DEVELOPMENT SOLUTIONS OF RIGA CITY LOCAL GEODETIC NETWORK

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Abstract

Throughout the centuries, capital Riga always has been city with dynamic development. Its territory has unceasingly expanded, whereby previously unused territories were built. Managers of the city understood already at the end of 19th century that united geodetic network has great importance in the development of the city. Since then, Riga's local geodetic network has evolved with the city, several coordinate and elevation systems have replaced each another, but the task has remained the same - to provide a flawless, homogeneous geodetic foundation for various surveying activities. In 2018, the development of the local geodetic network in several parts of the city was completed, whereby the problem arose - altitude values for surveyed terrain situation points determined using the improved geodetic network do not coincide with altitude values determined using GNSS methods. Considering the above-mentioned problem, the objectives of this bachelor thesis were set: to develop a project for carrying out control measurements, to carry out control measurements for the improved local geodetic network in the vicinity of Grizinkalns and to provide analysis of the obtained results. The difference between the elevations determined by the geometric leveling method and the elevations determined by the GNSS methods shall not exceed 2 mm. According to GNSS methods, using the quasi-geoid model LV'14 v2, the determined heights of the geodetic grid points differ from the given ones by 0.062 m on average. The differences are with the same signs i.e. systematic. To overcome these differences, the quasi-geoid model needs to be refined.

Introduction

The purpose of the local geodetic network is to provide the necessary geodetic reference points for surveying in the relevant administrative area. Geodetic support points are needed for cadastral survey, for obtaining highly detailed topographic data, for performing executive surveying, for geodetic works in construction, ensuring precise attachment of designed engineering structures and buildings to the terrain (Vietējā ģeodēziskā…,2012). After completing the local geodetic network development in several neighborhoods of the city in 2018, it was found that elevation values for surveyed terrain situation points determined using the optimized geodetic network did not coincide with elevation values determined using GNSS methods. Therefore, the aim of the publication is to develop a control measurement project, to perform control measurements for the improved local geodetic network in the Grizinkalns neighborhood and to provide an analysis of the obtained results. In order to achieve the set goals, the following tasks must be fulfilled: control measurements shall be made between selected points of the levelling network of class N1 of the national geodetic network; perform control measurements between the points of the levelling network of class N1 of the national geodetic network and the upgraded points of the local geodetic network; perform GNSS measurements at selected points 6475 and 626a of the levelling network of class N1 of the national geodetic network and at points 6618, 6600 of the local geodetic network; the elevations determined by GNSS methods shall be compared with those obtained by geometric leveling; analysis of the results of the control measurements shall be carried out and proposals to the local geodetic network development solutions shall be submitted.

Materials and methods

The history of development of Riga local geodetic network is almost 140 years long (Kletnieks, 2012, Silabriedis, 2010)). According to the results of the local geodetic network survey in 2012 and 2013, only slightly more than half of the local network geodetic points were recognized as normal for use in Riga, and many (34.5%) destroyed points were found. (Fig. 1) (Rigas vieteja geodeziska…, 2017). To solve the situation, the Riga Local Geodetic Network Development Concept for 2014-2022 was developed. According to the concept, the renovation and development of the local geodetic network is under way (Reiniks, 2013).

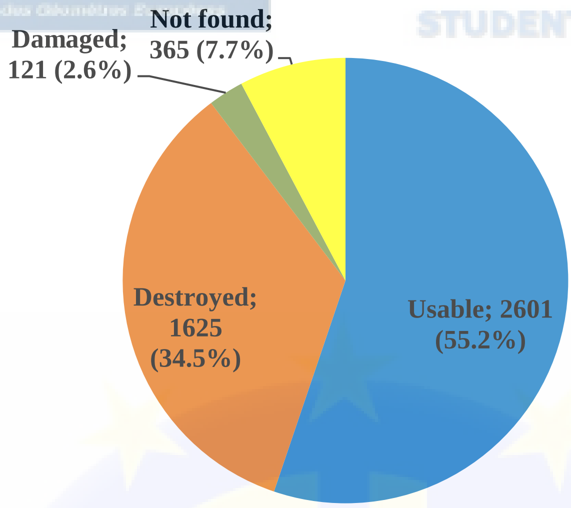

Fig. 1. **Results of the inspection of the local geodetic network in 2012. - 2013.** *(Source: compiled by the author according to data of City Development Department of Riga Council)*

Grīziņkalns is neighborhood in Latgale Suburb of Riga City, although it is partially situated in Centre Region of Riga. Neighborhoods and their boundaries in Riga are formed taking in account the geographical, cultural-historical and functional factors with gentle attitude to toponyms. They are not considered as administrative units. There are cases, when individual neighborhoods are situated in several administrative regions in the same time.

