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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

METHODOLOGY FOR CREATING A CADASTRAL DATABASE AND DIGITAL MAPS BASED ON MODERN TECHNOLOGIES

Speciality: 2504.01 – Geodesy

Field of science: Technique

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prof. T.A. Hagverdiyev

General characteristics of the work

Relevance of the topic. As society develops, the requirements for the work and informativeness of cadastre databases are gradually increasing. Establishing these systems in accordance with modern requirements requires the use of new technical means and methods.

Comparing these methods among themselves and, if necessary, using them together in an optimal way is undoubtedly an urgent issue. It is important to create a special geoinformation system for the purpose of registration of property rights on real estate and provision of electronic services in the field of cadastre. Creating a relational database (RB) based on geographic information systems (GIS) technology is an urgent issue in the implementation of cadastral works, in order to collect, systematize and use cadastral data in an automated manner, as cadastral data collection and creation of cadastral maps based on such VB an automated system can be created for the process.

Checking the quality of service to the customers of the cadastral system, increasing the informativeness and efficiency of its work can be achieved by optimizing the system's work in the process of collecting measurement information and checking the realization of optimal mode indicators.

The real conditions of carrying out cadastral measurements in many cases dictate the need to apply various measurement tools in a combined manner. The main disadvantage of using electronic total stations is the need to have a direct optical view. Therefore, carrying out cadastral measurements combined with the involvement of modern technologies - GPS measuring devices, electronic total stations and high-resolution satellite images can have a significant positive effect in many cases.

Optimum execution of complex cadastral measurements by involving various geodetic methods and measuring tools, ensuring the accuracy and authenticity of the initial information included in the cadastral information system database entry, using different price criteria in relation to the land plots measured in the area, which is heterogeneous due to its composition is one of the important issues to be fulfilled in the field.

Research goals. The purpose of the work is to improve the modern geodetic measurement technologies and develop the methodology of creating real estate cadastral database and digital maps based on them.

The scientific and practical results obtained during the dissertation research, are recommended to create an electronic database and digital maps of real estate available in the republic.

Research methods. In the process of solving the set theoretical problems, methods and elements of mathematical analysis, linear programming, multi-criteria optimization, remote sensing data, GIS technologies, geodetic measurements theory were used, and the obtained theoretical results were verified by conducting experimental-model studies.

The main provisions defended:

- Method for assessing the effectiveness of combined joint optimal cadastral measurements.
- Study of the possibilities of joint application of linear programming and multi-criteria optimization methods for the optimization of complex cadastral measurements.
- A method for assessing the effectiveness of combined joint optimal cadastral measurements.
- Study of the possibilities of joint application of linear programming and multi-criteria optimization methods for the optimization of complex cadastral measurements.
- Method for assessing the effectiveness of combined joint optimal cadastral measurements.
- Study of the possibilities of joint application of linear programming and multi-criteria optimization methods for optimizing complex cadastral measurements.
- Development of a block diagram of the software created in

stages, analysis of the possibility of obtaining higher quality results based on the relationships between the customer (client)-server data in the relational database.

- Method for compiling a cadastral information model, method for compiling a cadastral database and digital maps of real estate based on this model. Development of a methodology for preparing a cadastral information model and digital maps on the example of the city of Sumgayit.

The scientific novelty of the study is that for the first time**:**

1. The method of evaluating the effectiveness of the combined joint optimal cadastral measurements was irradiated, the issue of optimization of the performed measurements using the linear programming method was solved, a new formula for calculating the informativeness of the measurement results, a new processing method of the results of the series of measurements of various sets of rectangular areas to increase the authenticity of the information contained in the cadastral databases has been proposed.

2. Statements have been obtained that allow for the selection of geodetic measurement tools in a justified manner according to the accepted criteria for performing geodetic measurements of local forest massifs within the boundaries of urbanized areas.

3. The issue of determining the minimum relative mean square error of the cadastral value of the land area was formulated and resolved. An invariant characterizing the main accuracy parameters of the method of determining the cadastral price of land in the optimal mode was formed. The methodology of selecting the main accuracy indicators when conducting optimal cadastral measurements has been developed.

4. A method of selective aerial photography based on the height of terrestrial objects has been proposed, which allows to minimize the total distortions, which consist of the shift of the high points of high terrestrial objects in the aerial photographic images. It has been shown that the distribution curves of the measurement error of land areas obtained on the basis of Cartosat-

2 and Geo-Eye satellites can be characterized by a single limitation condition. The optimization problem that allows to calculate the total value of errors arising during satellite measurements is formulated and it is shown that the use of satellites with higher geometric resolution allows to obtain the minimum total error of cadastral accounting. The problem of optimal selection of the number of ground control points was formulated when satellites with very high resolution are used for conducting cadastral measurements. A mathematical optimization problem has been formulated that allows reducing the total error of cadastral measurements carried out on the basis of satellites with very high resolution, and the solution of this problem allows to minimize the number of used control points.

5. It has been shown that the averaging process performed in RTK GPS systems performing cadastral measurements does not lead to an immediate extreme increase in the informativeness of those systems, while increasing the accuracy of the measurement results.

6. The problem of optimization of complex cadastral measurements was formulated, and the possibility of applying the linear programming method for solving this problem was shown. A multi-criteria optimization method based on the linear programming method, which involves the application of weighted linear covering of specific objective functions, is proposed.

7. It has been shown that carrying out geodetic spectral aerial photo measurements in the optimal mode that ensures the minimum value of the total measurement time allows to ensure the maximum quality of input information of the land cadastre database by ensuring the minimum value of the total measurement time. The issue of building a cadastral database that performs quality control of input information on newly organized land plots has been formulated and resolved. The mathematical basis of the proposed method for quality control of input information is

explained. The essence of this method consists in analyzing the optimal mode of geodetic measurements and comparing the optimal and real mode indicators of measurements. The quality measure of the input information related to the newly formed cadastral area included in the database of the land cadastre was proposed.

8. The block diagram of the software created in stages is proposed, it is shown that such a relational database differs from the geo-relational database available in ArcGIS, so that in the previous VB only ArcGIS overlays, shapefiles and formats relationships were created with, and in the relational VB created in Arc GIS, the data is not only formally modeled, but also between the client (client) and the server, relationships are created between a large number of data, which leads to obtaining higher quality results, and here every real conditions are modeled, not some object.

9. The method of compiling a cadastral information model in GIS, the method of integrating geospatial data into GIS and the method of compiling a base map in the process of cadastral management, the method of creating a block of cadastral objects that graphically describes cadastral objects and layers, real estate registration, cadastral and management system - the method of creating the data model was developed, the information layers used in the creation of the cadastral data model and the main functions performed by it were defined. On the example of the city of Sumgait, the methodology of preparing the cadastral data model and digital maps was worked out, the collection, processing and creation of a cadastral data model was carried out, and digital cadastral maps reflecting the city of Sumgait were compiled.

