ASPECTS CONCERNING THE SELECTION OF TECHNICAL SOLUTIONS FOR REHABILITATION AND MODERNIZATION OF A CITY GEODETIC NETWORK

Dan PADURE, Assistant, PhD Stud. Eng. „Gheorghe ASACHI” Technical University of Iasi, Romania, danny_pad@yahoo.com
Dragos-Constantin NICA, Assistant, PhD Stud. Eng., „Alexandru Ioan CUZA” University of Iasi, Romania, nicadragos42@yahoo.com

Abstract: *In order to realize the digital cadastral plan of the administrative territory of a city and spatial mapping database arise the necessity to determine a geodetic control network, to complete and modernize the existing network. For this purpose, will be reviewed the technical standards required by current legislation regarding the introduction and the execution of general cadastre and information systems on the fields of activity. Rehabilitation, determination and modernization operations, of existing geodetic network will be made using the European geocentric datum, adopted by Romania in 2009, with the RO_ETRS89 indicative, by using traditional methods and modern methods using GNSS satellite technology. It will be presented a case study in which the highlighted measurement and processing data operations have led to the establishment of the geodetic control network of a city.*

Keywords *:digital plan, geodetic networks, classical and satellite methods.*

1. Introduction

The rehabilitation and practical modernization of geodetic networks of a city, requires the execution of some complex and sustained works, in collaboration with authorized individuals and institutions, that finally would be received by National Agency of Cadastre and Land Registration. Only by respecting such conditions and technical standards in force, can be obtained a firm basis for starting and control, ensuring the unity and homogeneity of subsequent liftings, regardless of the area where the work is executed [3, 4].

In order to achieve the real estate Informational System, in accordance with Art. 4 of Law No.7/1996, regarding the cadastre and land registration, the works will be executed under the following rules and methodologies:

– "Technical Standards on the execution of general survey" prepared by ONCGC under Order No.186/25.11.1997;

– "Basic technical standards for the preparation of basic topographic plan" drawn up under Decree No.305/1971 and approved by order of the Ministry of Agriculture and Food Industry (MAFI) No. 147/12.12.1980;

– "Methodology for execution of the real estate cadastre input works in localities" approved by the Ministry of Public Works and Territory Planning (MPWTP) by Order No. 90/02.06.1997 and ONCGC by Order No.911/ 02.06.1997;

– "Methodology for execution of the urban networks cadastre input works in localities" approved by Order MPWTP ONCGC No.91/02.06.1997 and the Order No.912/02.06.1997.

The goal of urban-real estate cadastre works is to set up databases for better management of cities, based on complete information on the existing built up background of urban networks. Also, it is aimed the possibility to optimize them, for an easier update or preparation of topographic and cadastral plans, for maintenance of land records, for evaluation of land and buildings from the inside of the city etc.

2. Method presentation

The data acquisition in a GPS network combined with classical measurements can be done through a double stationing in their points with different devices. The succession does not matter because the works are independent and are executed both with GPS equipment, which records the specific data of the location of the points, as well as with the total station which measures the angular and linear elements, characteristic to the classical networks of triangulation and trilateration.

The calculations that led to the determination of network points in the national reference system have been made based on complex programs of in block compensation by indirect measurement method. By compensating them in block, the networks based on heterogeneous observations, which are using the GPS system records, along with classical methods for locating the determined points, have proven their effectiveness due to the success of homogenization of the entire network.

3. Achievement of thickening and lifting network - Case study

A. ACHIEVEMENT OF THICKENING AND LIFTING NETWORK BY TRIANGULATION-TRILATERATION

To achieve lifting network for the administrative territory of Podu Iloaiei City were determined the coordinates of two new unknown points by backwards intersection method and rigorously compensation of them in a triangulation-trilateration network (Fig. 1).