The total area of Grīziņkalns neighborhood is 1.517 km², the length of its perimeter is 5547 m. Construction of this neighborhood was started at the end of 19th century, at the beginning of 20th century in empty place. It developed as typical worker suburb, where workers of nearby factories lived.

The points of the local geodetic network were destroyed as a result of diverse reconstruction works – construction works of revitalization of Grīziņkalns Park, reconstruction works of Daugava Stadium, Deglavs Bridge and Vagonu Street. It is planned to restore points after the completion of construction works.

Surveys for the improvement of the local geodetic network in Riga, Grīziņkalns neighborhood was started in 2009, but technical report on completed works was compiled in 2010. (Geodeziska tikla tehniska…, 2010). The territory of the project included also Avotu neighborhood, but the project of the improvement of the network is called just Grīziņkalns.

These works of improvement of the local geodetic network were done before the Regulations of the Cabinet of Ministers No.497 of July 24, 2012 "Regulation of the Local Geodetic Network" came into force. After July 24, 2012, the improved local geodetic network of Grīziņkalns could not be used legally for topographic and cadastral surveying.

In the same way in period from 2010, coordinates of LatPos base station „Ojārs" were recalculated, two EUPOS-Riga base stations were moved. On December 1, 2014, new height reference system LAS-2000,5 was implemented.

For these reasons, it was necessary to carry out recalculation of previously determined coordinates and heights of the improved local geodetic network and examine it in the procedure defined by regulatory acts in state agency "Latvian Geospatial Information Agency".

On October 27, 2017, state agency "Latvian Geospatial Information Agency" gave a positive opinion concerning overview of improvement of the local geodetic network "Riga local geodetic network in territories "Centrs", "Maskavas forštate" and "Grīziņkalns"". Use of the improved local geodetic network of Grīziņkalns became legal in works of topographic and cadastral surveying from this moment.

Unfortunately, when active use of the improved geodetic network in the performance of surveying works was started, it was found that in the framework of previously performed survey works, where points of survey network determined by GNSS served as geodesic base, the

determined heights do not match with the heights determined by measurements from the improved local geodetic network.
Due to this reason it was decided to perform control measurements of the local geodetic network of Grīziņkalns neighborhood and to find out the reasons for arising of discrepancy.
Before the performance of control measurements, project of performance of works was elaborated (Fig. 2). Considering the problem – mutual discrepancy of heights determined by different methods, decision was made to perform geometric leveling works and to measure elevations between points of leveling network N1 of the state geodetic network and points of the improved local geodetic network. And to determine these elevations by use of GNSS methods.
In the framework of project elaboration, recognition of the area was performed, points of state geodetic leveling network N1 and points of the local geodetic network wall mark No. 626a, ground mark No. 6475, fundamental mark No. 3378, polygonometry points No. 6600 and No. 6618 were inspected. Such activities were performed, to make sure, that the above-mentioned points of state and the local geodetic network can be found in the field and can be used, as well as to determine the best trajectories of leveling lines.

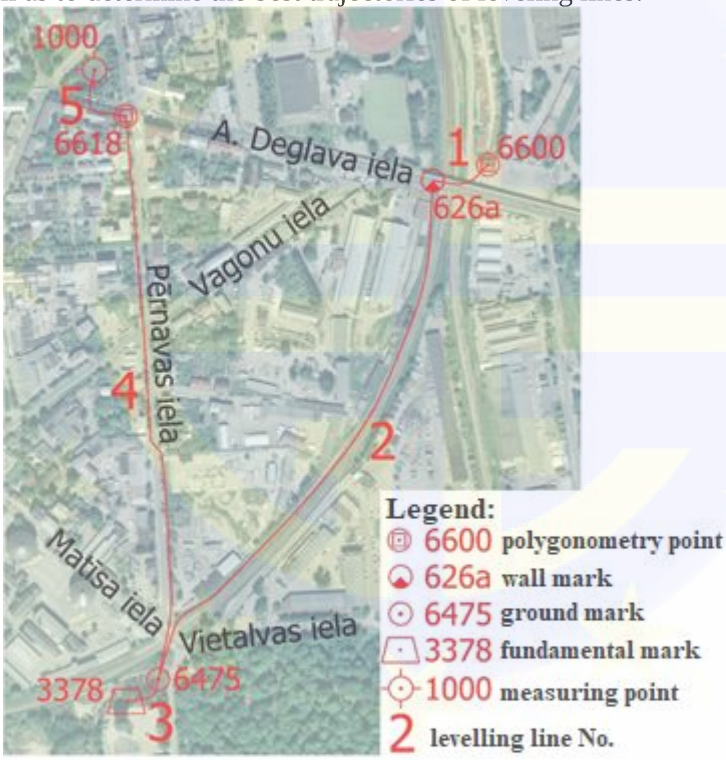

Fig. 2 **Project of performance of control measurements** *(Source: compiled by the authors)*
As a result of recognition of the area and inspection of geodetic points, decision was made:

