information that can be introduced to the real estate cadaster in connection with the use of three-dimensional technology - height, technical condition of a linear object has been established. The sections of the technical plan and the changes made to them have been given. In addition, it was revealed that when using three-dimensional data in the preparation of technical plans, it would be inevitable to develop the software that can create boundary, technical plans based on three-dimensional data.

1. Introduction

In the Russian Federation, the information about real estate objects, about rights to them, about restrictions, encumbrances, boundaries of administrative-territorial entities, is contained in the Uniform State Register of Real Estate (USTRE), which is a global database.

The real estate cadaster is a part of this database and consists of information entered in the process of cadastral registration regarding land plots, buildings, premises, structures, single real estate complexes, parking spaces and objects of unfinished construction.

USTRE and its component part of the real estate cadaster are of great importance in the following areas:

- state and municipal management of land resources and real estate, manifested in territorial planning and forecasting land use, land protection, monitoring of land and real estate, land management, provision, withdrawal, conservation of land and other disposal of real estate;
- the formation of an objective payment for the real estate use, which is expressed in the cadastral value determination, which affects the payment of land tax and the amount of lease payments;
- ensuring market turnover of land and objects related to them;
- recognition by the state of the existence or the existence termination of a real estate object, without which the implementation of the above-mentioned actions is impossible.

Based on the cadastral data influence significance, absolutely objective requirements are imposed on them: accuracy, relevance, reliability, availability.

Information entry is carried out during the state cadastral registration, on the basis of the following documents:

- land plot plan - for land plots;
- technical plan - for buildings, structures, premises, parking spaces, objects of construction in progress.

Work in relation to the above-mentioned objects, carried out to draw up either a boundary or technical plan, are called the cadastral works. The work technology can be divided into two stages: field and office.

At the field stage, geodetic work is carried out, during which the location, coordinates of characteristic points of the real estate objects boundaries in the local coordinate system are determined.

Currently, the field stage of cadastral work is mainly carried out using electronic total stations or satellite receivers.

However, there is a noticeable tendency to integrate another measurement tool - a laser scanner.

Laser scanning as a method of photographing the Earth’s surface and the objects on it was known back in the 80-90s of the XX century, but did not receive wide distribution in the Russian Federation, due to the high technology cost and the existing socio-political tension in that historical period [1]. Recently, there has been a tendency for the increasing introduction of laser scanning in many sectors of production and economic activity, such as environmental monitoring, monitoring of the state of infrastructure facilities, modeling, construction, architecture, mapping, geodetic and geological surveys, archeology, agriculture, certification of roads, including the real estate cadaster.

An example of the technology integration into the Russian real estate cadaster is a pilot project on the use of laser scanning for complex cadastral work in three municipal districts of the Republic of Dagestan, carried out until December this year. Moreover, it is planned to analyze the results of this work for the concept and proposals’ development for scanning real estate in other constituent entities of the Russian Federation.

The use of laser scanning technology allows obtaining high quality geoinformation data about an object. In addition, the use of laser scanning makes it possible to speed up the process of collecting geodata due to a wide range of shooting and automation of aiming a laser beam at the terrain objects, increases the information saturation of the material [2]. However, a large amount of data obtained as a set of data points requires optimization of their processing [1].

The study objective is to analyze the possibility and mechanism of using laser scanning data for the cadastral documentation preparation, to identify the changes in its structure in terms of adding the new objects’ characteristics.

To solve it, it is necessary to conduct an analytical review of the main sources of scientific literature on the use of laser scanning technology for cadastral work; search for the practical application of laser scanning technology in cadastral works; consider the structure of cadastral documentation; substantiate the improvement of geodetic works for the real estate cadaster formation.

2. The research question state analysis

A significant part of research in the field of laser scanning belongs to Professor V.A. Seredovich. In his works, the author describes the methods of performing work using scanning for a particular process, assesses the accuracy of the data obtained, analyzes the possibility and results of using ground, air and mobile laser scanning.
In the study [3,4], the authors reveal the concept and highlight the significance of the “height” parameter in the legal aspect of using, owning, disposing of real estate. In the work [3], the authors propose to use ground or air laser scanning for determining the powers of the owners of buildings structures, premises in the vertical parameter (“in height”); supervision over the use of land plots; clarification of information in the cadaster; bug fixes; cadastral assessment; in the procedures for monitoring the accuracy when registering objects. At the same time, it will be possible to expand the information content of the inventory due to accurate forecast and monitoring data in relation to the AUC technical condition and land conditions.

A significant part of the research [3, 5-7] highlights the principles of ground, air, mobile scanning, their advantages and disadvantages, scanning technology, the obtained accuracy of determining coordinates in plan and height, depending on the scanning type. In addition, the tasks of the cadaster that are supposed to be solved using the technology are indicated: correcting cadastral errors, performing supervision, monitoring land, adding a parameter to the volume of buildings, structures, premises in the cadastral data and accounting for it in cadastral valuation. The main task in these studies is the formation of a three-dimensional cadaster, where laser scanning acts as a means of geodesic provision.