Theoretical and practical significance of the study:

1. Conducting cadastral measurements combined with the involvement of GPS measuring devices, total stations and high-

resolution satellite images can in many cases have a significant positive practical effect.

2. Replacement of existing graphic systems of cadastral accounting with computer-analytical systems of cadastral accounting created on the basis of the appropriate methodical base, for the use of technological innovations in cadastral calculations, globalization, urbanization, acceleration of the pace of life, emergence of various projects on complex construction at a high speed, supported development It is of great practical importance to meet the real demands of the modern world, which is characterized by such factors as demand.

3. The implementation of the proposed methods, methods and algorithms of processing aerial images in the thesis work can lead to the minimization of total distortions caused by the shifting of the high points of high-ground objects in aerial images during aerial photography, and to the increase of the informativeness and practical value of aerial images.

4. As a result of the application of the proposed multi-criteria optimization method, by applying any of the various geodetic measurement methods, an initial version of the plots of land for which geodetic cadastral measurements should be performed is created, the selection of which allows to increase the effectiveness of cadastral measurements.

5. Checking the quality of service to customers of the cadastral system, increasing the informativeness and efficiency of its work can be achieved through the optimization of the system's work and the realization of optimal mode indicators in the process of collecting measurement information.

Approbation of scientific work. The scientific results obtained during the dissertation research were presented at the following international scientific conferences:

1. United Nations/ ICTP Workshop on the Use of Global Navigation Satellite Systems (GNSS) for Scientific Applications, ICTP, Trieste, Italy, December 1-5, 2014.

2. International scientific and technical conference "System analysis and information technologies" SAIT, НТУ of Ukraine "КПИ", Kyiv, 2016.

3. Инвестиции, строительств, недвижимост, 8-ой Международной научно-практической конференции, г. Томск, 2018.

4. Actual problems of ecology and labor protection, Collection of articles of the X international scientific and practical conference, Kursk, Russia, 01 June 2018.

Personal participation of the author. The scientific issues raised by the author in the dissertation and the scientific and practical results acquired were obtained directly by the author independently. The scientific results of the conducted research and the articles and conference materials compiled on their basis were discussed with the scientific supervisor and co-authors of the dissertation. The main objectives of the research and the issues set to achieve them were indicated and discussed.

Publication. 24 scientific works have been published in domestic and foreign scientific and technical publications on the results of the research reflected in the content of the dissertation.

The structure and scope of the dissertation work. The thesis consists of a general description, four chapters, main results, a list of references with 93 names, 148 pages of printed sheets, including 39 figures, 6 graphs and 20 tables. The total volume of the dissertation is 224952 characters (introduction - 18292 characters, first chapter - 48076 characters, second chapter - 65879 characters, third chapter - 68741 characters, fourth chapter - 20161 characters, conclusion - 3803 characters).

Main content of the dissertation

The introduction justifies the relevance of the topic, explains the purpose of the research, research methods, scientific innovations, the main provisions put forward for defense, the theoretical and practical significance of the work, and briefly explains the contents of individual chapters of the dissertation.

The first chapter of the dissertation work is devoted to working out the methodological bases of cadastre creation. At the beginning of the chapter, the proposed method for evaluating the effectiveness of combined joint cadastral measurements is explained.

The optimization of joint cadastral measurements performed using a pair of "Total station - Geo-Eye" satellite images was considered[1]. In this case, the limits set for the cumulative error of the measuring instruments used for the calculation of informativeness are used. Those restrictions are formulated as follows:

$$N_1 \cdot x_{cp.0} + N_2(x_{cp.0} + x_{cp}) \le \alpha_1 \quad (1)$$

Here: N1 – total number of measurements performed by the station; N2 – the number of measurements performed using Geo-Eye satellite images; x_{cp} – is the difference of the average values of the errors of the applied measurement tools; α1 is the limit requirement imposed on the cumulative error of area measurement.

According to inequality (1), analogous constraint requirements can be written on the sum errors of perimeter (Y) and position (Z) measurements.

Inequalities similar to the expression (1) for X,Y.Z, and the linear objective function allow determining the optimal values

[1]Er. Pravesh Yagol Comparative study on Cadastral Surveying using Total Station and High Resolution Satellite Image. FIG-ISPRS workshop, 2015: International workshop on role of land professionals and SDI in Disaster Risk Reduction: In the Context of Post 2015 Nepal Earthquake. Kathmandu, – Nepal: 25th – 27th November, – 2015.

of N1 and N2, which provide the minimum value of this function, by linear programming method[2].

It has been shown that the efficiency criterion of joint combined measurements can be calculated based on the following formula:

$$\eta = \frac{1}{[N_{1opt}(x_{cp.0} \cdot y_{cp.0} \cdot z_{cp.0}) + N_{2opt}(x_{cp.0} + x_{cp} + y_{cp.0} + y_{cp} + z_{cp.0} + z_{cp})]} \times$$

$$\times \log_2 \frac{(x_m \cdot y_m \cdot z_m)^{(N_{1opt}+N_{2opt})}}{(x_{cp.0} \cdot y_{cp.0} \cdot z_{cp.0})^{N_{1opt}} \cdot [(x_{cp.0} + x_{cp}) \cdot (y_{cp.0} + y_{cp}) \cdot (z_{cp.0} + z_{cp})]^{N_{2opt}}} \qquad (2)$$

In the first chapter, the next research problem is formulated as follows: suppose a set of rectangular areas is given. Each of these areas is characterized by the same m_F indicator for their vertices. Thus, against the set $\{A_i\}$, $i = \overline{1, n}$, consisting of n areas (where A_i is the area of the i-th piece of land), the set $\{m_{Fi}\}$ is set, where m_{Fi} is the position error of any vertex of the i-th area.

Here, the set $\{m_{Fi}\}$ is an ordered set, and there is a certain functional dependence between m_A and m_{Fi} i.e.

$$m_{Ai}=\varphi(m_{Fi}) \qquad (3)$$

However, a certain restriction condition can be applied to the function (3):

$$\frac{1}{m_{F_n}} \sum_{i=1}^{n} \varphi(m_{F_i}) = C_1; \quad C_1 = const \qquad (4)$$

Taking into account the conditions (3) and (4), it is required to find such an optimal type of the function (3) that the total area of the considered land parcels takes an extreme value.

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[2] Танырвердиев, Ч.Г. Метод многокритериального оптимального выбора технических средств для проведения комплексных кадастровых измерений // – Москва: Маркшейдерский Вестник, – 2018. №3, – с. 51-55.

The optimal function $\varphi(m_F)$, is found as follows.

$$\varphi(m_F) = \frac{3C_1 \cdot m_F^2}{m_{F_m}^3} \tag{5}$$

As a result, a method of processing the results of measuring different sets of rectangular areas was proposed[3].

In the first chapter, the criteria for selecting geodetic technical tools for conducting geodetic measurements in small forest massifs in urbanized areas were developed[4]. It is known that the regularity of variation of the error of GPS measurements in dense forest conditions is characterized by the following regression equation:

$$\Delta_{GPS} = a_1 - a_2L + a_3L^2 - a_4L^3 \tag{6}$$

Here: $a_1; a_2; a_3; a_4$ are constant quantities.