- 1st leveling line shall be drawn between polygonometry point No. 6600 and wall mark No. 626a,
- 2nd leveling line shall be drawn from wall mark No. 626a up to ground mark No. 6475 along the railway, along, along unused track,
- 3rd leveling line shall be drawn from ground mark No. 6475 and fundamental mark No. 3378,
- 4th leveling line shall be drawn from ground mark No. 6475 up to polygonometry point No. 6618 along Pērnavas Street, by use of sidewalk,
- 5th leveling line shall be drawn between polygonometry point No. 6618 and measuring point No. 1000, that shall be fixed in the field with temporary mark.

1st and 5th leveling line is necessary to transfer height determined by GNSS methods for wall mark No. 626a and polygonometry point No. 6618 by geometric leveling. 2nd and 3rd leveling line is between points of leveling network of class N1 of state geodetic network, to examine

previously measured elevations. 4th leveling line is necessary to examine linkage of the point of local geodetic network to the state geodetic point.
It is planned to determine the height of polygonometry point No. 6600, ground mark No. 6475 and measurement point No. 1000 by use of GNSS methods.

When control measurements were performed, elevations between the used points of state geodetic network and points of the local geodetic network were determined by use of geometric leveling and GNSS methods. Geometric leveling was performed by use of digital level Trimble DiNi and two 3 m long barcode invar rods. Digital level Trimble DiNi with 0.3 mm standard deviation to 1 km double traverse is one of most stable and durable, it is intended for precision measurements in works of establishing of geodetic networks, construction, supervision and observation of deformations.
For the performance of GNSS measurements, aerial Viva GS14 produced by company Leica was used. It is compact and powerful GNSS aerial that is intended for wide spectrum of works. GS14 aerial has built-in GSM modems and radio modems, which provides reception and transmission.
GNSS control measurements were performed in three points: ground mark No. 6475, polygonometry point No. 6600, provisional measurement network point No. 1000 (see Fig. 2). In each point, measurement session duration or data capture duration was 5 hours. For the post-processing and alignment of measurement data, software Leica Infinity, which is intended for processing and alignment of measurement data of all types, was used. In calculations, data from 6 permanent global positioning base stations were used.

Results and discussion

As fundamental mark (fr) No. 3378 and ground mark (gr) Nr. 6475 were installed already in leveling works of class II of year 1975, there is possibility to compare the measured heights between measurements of year 1979 (h_{1979}), between heights available in database of the state geodetic network ($h_{VĢTDB}$) and measurements performed in the framework of bachelor thesis ($h_{measured}$). It is possible to compare the measured elevation between ground mark No. 6475 and wall mark (sr) No. 626a only with the elevation that is calculated taking heights of geodetic points available in the database of state geodetic network as base. Comparison is given in Table 1.

Table 1

Historical and measured elevations

Type of point, No.	h_{1979} (m)	$h_{VĢTDB}$ (m)	$H_{measured}$ (m) 2019.g.	Δ h_{1979}- $h_{VĢTDB}$ (m)	Δ $h_{VĢTDB}$- $h_{measured}$ (m)
fr 3378 gr 6475	-1.1560	-1.1570	-1.158	-0.001	-0.001
gr 6475 sr 626a	-	-2.770	-2.772	-	-0.002

The measured elevations ($h_{measured}$) between ground mark No. 6475 and point of the local geodetic network No. 6618, wall mark No. 626a and point of the local geodetic network No. 6600 can be compared with the elevations ($h_{calculated}$), which are obtained by calculation the difference between heights of geodetic points available in the database of state geodetic network and heights published in the overview of improvement of Grīziņkalns local geodetic network. Comparison of them given in Table 2.

Table 2

Calculated and measured elevations

Type of point, No.	$H_{calculated}$ (m)	$H_{measured}$ (m) 2019	Δh (m)
gr 6475	-2.336	-2.331	0.005
cs 6618			
sr 626a	-1.840	-1.842	-0.002
cs 6600			

As comparison of the measured elevations shows – heights of points of the local geodetic network are determined by linking to points of state geodetic network of class N1.

To research the problem raised in the framework of the bachelor thesis– discrepancy of heights of points of improved local geodetic network and heights determined by GNSS methods, it is necessary to compare elevations obtained as a result of geometric leveling with elevations obtained by GNSS methods. The measured elevations and their comparison are summarized in Table 3.