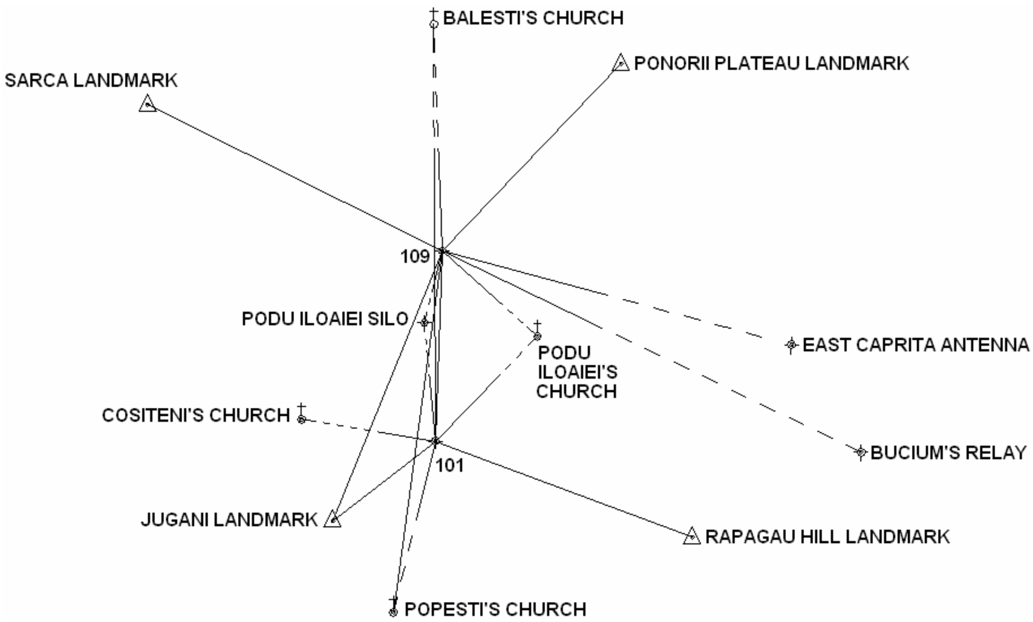

Fig. 1 The outline of determination visas for the 101 and 109 points, using the method backwards intersection

The existing cartographic and geodetic base regarding the execution of cadastre works for the administrative territory of the City of Podu Iloaiei consists in the topographic plan at scale 1:25.000, from the year 1984, and the orthophotomap made in the year 2005.

Further, it is shown the way of processing and compensation of the elements measured in the field:

- The angular and linear elements measured on the field are processed in Table 1 and Table 2, as follows:

Table 1. Processing of linear elements measured in the field

Network side		Provisional distance (m)	Reduced distance to the plane (m)
Starting point	Arrival point		
101	1002	1872.4970	1872.6217
101	109	2740.5690	2740.3907
101	1001	3969.5840	3969.5796
109	1003	4753.1100	4752.9610
109	1004	3739.9760	3740.2737
109	101	2740.5990	2740.3907
109	1002	4194.4100	4194.3180

Table 2. Processing of angular elements measured in the field

Station point	Visa point	Meas. average direction ($^{g\ c\ cc}$)	Corr. red. (^{cc})	Reduced direction ($^{g\ c\ cc}$)	Provisional distance (m)	Provisional orientation ($^{g\ c\ cc}$)
101	2007	14.712100	-	305.215400	5528.130	215.357157
	1002	57.353250	-	347.856550	1872.622	257.995418
	2001	109.496700	-	0.000000	1963.461	310.143068
	2003	199.092200	-	89.595500	6007.592	399.749182
	109	201.626450	-	92.129750	2740.391	2.267135
	2004	205.261200	-	95.764500	1804.750	5.905586
	1004	228.623250	-	119.126550	6063.899	29.264493
	2006	246.556900	-	137.060200	2199.197	47.204989
	1001	322.061950	-	212.565250	3969.580	122.698822
109	1004	71.558600	-	119.512800	3740.274	48.760423
	2008	139.403200	-	187.357400	15686.553	116.602014
	2009	151.157800	-	199.112000	33062.316	128.362091
	2006	165.938800	-	213.893000	1781.336	143.140514
	2004	218.108200	-	266.062400	944.232	195.302711
	101	225.073650	-	273.027850	2740.391	202.267135
	2007	233.822900	-	281.777100	8229.836	211.025717
	1002	247.343600	-	295.297800	4194.318	224.541550
	1003	352.045800	-	0.000000	4752.961	329.250197

The inventory of the coordinates of the geodetic points belonging to the lifting network is shown in Table 3.