The increase in error when making measurements by the chain walking method with a compass is characterized by the following regression equation:

$$\Delta_{C.} = b_1 + b_2L \tag{7}$$

Here: $b_1 = 34{,}79; b_2 = 0{,}03188$

Taking into account statements (6) and (7), the question of using one or another measurement method at different distances was studied. To solve this problem, various criteria have been proposed and the methodology for selecting technical tools based on these criteria has been developed.

At the end of the first chapter, the new methodology developed for determining the optimal cadastral value of land plots with the minimum mean square error is explained.

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[3]Ганиева, С.А. Разработка методики проверки достоверности результатов серийных кадастровых измерений различных множеств прямоугольных земельных участков / С.А.Ганиева, Ш.Ф.Муталлибова, Ч.Г.Танырвердиев [и др.] // Известия вузов. Инвестиции. Строительство, Недвижимости, – Иркутск: 2018. – т. 8. №1, – с. 40-45.

[4]Танырвердиев, Ч.Г. Критерии выбора геодезических технических средств для геодезических измерений в малых лесный массивах урбанизированных территорий // – Москва: Российский Государственный Аграрный Университет – МСХА имени К.А.Тимирязева, Природообустройство, научно-практический журнал, – 2018. №4, – с. 117-121.

The second chapter of the dissertation work is devoted to the issues of optimization of geodetic measurement methods related to land cadastre based on modern technologies[5].

An unmanned aerial vehicle equipped with aeronautical equipment performs flight on an inclined trajectory and increases flight height according to a linear law.

$$H = k \cdot t; \quad k = const. \; T = T - t_0; \quad T \geq t_0; \quad t_0 = const.$$

The following formula was obtained to calculate the total radial displacement of the upper points of high-ground objects.

$$\Delta_\Sigma = \int_0^{H_{max}} \frac{r \cdot h(H-h)}{H \cdot f} dH \tag{8}$$

Fig. 1 shows the horizontal (radial) shift effect of the positions of high ground objects in aerial images.

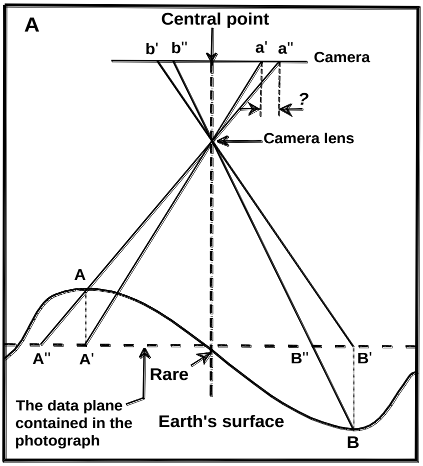

Figure 1. Geometrical interpretation of the radial shift effect of the positions of high ground objects in aerial images

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[5]Ганиева, С.А., Танырвердиев Ч.Г. Вопросы оптимизации процесса аэрофотографирования с помощью носителя топографического измерителя при кадастровых изысканиях // – Москва: Маркшейдерия и Недропользование, – 2017. №6 (92), – с. 17-20.

The problem of finding the minimum of the functional (8) is formulated. To this end, it is proposed to consider the following management function:

$$h = h(H) \tag{9}$$

After applying a certain restriction condition to the control function, the condition of getting the minimum value of the functional (8) according to the function *h(H)* was studied by Euler's method.

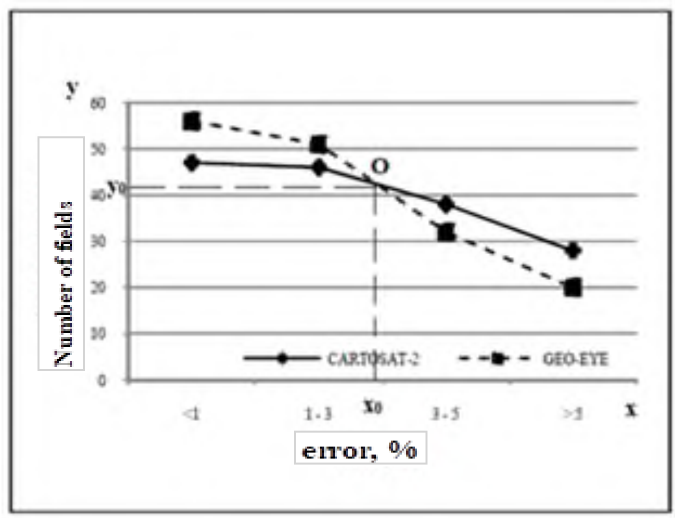
It is shown that the functional (8) takes a maximum value under the condition of the solution of (10) shown below, taking into account the aforementioned restriction condition. Heuristically, it can be concluded that the optimal sought function that brings the functional (8) to its minimal value is the function that is the inverse of the function (10).

$$h(H) = \frac{H}{2} + \frac{\left(C_1 - \frac{H_m^2}{4}\right)}{H \cdot ln\, H_m} \tag{10}$$

Then, in the second chapter, based on the datasets of Cartosat-2 and Geo-Eye satellites, which have a very high resolution, the issues of comparing cadastral land plots separately according to existing features were considered, and the procedure for optimal selection of datasets of this or that satellite was determined.

In Graphic 1, based on Cartosat-2 and Geo-Eye satellite data, and when these data are compared with Electronic tachometer-GPS data, the known graphs of the distribution of areas are given, taking into account the received errors[6].

[6]Rao, S.S., Sharma, J.R., Rajasckhar, S.S., Rao, D.S.P., Arepalli, A., Arora, V., Kuldeep, Singh, R.R., Kanaparthi, M. Assessing usefulness of high-resolution satellite imagery (HRSI) for re-Survey of cadastral maps // ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-8, 2014. ISPRS Technical Commission VIII Symposium, – Hyderabad, India, – 09-12 December, – 2014.



Graphic 1. Distribution graphs of area measurement values based on Cartosat-2 and Geo-Eye data according to the parameter "area of a piece of land".

As can be seen from Graphic 1, the following constraint condition is true for the straight function *y=f(x)* and the inverse function $\varphi(x)$

$$E_{y.l.} = \int_{y_1}^{y_2} \varphi(y)dy = C; \;\; C = const \tag{11}$$

To find the extremum of the integral value of the residual entropy of the measurement results after receiving the measurement indications, an unconditional variation optimization functional was formulated:

$$E_0 = E_{y.in.} + \lambda(E_{y.l.} - C) = \int_{y_1}^{y_2} y \ln 2\varphi(y)dy + \lambda\left[\int_{y_1}^{y_2} \varphi(y)dy - C\right] \tag{12}$$

Solution of the optimization problem (12) of the functional

$$\varphi(y) = \frac{2C \cdot y}{y_2^2 - y_1^2} \tag{13}$$

showed that he got the maximum value within the solution.