In works [5,6] the characteristics of scanning systems are given. In the study [5], the most famous firms producing terrestrial laser scanners are indicated - Leica Geosystems (Switzerland), Topcon (Japan), Trimble (USA), Zoller + Fröhlich (Z + F) (Germany), Riegli (Austria), Callidus (Germany), Optech (Canada). The article [6] provides the technical characteristics of the scanners produced by the above companies, according to the parameters "maximum measured distance", "accuracy of distance determination" depending on the measurement principle: impulse, phase, distance determination method, optical triangulation method. The study concludes that distance measurement determines the accuracy of distance determination. The features of scanners Topcon GLS-2000, IMAGER 5010, Leica HDS8800, Trimble TX6, RIEGL VMX-1HA are considered.

The research [8] is characterized by a greater degree of the scanning performance issue study. As a result, the criteria for choosing a scanning method when performing measurements to form a three-dimensional inventory were developed. It was revealed that when creating separate 3D models of real estate objects, the method of ground laser scanning should be used. In addition, a technique for obtaining a three-dimensional model of a real estate object with the required accuracy has been developed. The relationship between the removal of scanning stations and the degree of three-dimensional model detail is shown. A detailed study of the accuracy issue of constructing such models is described in [9]. Accuracy assessment can also be performed by comparing the coordinates of the control points of the corners of the roofs of buildings, determined by the total station with the coordinates of the same points of the model [10].

The study [11] indicates that according to surveyors, after 10 years, the scanner is considered as one of the best tools for obtaining the vertical cadastral information of apartments with shared ownership units. In this regard, in this work, we compared the use of lidars (Callidus and Faro) and a rangefinder when preparing floor plans in both two-dimensional and three-dimensional formats. As a result, it was revealed that lidar survey is more efficient for the production of 3D models than for drawing up 2D plans. The transition to a two-dimensional image to create a 2D plan from a three-dimensional one occurs with errors associated with an ambiguous definition of the object geometry.

The results of the practical application of three-dimensional data for the inventory are given in articles [10, 4].

In [10], much attention is paid to foreign experience. The Netherlands and China, Singapore, Sweden, Australia are rightfully considered to be the most successful pioneers in the three-dimensional cadaster geodesic provision issue. The authors identify the trend of transition from a two-dimensional inventory to a three-dimensional one, which consists in the formation of three-dimensional models from the existing documents (for example, a floor plan). In addition, the dynamics of the BIM technologies introduction at the stage of designing the objects is traced in order to obtain a model of an object without scanning, and correcting the model at the stage of accounting for an object. It is assumed that the application of scanning will be carried out for some objects [10].
The study [4] describes the process of the first cadastral registration of multi-level rights in relation to a railway zone project, which is a combination of infrastructure, mainly a railway, and urban reconstruction based on a 3D act (3D PDF). Such an act contains a three-dimensional representation of rights; rights legend, object location coordinates, 2D cadastral map. The 3D act was obtained by exporting a title deed from specialized software CAD (Rhino 3D).

In the Russian Federation, back in 2010, a joint Russian-Dutch project “Creation of a model of a three-dimensional real estate cadaster in Russia” was launched. When creating three-dimensional objects for the prototype, the GoogleSketchUp software package was used. It should be noted that in the course of the project, floor plans were used to prepare three-dimensional models of pilot objects (buildings), and not newly performed geodetic measurements [10]. However, in 2020, the implementation of complex cadastral works, in which the location and characteristics of the object are obtained from the data of three-dimensional laser scanning is being tested.

The order of data processing is a "connecting bridge" between receiving the data and receiving the result. [12]. In this regard, a large number of scientific works are devoted to processing technology, accuracy assessment, equalization of point clouds, classification and recognition of objects, algorithms for obtaining a three-dimensional model, analysis of software required for data processing, depending on the required tasks [13-17]. An overview of the most common programs used in office processing is considered in [15]. The authors distinguish three groups of software: "software from laser scanner manufacturers" (for example, LeicaCyclone 9, RiScanPro, RiProcess TrimbleRealWorx) "Independent solutions" (TerasolidTerraScan, GeoPlusVisionLidar 2018, Technodigit 3DReshaper 2017), “Solutions inside large CAD» (AutodeskAutoCADcivil 3D 2018, BentleyPointools, Descartes, Credo 3D Скан 1.4, «IndorSoft» IndorCAD 2018) [15].

The authors of [18] point out that lidar technology provides a fast, continuous and cost-effective opportunity to obtain 3D geospatial information for cadastral, urban planning, infrastructure mapping and security analysis in urban environments. The study focuses on the issue of data processing for the classification and retrieval of cadastral information. The authors have developed a technique for such actions using digital images and lidar data. The first source is needed to obtain information about the brightness of targets, and the second - for the parameter of the height and intensity of the reflected signal, on the basis of which the recognition of infrastructure objects is carried out.

The analysis of literature sources showed that there is a significant number of scientific works on the application of laser scanning technology to obtain cadastral data and create a three-dimensional cadaster. Methods for performing cadastral surveying, criteria for choosing a measuring instrument, methods for assessing the accuracy of coordinates, algorithms for processing scan data, building models have been developed.