Table 3

Comparison of geometric leveling and GNSS elevations

Type of point No.	Geometric leveling elevation (m)	GNSS measured elevation LAS 2000,5 (m)	GNSS measured elevation ellipsoidal (m)	Δ geometric leveling-GNSS LAS2000,5 elevation (m)
gr 6475	-2.331	-2.333	-2.357	-0.002
cs 6618				
sr 626a	2.772	2.773	2.797	-0.001
gr 6475				

Elevations, which were measured by geometric leveling methods, and elevations, which were obtained by calculations where heights obtained by GNSS methods were taken as basis and quasigeoid model LV'14 v2 was used, differ within limits of several millimeters.

For a complete picture on problematics of usage of the improved local geodetic network for performance of geodetic works, it is necessary to compare heights determined by GNSS methods using quasigeoid model LV'14 v2 with heights available in database of the state geodetic network and heights of the improved local geodetic network. Their comparison is given in Table 4.

Table 4

Comparison of heights of geodetic points

Type of point, No.	H LAS 2000,5 given (m)	H LAS 2000,5 measured (m)	ΔH given-measured (m)
fr 3378	16.509	16.573	-0.064
gr 6475	15.352	15.415	-0.063
sr 626a	12.582	12.642	-0.060
cs 6618	13.016	13.082	-0.066
cs 6600	10.742	10.800	-0.058
Average:			**-0.062**

Differences of heights of geodetic points actually show that in the territory of Grīziņkalns points of surveying network, heights of which are determined by GNSS methods and use of quasigeoid LV'14 v2 should not be used for purposes of surveying works.

Heights of points of surveying network, which are obtained in such a way, do not satisfy the accuracy requirements stipulated by point 24.1 of Regulations of the Cabinet of Ministers No.

281 of 24.04.2012. “Regulations on High Level of Detail Topographic Information and Its Central Database” – when the corresponding territory is repeatedly surveyed, difference of heights shall not exceed for clearly visible objects and contours of situation 3 cm.

When the results obtained in control measurements are taken into account and their analysis is performed, it is clear that with current pace of the improvement of the local geodetic network of Riga and the elaborated scenario it is necessary to improve quasigeoid model in the territory of the city. It is necessary also to be able to use both the improved points of the local geodetic network and GNSS methods as geodetic base of surveying also in future and to obtain equal results.
In the same way, it is necessary to continue to improve the local geodetic network in densely built-up areas and areas of new development, to provide obtaining of homogenous geospatial data for purposes of public administration, municipalities, and economics.
Authors propose three solutions of Riga local geodetic network that are listed in Table 5.

Table 5

Riga local geodetic network development solutions

No.	Geodetic network solution	Notes
1	Improved and fixed in area local geodetic network in entire territory of the city.	The most expensive solution that will require large financial investments and regular maintenance, but will provide obtaining homogenous geospatial information.
2	Improved and fixed in area local geodetic network in densely built-up areas and areas of new development + global positioning permanent base station network in other areas of the city	Optimal solution that will provide obtaining homogenous geospatial data both in densely built-up areas and outside of them. However, it is mandatorily necessary to make the quasigeoid model in the territory of the city more accurate.
3	Network of global positioning permanent base stations in the entire territory of the city	Solution that has been the only legal geodetic base of the surveying from 2012-2018. It does not require large financial investments, but it is mandatorily necessary to make the quasigeoid model in the territory of the city more accurate.

Conclusions

1. Riga local geodetic network has more than 100 years long and rich history. It contains geodetic points that are measured in different periods with different accuracy. They as a whole make geodetic network that does not comply with requirements of regulatory acts.
2. In the surveying of Riga local geodetic network, wide range of geodetic instruments is used beginning with optical instruments and ending with electronic devices that maximally exclude the factor of human error, improve the efficiency and accuracy of performance of geodetic works.
3. The main improvements that contributed to accuracy of performance of measurements is implementation of electronic distance measurement, automatization of performance of readings and of recording, appearance of electronic measurement data processing and implementation of GNSS technologies in civil usage.
4. Geometric leveling works that are performed in the framework of the research correspond to accuracy requirements of leveling of class I.
5. Results of control measurements performed between points of leveling network of class N1 of state geodetic network show that network of class N1 situated in Grīziņkalns neighborhood is stable; changes of mutual elevation of leveling marks fixed in the area do not exceed 2 mm.

6. Mutual differences of elevations determined by geometric leveling methods and of elevations determined by GNSS methods do not exceed 2 mm.
7. Heights of points of geodetic network determined by GNSS methods by use of quasigeoid model LV'14 v2 differ from the given ones by 0.062 m in average. Differences have the same signs, i.e., they are systematic. To eliminate these differences, it is necessary to make quasigeoid model more accurate.
8. To provide obtaining basic geospatial data according to requirements of regulatory acts, when surveying works are performed, it is necessary to use state geodetic network, improved local geodetic network as geodetic base or to link measuring network to both above mentioned ones.

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