Based on heuristic judgment, it can be said that the minimum error result of cadastral accounting can be obtained if there is a decreasing linear dependence between x and y.

Then, the issue of optimization of the sum of values obtained from the averaging of information indicators of multi-cycle measurements over regular time intervals was considered[7].

Consider the following ordered set:

$$T_{av} = \{T_{av.i}\}; i = \overline{1, n} \tag{14}$$

Here: $n-$ is the number of measurement cycles,

$$T_{av.i+1} = T_{av.i} + \Delta T_{av};\ \Delta T_{av} = const \tag{15}$$

The amount of information that can be potentially obtained when multi-cycle measurements are performed using the averaging period $T_{av.i}$ is determined as follows:

$$M_{in} = \int_{T_{av.\min}}^{T_{av.\max}} \frac{T_{из}}{T_{av.i}} \cdot \log_2 \frac{U}{\Delta(T_{av})} dT_{av} \tag{16}$$

Here: $T_{из}$ – duration of one measurement cycle; $T_{из} = const; U$ – is the average value of the measured quantity. $\Delta=\Delta(T_{av})$- is a function of the dependence of the signal quantum on the averaging time. The condition for functional (16) to reach its maximum value depending on the function when $\Delta=\Delta(T_{av})$- appropriate constraints are applied is defined. At the end of the second chapter, the method of optimal placement of ground control points by time during the day is explained. It is shown that, according to the proposed method, in the optimal case, the maximum number of control points should be used in the period when the total measurement error takes the largest values. Then the proposed multi-criteria optimal selection method of technical means for conducting complex geodetic cadastral measurements

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[7]Муталлибова, Ш.Ф. Оптимизация режимов функционирования RTKGPS геодезических сетей для кадастровых измерений / Ш.Ф.Муталлибова, Ч.Г.Танырвердиев, С.А.Меджидова [и др.] // Геодезия и картография, – Москва: – 2018. №2, – с. 17-21

is explained[8].

Some simplifying assumptions are made below:

1. We accept that cadastral measurements are carried out in 3 stages.

2. We accept that at each stage, each type of land plot is performed with a previously unused type of technical means of geodetic measurements.

3. We assume that the number of land plot types is equal to 2.

Taking into account the above judgments, the constraint conditions can be presented as a system of inequalities shown below.

$$C_1 N_1(z_1) + C_2 N_2(z_2) \le A_1 \tag{17}$$

$$C_3 N_1(z_1) + C_4 N_2(z_2) \le A_2 \tag{18}$$

$$C_5 N_1(z_1) + C_6 N_2(z_2) \le A_2 \tag{19}$$

Here: A_1 , A_2 , A_3 - are the pre-determined limit values of the permissible values of the costs incurred for carrying out cadastral measurements of two Z_1 and Z_2 type land plots with N_1 and N_2 hectares, respectively.

The objective function can be written as:

$$F_j = N_1(z_1) \cdot P(z_1, e_j) + N_2(z_2) \cdot P(z_2, e_j) \tag{20}$$

When two evaluation methods are used, the coverage of the criteria reflecting the objective functions is drawn up:

When two evaluation methods are used, the coverage of the criteria reflecting the objective functions is drawn up:

$$F_{св} = \alpha_1 F_1 + (1 - \alpha_1) F_2 \tag{21}$$

Here: $0 < \alpha < 1$.

It is shown that the problem of multi-criteria optimization can be solved by the method of linear programming.

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[8]Танырвердиев, Ч.Г. Метод многокритериального оптимального выбора технических средств для проведения комплексных кадастровых измерений // – Москва: Маркшейдерский Вестник, – 2018. №3, – с. 51-55.

The third chapter is devoted to the creation and updating of the real estate cadastre database[9].

The proposed structure of the cadastral relational database showing the relationship between real estate objects and their addresses can be shown as follows (Figure 2).

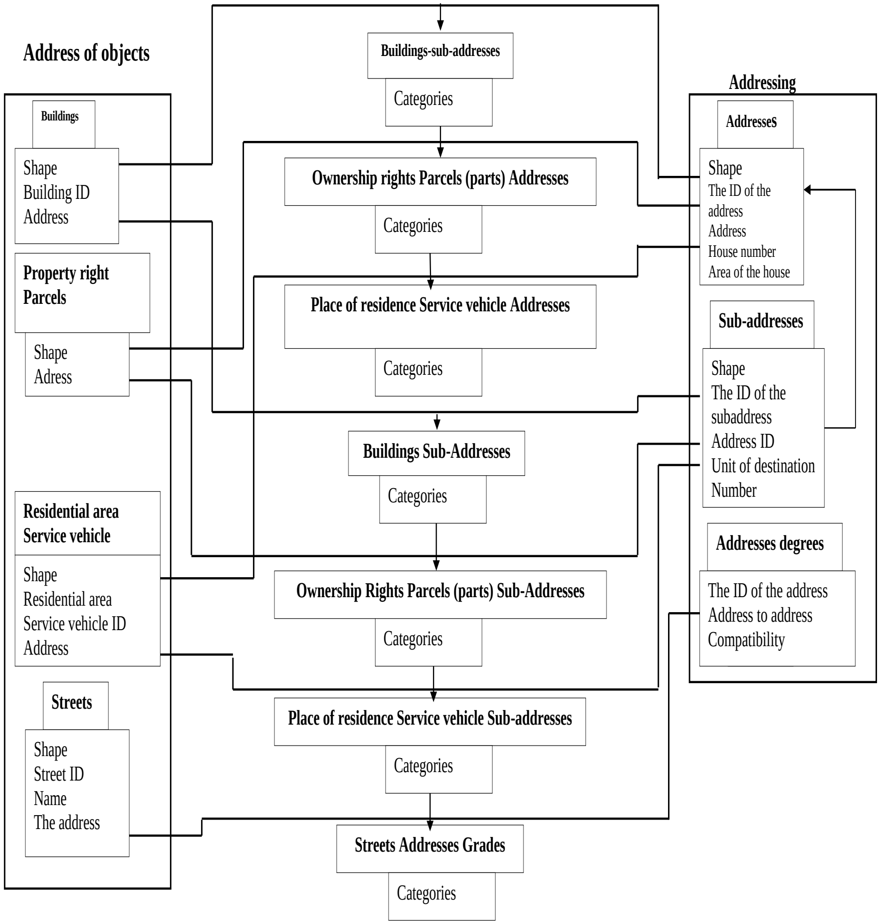

Figure 2. Schema of cadastre relational database showing the relationship between objects and their addresses

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[9]Майкл, Де Мерс. Географические информационные системы основы / Майкл.Де.Мерс. Издательство Дата +, – 1999. – 490 с.

During the modeling based on the relational database, it is possible to simplify the complex issues, to divide them into several stages and to fully control the system[10] (Figure 3).