The tendency of large-scale use of laser scanning in cadastral works is revealed. However, the issues of preparing cadastral documentation based on scanned data are little studied. This topic from the studied works is devoted to the articles [19, 4]. The possibility of using three-dimensional data for the cadastral documentation (technical plan) development is discussed in the article [19]. However, the work is characterized by an insufficient degree of the methodology elaboration for carrying out such a process, the required software or the necessary parameters for its creation is not specified, the analysis of the existing form of the technical plan and the information specified in this document is not carried out, it is not indicated what information will be added to the technical plan by using a fundamentally different shooting method.

In this regard, we can conclude that the further improvement of geodesic provision of cadastral works will be associated with the three-dimensional data processing improvement, the modernization of cadastral documentation for the real estate objects’ cadastral registration and the development of software that carries out the most automated preparation of such cadastral documentation.

3. Improvement of geodesic provision for cadastral works
The operation principle of a laser scanner is to measure the angles and distances to terrain points in the vertical plane up to 270 degrees and in the horizontal plane up to 360 degrees with fixing XYZ
coordinates for each point [20]. The collection of such points forms a three-dimensional digital geospatial image of the scanned array, presented initially as a point cloud [21].

Depending on the measurement technologies used, a distinction between ground, air and mobile laser scanning is made. The choice of the shooting method is determined based on the goals, objectives and types of scanned objects. If it is necessary to scan the small objects, then ground scanning is used, for the large areal objects - aerial, and for the extended linear ones - mobile (Figure 1).

Based on the conclusions drawn from the analytical review results, the scope of laser scanning data processing will be considered in more detail, in terms of drawing up the cadastral documentation for a linear object.

![Figure 1. Point cloud obtained from the ground laser scanning results](image1)

![Figure 2. Three-dimensional model of the object after data processing](image2)

The concept of improving geodesic provision can be schematically represented in the form of the following directions (Figure 3).
The basis for cadastral registration of a linear object is a technical plan, consisting of the sections: general information, initial data, information on the measurements and calculations performed, characteristics of the real estate object, the conclusion of a cadastral engineer, a diagram of geodetic constructions, a layout on a land plot, a drawing. When using laser scanning in some sections of the technical plan, new information will appear (Table 1).

**Figure 3.** Concept for the geodesic provision development for cadastral works

| Section                                    | Section Description                                                                 | New Information                          |
|--------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------|
| Initial data                               | Information about the geodetic base                                                | Z                                        |
| Information about measuring instruments    | Laser scanner                                                                      |                                          |
| Measurement and calculation information    | Coordinate determination method                                                   | Ground-based laser scanning method;      |
|                                            |                                                                                    | Aerial laser scanning method;            |
|                                            |                                                                                    | Mobile laser scanning method             |
| Object location description                | Description of the location of the building, structure, object of construction in progress on the land plot | Z                                        |
| Real estate object’s characteristics       | Characteristics’ description                                                      | Height, technical condition [21]          |
Scheme of geodetic constructions

| Scanner points (for terrestrial scanning): |
| Flight plan, points of standing of satellite GNSS receivers (for aerial scanning); |
| scheme of the route of movement, points of standing of satellite GNSS receivers (for mobile scanning) |

| Layout on the land |
| Outline drawing |
| Three-dimensional model of the object |

Currently, the programs most used by the cadastral engineers to create a technical, boundary plan are: «Polygon», «PCZO», «TechnoCAD», «ARGO», however, these programs do not have functionality for working with laser scanning data.

4. Summary

Laser scanning is a high-tech, fast and accurate method of shooting. The integration of this method for obtaining spatial information has also affected the real estate cadaster, an integral part of which is the cadastral documentation - landmarks and technical plans. When drawing up a technical plan for a linear object according to three-dimensional laser scanning data, in our opinion, the information will be added to the document structure - the value of the Z coordinate (in the information on the geodetic base and the requisite "the location description of a building, structure, object of construction in progress on a land plot"), the name of the new measurement method is the method of ground-based laser scanning; aerial laser scanning method; the method of mobile laser scanning, the value of the height of the technical state of the object (in the attribute “name of the characteristic”). In the graphic part (in the geodetic constructions scheme), an image of the scanner positioning points (for ground scanning), the flight plan, the positioning points of GNSS satellite receivers (for air scanning) will be added; scheme of the movement route, the location points of GNSS satellite receivers (for mobile scanning); a three-dimensional model of the object will be added to the object layout diagram on the land plot and the outline drawing.

When introducing laser scanning as a geodesic provision for cadastral work, it is necessary to pay attention to the development of software that allows the formation of cadastral documentation based on three-dimensional data. The following basic requirements for the program can be distinguished:

- modularity;
- data format support LAS/LAZ;
- laser scanning point classification and real estate recognition;
- automated reconstruction of a three-dimensional model of an object using point clouds;
- the presence of a graphic editor;
- formation of cadastral documentation;
- generating XML files.

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