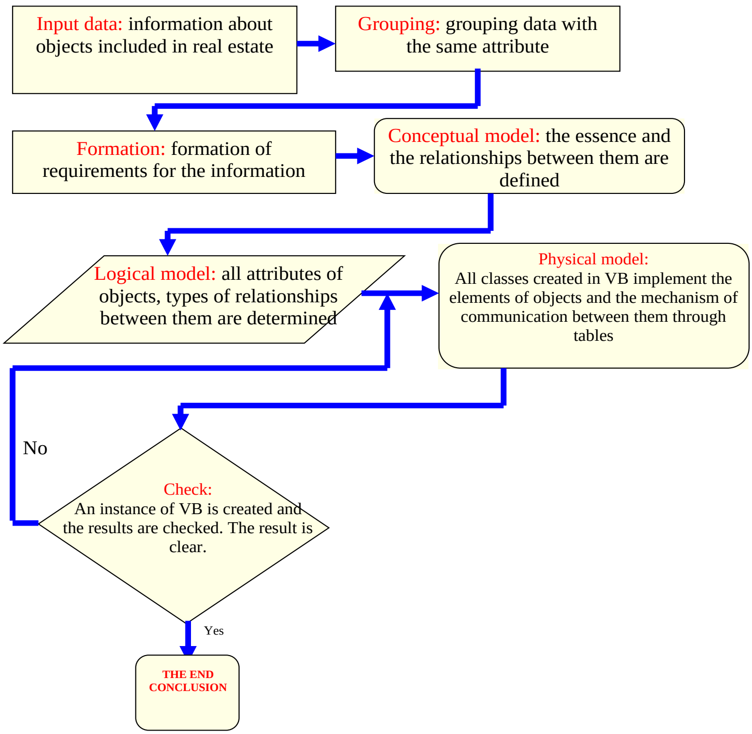

Figure 3. Block diagram of the software to be created in stages

It was noted that the real estate cadastral information model (RECİM) means the creation of information security for the management of the immovable property cadastre in the Republic of Azerbaijan by electronic means[11]. Two blocks were taken as a basis when establishing the RECİM (Figure 4).

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[10]Tanırverdiyev, Ç.Q. Daşınmaz əmlak kadastrının həyata keçirilməsində relyasion verilənlər bazasının yaradılması üsulu // – Bakı: AzMİU, Elmi əsərlər, – 2015. №2, – s. 122-128.

[11]İsmayılov, M.M. Torpaq və çoxməqsədli kadastr. Ali məktəblər üçün dərs vəsaiti. // M.M.İsmayılov, S.A.Qəniyeva – Bakı: Ziya A+ mətbəəsi, – 2006. – 345 s.

In the third chapter, the method of creating the proposed block of cadastral objects, which graphically describes the cadastral objects and their layers, is explained[12].

At this time, the boundaries and frameworks of cadastral operations are conditioned by both certain geographical boundaries and certain administrative steps and actions. The description of the information provision of these boundaries and frames is also included in the data model of the base map data. The structure of the real estate cadastral information model is divided into groups, and those groups themselves are divided into certain subgroups. Connections are made between each subgroups and groups.

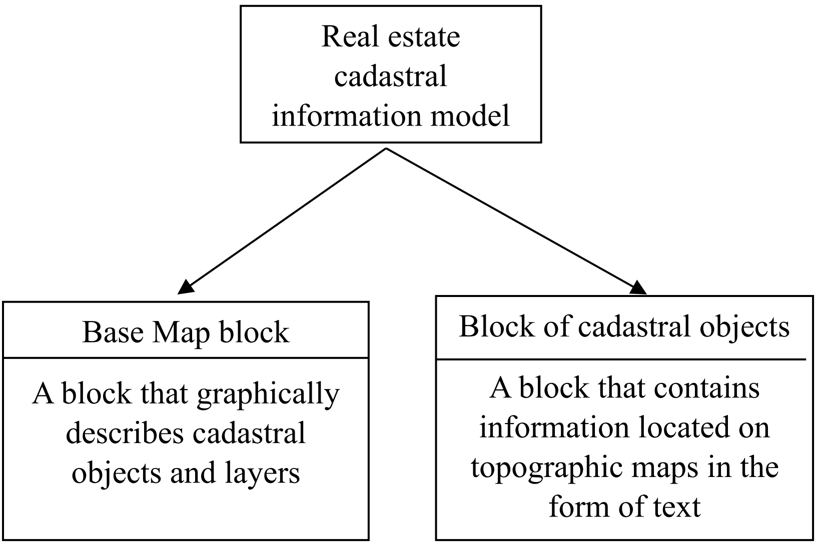

Figure 4. Block scheme of cadastral information model of real Estate

[12]Ганиева, С.А. Составление кадастровой информационной модели на основе метода интеграции геопространственных данных в географическую информационную систему / С.А.Ганиева, Ч.Г.Таныրвердиев, С.Н.Ганиева [и др.] // Томский государственный архитектурно-строительный университет, Томск, часть 2, – Россия: – 2018. – с.123-134.

The third chapter further explains the proposed method for creating a real estate registration, cadastre and management system (RERCMS) - a high-level cadastral information model[13]. Based on the collected data, a diagram showing the model of high-level data objects of the system RERCMS was constructed (Figure 5).

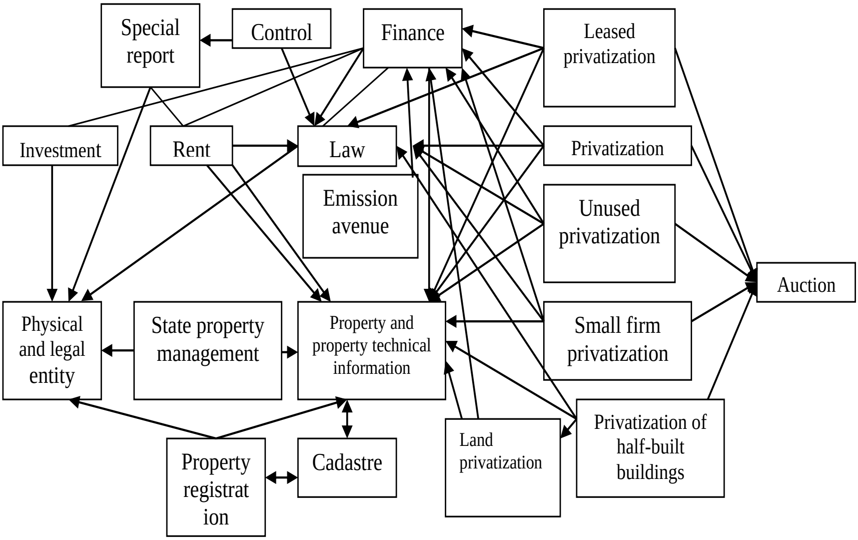

Figure 5. High-level data objects scheme of the model

Blocks containing information (in the form of text) mainly located on topographic maps called base maps, specifications of groups, subgroups and classes of cadastral map base objects in GIS are presented in the form of tables, a method of creating a block of cadastral objects graphically depicting cadastral objects and layers is given[14].

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[13]Qəniyeva, S.A. Daşınmaz əmlakın qeydiyyatı, kadastrı və idarəetmə sisteminin yaradılması üsulu / S.A.Qəniyeva, Ş.F.Mütəllibova, Ç.Q.Tanırverdiyev [və b.] // AzMİU, Elmi əsərlər, – Bakı:– 2017. №2, – s. 119-124.

[14]Ганиева, С.А. Составление кадастровой информационной модели на основе метода интеграции геопространственных данных в географическую информационную систему / С.А.Ганиева, Ч.Г.Танырвердиев, С.Н.Ганиева [и др.] // Томский государственный архитектурно-строительный университет, Томск, часть 2, – Россия: – 2018. – с.123-134.

In the third chapter, the method of creating the data model of the real estate cadastre using the information exchange mechanism on the Interlıs information systems is explained[15].

In the third chapter, the proposed method for collecting the combined measurement information on the green areas of the morning area in the database of the cadastre is explained. The database creation process consists of the following stages:
(a) Requirements gathering and analysis; (b) conceptual development; (c) selection of database structure; (d) logical development; (c) physical development; (f) implementation of the database system.

The basic requirements for conceptual modeling of the cadastral database must be met, which include modeling of spatial-temporal objects, attributes, or relationships between objects[16].

In the conceptual model, the set of objects can be in the following relationships:

1. Set of time relationships;
2. Set of space relationships;
3. Set of space-time relationships.

Verification of the quality of service to the clients of the cadastral system, improvement of the informativeness and efficiency of its work can be achieved by optimizing the system's operation in the process of collecting measurement information and verifying the implementation of optimal regime indicators.

When cadastral measurements are carried out using combined measurements using various geodetic measurement tools, while considering the method of creating a cadastral database, it

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[15]INTERLIS: [Elektron resurs] / – 2021, 19 Noyabr. URL: http://www.İnterlish.ch/İnterlis1/does/Iref_11_e.doc.

[16] Alkan, M., Polat, Z.A. Determining spatio-temporal cadastral data requirement for infrastructure of LADM for Turkey // The International Archives of the Photogrammetry. Remote Sensing and Spatial Information Sciences. Volume XLI-B2, 2016. XXIII ISPRS Congress, – Prague, Czech Republic, – 12-19 July, – 2016, – p. 3-7.

becomes clear that the accuracy of electronic total stations is higher than the analogous indicator of other methods and tools. The accuracy and time indicators of measuring tools differ significantly from each other, which makes it relevant to carry out measurements using a combination of measurement methods and tools.

The selected model of the implementation of combined measurements is characterized as follows: "Measuring devices included in a pair of measuring devices of different types apply sequentially in time, and optimization is carried out according to the criterion of the minimum total duration of cadastral measurements".

At the end of the third chapter, in the stage of updating the cadastral database data the proposed method for quality control of geodetic measurements is explained[17].

The data update process is divided into two parts:

1. Administrative and legal activity on updating and registering data in automated cadastral registers.
2. Conducting cadastral measurements, drawing up new maps with geometrical data, and making appropriate changes to the relevant measurement and mapping system.

The optimization of the geodetic measurement regime in the newly formed land areas of the cadastre was carried out for the purpose of further control of the quality and authenticity of the real measurement information included in the database entry.

The issue of quality control of incoming information about the plot of land is solved based on the following algorithm:

The land cadastre database collects the following data:

$$\sigma_{x_1}; \sigma_{x_2}; \sigma_{y_1}; \sigma_{y_2}; P_1; P_2.$$

[17]Танырвердиев, Ч.Г. Метод построения кадастровой базы данных с контролем качества входной информации с растительных участках городской местности // – Москва: Маркшейдерия недропользование, – 2018. №3 (95), – с. 52-55.

1. The optimization problem of determining the optimal values of N_{1opt} and N_{2opt} is initially solved.

2. Receiving measurement information obtained as a result of geodetic measurements, including information about real values of N_{1p} and N_{2p}

The following indicator is taken as a measure of the quality of input information about the plot of land.

$$\psi = \sqrt{(N_{1op.} - N_{1.p})^2 + (N_{2op.} - N_{2.p})^2}$$

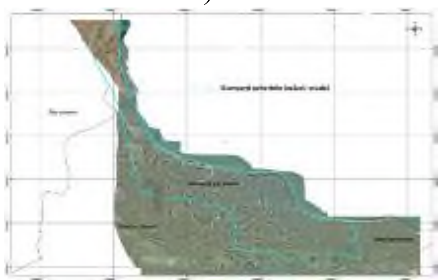
The fourth chapter of the dissertation work is devoted to the elaboration of the cadastral information model and digital cadastral map preparation methodology on the example of Sumgayit city. The role of modern technologies in the process of creating and mapping a real estate cadastre was examined at the beginning of the chapter[18]. It should be noted that the correct selection of geoinformation technology in the implementation of automated systems of a real estate cadastre requires a correct approach to the provision of tools or equipment necessary for the project, system software and the general characteristics of the operating environment, since the geoinformation system itself consists of a software-hardware complex. The principle of uniformity of the land cadastre is the implementation of state land cadastre measures on the basis of a single system covering the entire territory of the country. This principle allows for the correct analysis of the state and distribution of the single land fund and planning ways of efficient use of land resources within various territorial units. These works can be successfully carried out on the basis of modern GIS technologies, in particular by applying

[18]Ганиева, С.А., Танырвердиев, Ч.Г., Муталлибова, Ш.Ф. Метод создания электронной кадастровой информационной базы недвижимости и цифровых кадастровых карт на примере города Сумгаит // Міжнародна науково-технічна конференція «Системний аналіз та інформаційні технології» SAIT, – Київ: – 15 июня, – 2016, – с. 338-340.

the modules included in the modern GIS platform.

The fourth chapter then explains the methods of collecting, processing and creating a cadastral data model of the existing linear and area parcels in the selected study area of Sumgayit (Figure 6).

a)



b)

Figure 6. a) Administrative area where Sumgait is located;
b) Selected research area

The study area in the dissertation mainly includes the Sumgayit region.

An area of 12,500 ha within the administrative territory of Sumgayit was taken as a research area. The number of parcels included in the study area was 67,000 parcels.

The following optimal sequence of work was determined for the collection and analysis of existing data on real estate objects in the territory of Sumgayit city and the initial identification of objects based on it. has been implemented.

- Geographical objects or their corner points are identified on the orthophoto;

- If it is not possible to take the geometric and geographical parameters directly from the orthophoto, orientation points are taken from it;
- Relative distance and angle measurements were made using a distometr on the ground, if not obtained - a total station;
- In exceptional cases, absolute coordinates of points were measured by means of GPS devices.

At this time, using photogrammetric devices, border lines of all types of real estate objects, regardless of the type of ownership, as well as unfinished buildings, engineering communication objects, brought to the digital environment, using high-precision electronic geodetic tools (total station, GPS, etc.) in Universal Transverse Mercator (UTM) projection, cadastral data on real estate objects were collected by determining the geographic locations in the World Geodetic System 1984 (WGS 84) coordinate system.

In the 2nd stage, the coordinates of the real estate objects were determined on the available orthophotos within the limits of allowable errors using special photogrammetric devices in camera conditions.

In the 3rd stage, within the boundaries of the research area, in accordance with the principle of cadastral division of the area, all existing land plots and their parts (buildings, structures, facilities, property complexes, administrative areas, purpose-used areas, transport infrastructures, hydrographic elements, etc.) , in other words, the borders of all types of real estate objects that can be the object of cadastral accounting are determined in kind and the cadastral numbers to be given to the land area are formed. As a result of the field geodetic works conducted in the 4th stage, data on all types of real estate objects located within the boundaries of the research area were systematized, and as a result, a cadastral data model (database) was created. Compilation of digital cadastral maps for Sumgait territory was carried out using the method based on the 2nd, 3rd and 4th stages indicated in the previous section.

The maps extracted from the stereo models were analyzed by carrying out ground measurements in the area, changes were revealed based on the data obtained from the space images, and details that were not well visible on the stereo models were identified. A cadastral map has been prepared for an area of approximately 12500 ha. Detailed measurements were made through ground measurements. At that time, the measurements were carried out in unpopulated areas with GPS Real Time, and in populated areas with Total Station. At this time, Real Time kinematic measurements and AZPOS data were also used.

Cartographic images of lands, including real estates, are taken in the following accuracy: WGS-84 coordinate system, Reference height-Baltic sea level, UTM projection (zone 6 degrees within UTM 38-39, scaling factor 0.9996 in the Central meridian).

First, existing old points were searched in the study area, and 204 new territorial ground control points were established among the recorded old points. These points covered the entire study area (Figure 7, a). Those points are marked on the map using GPS (Figure 7, b).

a) b)

Figure 7. a) Selected ground control points on the study area, b) Transfer of points to the map using GPS.

Maps of the entire research area were prepared by photogrammetric method or on the basis of photographs. A connection has been made between the database and a digital cadastral map. So, it is possible to see the spatial geographical location of real estate and its associated attributive cadastral indicators (Figure 8).

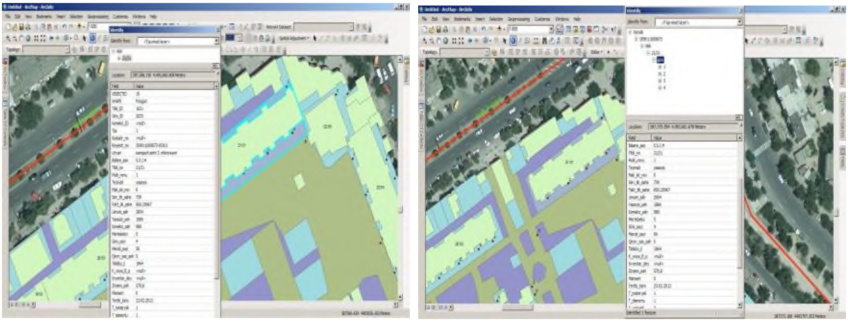


Figure 8. Fragments of the connection of the electronic cadastral database of real estate with the digital cadastral map.

At the end of the work, the following results were possible:

- the boundaries of real estate types throughout the entire territory of Sumgayit as a research area were clarified, the users and owners of real estate property types were identified in kind, and documents related to them were collected;
- a digital map was prepared based on remote sensing data using photogrammetry equipment;
- the collected cadastral data has been systematized in accordance with the structure of the relational database, and a real estate cadastral information database has been created;
- digital cadastral map and electronic cadastral database are connected.

Main results

1. Methods of evaluating and optimizing the effectiveness of optimal cadastral measurements with various geodetic measurement tools were developed, a new formula for calculating the informativeness of measurement results was proposed, and a new processing method of the results of the series of measurements of sets of rectangular fields was created to increase the authenticity of the relevant information [10], [14], [21].

2. The method of selection of geodetic measurement tools on a criterion-based basis was developed for performing geodetic measurements of forest massifs in urbanized areas [17].

3. The issue of minimizing the relative mean square error of the cadastral value of land was solved mathematically. The invariant characterizing the accuracy parameters of the cadastral price in the optimal mode was determined, and the methodology for selecting the main accuracy indicators when conducting optimal cadastral measurements was drawn up [9].

4. A selective aerial photographing method has been proposed, which allows to minimize the total distortions, which consists of the shifting of the high points of the high objects on the aerial photographs. The problem of optimization, which allows to calculate the total cost of errors arising during satellite measurements, has been solved. When using satellites with very high resolution for cadastral measurements, the issue of optimal selection of the number of ground control points was solved. Solving the issue of reducing the total error of cadastral measurements carried out on the basis of satellites with very high resolution allowed to minimize the number of used control points [8], [12], [15].

5. The possibility of increasing the accuracy of the measurement results in the case of averaging in the RTK GPS systems performing cadastral measurements was assessed, and the non-extreme feature of the informativeness of these systems was

revealed [16].

6.The problem of optimization of complex cadastral measurements was formulated, and a multi-criteria optimization method based on the linear programming method was proposed for the solution of this problem [18].

7. The optimal implementation mode, which minimizes the total measurement time of geodetic spectral aerial photo measurements, ensures the minimum value of the total time of the measurements and allows to ensure the maximum quality of the input information of the dynamic nature of the land cadastre database. The issue of building a cadastral database that performs quality control of input information on newly organized land plots has been formulated and resolved. A quality measure of dynamic input information related to newly formed cadastral areas included in the land cadastre database entry is proposed [19], [20].

8. A block diagram of the software created in stages was proposed, the advantage of such a relational database over the existing georelational database in ArcGİS was revealed, and it was shown that the created model can lead to the collection of more information about real-world objects and their efficient use[5], [7].

9. The method of compiling the cadastral data model in the Geographical Information System, the method of integrating geospatial data into the geographic information system and the method of compiling the base map in the process of cadastral management, the method of creating a block of cadastral objects that graphically describes the cadastral objects and their layers, the real estate registration, cadastral and management system - the method of creating a data model has been developed. On the example of the city of Sumgait, the methodology of preparing the cadastral data model and digital maps was worked out, the corresponding cadastral data model was created and as a result, an electronic cadastral database was created and digital cadastral maps were compiled [6], [13].

The main results of the work were published in the following works:

1. Gulmaliyev, F.Z. True orthoimage generation for aeronavigation tasks / F.Z.Gulmaliyev, C.G.Tanirverdiyev, M.G.Mahboob [et al.] // Bangladesh J.Prog. Sci Tech, – 2009. – v. 7 (71). – p. 61-64.
2. Tanırverdiyev, Ç.Q. Azərbaycanda daşınmaz əmlakın vahid kadastrı mərhələlərlə inkişaf etdiriləcək // – Bakı: Əmlak Bazarı Analitik İnformasiya Jurnalı, – 2009, №2, – s. 11-14.
3. Tanırverdiyev, Ç.Q. Azərbaycanda daşınmaz əmlakın vahid dövlət kadastrı // – Bakı: AzMİU, Elmi əsərlər, – 2011. №2, – s. 74-79.
4. Tanirverdiyev, C.Q. Azerbaijan: Azerbaijan positioning observation system for real estate cadaster data base // – Trieste, Italy: United nations ICTP workshop on the use of global navigations satellite systems (GNSS) for scientific applications, – 1-5 December, – 2014. – p.4-5 (slayd 27).
5. Tanırverdiyev, Ç.Q. Daşınmaz əmlak kadastrının həyata keçirilməsində relyasion verilənlər bazasının yaradılması üsulu // – Bakı: AzMİU, Elmi əsərlər, – 2015. №2, – s. 122-128.
6. Ганиева, С.А., Танырвердиев, Ч.Г., Муталлибова, Ш.Ф. Метод создания электронной кадастровой информационной базы недвижимости и цифровых кадастровых карт на примере города Сумгаит // Міжнародна науково-технічна конференція «Системний аналіз та інформаційні технології» SAIT, – Київ: – 15 июня, – 2016, – с. 338-340.
7. Qəniyeva, S.A. Daşınmaz əmlakın qeydiyyatı, kadastrı və idarəetmə sisteminin yaradılması üsulu / S.A.Qəniyeva, Ş.F.Mütəllibova, Ç.Q.Tanırverdiyev [və b.] // AzMİU, Elmi əsərlər, – Bakı:– 2017. №2, – s. 119-124.
8. Ганиева, С.А., Танырвердиев Ч.Г. Вопросы оптимизации процесса аэрофотографирования с помощью носителя топографического измерителя при кадастровых

изысканиях // – Москва: Маркшейдерия и Недропользование, – 2017. №6 (92), – с. 17-20.

9. Танырвердиев, Ч.Г. Разработка методики оптимальной оценки кадастровой стоимости земельных участков с минимальной среднеквадратической погрешностью // – Иркутск: Известия вузов. Инвестиции. Строительство, Недвижимости, – 2017. – т. 7. №4,–с. 126-131.
10. Ганиева, С.А. Разработка методики проверки достоверности результатов серийных кадастровых измерений различных множеств прямоугольных земельных участков / С.А.Ганиева, Ш.Ф.Муталлибова, Ч.Г.Танырвердиев [и др.] // Известия вузов. Инвестиции. Строительство, Недвижимости, – Иркутск: 2018. – т. 8. №1, – с. 40-45.
11. Ганиева, С.А., Танырвердиев Ч.Г. Вопросы функционирования земельного кадастра зон повышенного риска, подвергнувшихся воздействию придных чрезвычайних событий // – Москва: Проблемы безопасности и Чрезвычайных ситуаций, – 2018. – с. 96-104.
12. Ганиева, С.А. Вопросы оптимизации кадастровых измерений с применением спутниковых изображений сверхвысокого разрешения / С.А.Ганиева, Ч.Г.Танырвердиев, С.М.Аббасова [и др.] // Геодезия и картография, г. – Москва: – 2018. №1, – с. 43-46.
13. Ганиева, С.А. Составление кадастровой информационной модели на основе метода интеграции геопространственных данных в географическую информационную систему / С.А.Ганиева, Ч.Г.Танырвердиев, С.Н.Ганиева [и др.] // Томский государственный архитектурно-строительный университет, Томск, часть 2, – Россия: – 2018. – с.123-134.
14. Ганиева, С.А., Танырвердиев, Ч.Г., Курзин, А.А., Шатохина, С.А. Вопросы оптимизации комбинированных измерений земельных участков // Актуальные проблемы экологии и охраны труда, Сборник статей x. международной научно-практической конференции, – Курск: – 01 июня, – 2018, – с. 100-110.

15. Муталлибова, Ш.Ф., Танырвердиев Ч.Г. Оптимальный выбор количества наземных контрольных пунктов при использовании спутников сверхвысокого разрешения для проведения кадастровых измерений // – Москва: Маркшейдерия и недропользование, – 2018. №1(93), – с. 54-58.
16. Муталлибова, Ш.Ф. Оптимизация режимов функционирования RTKGPS геодезических сетей для кадастровых измерений / Ш.Ф.Муталлибова, Ч.Г.Танырвердиев, С.А.Меджидова [и др.] // Геодезия и картография, – Москва: – 2018. №2, – с. 17-21.
17. Танырвердиев, Ч.Г. Критерии выбора геодезических технических средств для геодезических измерений в малых лесный массивах урбанизированных территорий // – Москва: Российский Государственный Аграрный Университет – МСХА имени К.А.Тимирязева, Природообустройство, научно-практический журнал, – 2018. №4, – с. 117-121.
18. Танырвердиев, Ч.Г. Метод многокритериального оптимального выбора технических средств для проведения комплексных кадастровых измерений // – Москва: Маркшейдерский Вестник, – 2018. №3, – с. 51-55.
19. Танырвердиев, Ч.Г. Метод построения кадастровой базы данных с контролем качества входной информации с растительных участках городской местности // – Москва: Маркшейдерия недропользование, – 2018. №3 (95), – с. 52-55.
20. Танырвердиев, Ч.Г., Зейдан, З.У. Вопросы обновления содержания базы данных земельного кадастра с контролем качества вновь поступающей информации // Актуальные проблемы экологии и охраны труда, Сборник статей х. международной научно-практической конференции, – Курск: – 01июня, – 2018, – с. 196-203.
21. Танырвердиев, Ч.Г. Метод оценки эффективности совместных комбинированных оптимальных кадастровых

измерений // – Bakı: AzMİU, Elmi əsərlər, – 2011. №2, – s. 132-140.
22. Танырвердиев, Ч.Г., Паукова Ю.С., Шатохина С.А. Критерии выбора геодезических технических средств для геодезических измерений в малых лесных массивах урбанизированных территорий// Актуальные проблемы экологии и охраны труда, Сборник статей х. международной научно-практической конференции, – Курск: – 01июня, – 2018, – с. 203-209.
23. Tanirverdiyev, Ch.Q. Methodology for creating a real estate cadastral system with the application of modern technologies// International Research Journal of Modernization in Engineering Technology and Science, – Madhya Pradesh, India: – December, – 2024, – p. 3181-3188.
24. Tanirverdiyev, Ch.Q. 3D cadastre system in azerbaijan: development perspectives and challenges// European Conference, – Munich, Germany: – January, –2025, – p. 302-304.

Personal contribution of the applicant to the published works

The author independently performed the works [2, 3, 4, 5, 9, 17, 18, 19, 21, 23, 24].

In the scientific works [1, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 20, 22] the author participated in the formulation of the problem, the implementation of the experimental research and the analysis of the results.

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