Table 3. Old points coordinate inventory

Point no.	Point name	Point order	STEREO '70 coordinates	
			X (m)	Y (m)
1001	Răpăgău Landmark	III	634244.966	674837.099
1002	Jugani Landmark	IV	634482.680	669637.604
1003	Sârca Landmark	I	640476.955	666954.714
1004	Ponorii Plateau Landmark	IV	641064.948	673807.531
2001	Cosițeni's Church	V	635942.040	669178.590
2003	Băleşti's Church	V	641638.075	671093.514
2004	Podu Iloaiei Silo	V	637427.520	671284.360
2006	Podu Iloaiei's Church	V	637252.350	672602.500
2007	Popeşti's Church	V	630262.467	669796.530
2008	East Caprița Antenna	V	634324.594	686370.915
2009	Bucium Relay	V	624122.010	701049.880

➢ The provisional coordinates calculation of new points 101 and 109 is presented in Table 4 and Table 5:

Table 4. Provisional coordinates of the point 101 (16-Combinations)

Combination	Provisional coordinates of the point 101		Differences	
	X'101 (m)	Y'101 (m)	ΔX (m)	ΔY (m)
2006-2004-2001	635630.444	671117.016	-0.176	-0.239
1002-2007-2004	635630.395	671117.151	-0.225	-0.104
…	…	…	…	…
1002-1004-2001	635630.686	671117.315	0.066	0.061
1002-1004-2004	635630.671	671117.299	0.051	0.045
101	635630.620	671117.254	Ray = 9.8 [cm]	

Table 5. Provisional coordinates of the point 109 (22-Combinations)

Combination	Provisional coordinates of the point 109		Differences	
	X'109 (m)	Y'109 (m)	ΔX (m)	ΔY (m)
1004-2006-2009	638369.338	671214.684	0.132	-0.249
1004-2006-2008	638368.971	671214.854	-0.235	-0.079
…	…	…	…	…
1003-2004-2006	638369.148	671214.896	-0.058	-0.037
1003-2007-2004	638369.149	671214.896	-0.057	-0.037
109	638369.207	671214.933	Ray = 13.3 [cm]	

The provisional plane rectangular coordinates of the point 101 were obtained from the average of 16^{th} combinations resulted from the visa of 7 geodetic points, respectively for the point 109 from of the average of 22^{nd} combinations resulted from the visa of 9 geodetic points. The average error of plan positioning of determined points is ± 9.8 cm for the point 101 and ± 13.3 cm for the point 109.

➢ Rigorous compensation of the coordinates of the new points 101 and 109 (Table 6) and the results accuracy evaluation:

Table 6. The compensated coordinates inventory of new points

Point no.	Compensated coordinates	
	X (m)	Y (m)
101	635630.537	671117.209
109	638369.177	671214.886

For complete evaluation of accuracy of the indirect measurements, first it is calculated the square average error of a single angular measurement, characterizing the network, with the relation:

$$s_0 = \pm\sqrt{\frac{[vv]}{r-n}} = \pm 12.8^{cc}$$

The square average error of compensated distances from the network, it is calculated with the relation:

$$s_{D_{ij}} = \pm s_0 \sqrt{Q_{D_{ij}}} = \pm 0.086\ m$$

The error ellipse calculation elements for the new points are presented in Table 7.

Table 7. Error ellipse calculation elements

Point no.	Coordinated errors		Semi-axes ellipse		Large ellipse axis orientation ($^{g\ c\ cc}$)
	s_X (m)	s_Y (m)	A (m)	B (m)	
101	0.107858	0.056281	0.10836	0.05532	192.893022
109	0.076664	0.074549	0.08798	0.06078	47.481058

B. THE MAKING OF GEODETIC NETWORK BY GPS TECHNOLOGIES

In order to create the thickening and lifting network made of two new points it was used the GPS measurement technology (Fig. 2) to determine the point's position in real time through the Romanian position determination system (ROMPOS). ROMPOS system is based on a national network of permanent stations installed by Cadastre and Land Registration Office, which are base stations that operate continuously providing real time data, and at predetermined intervals [1, 2].

To carry out observations the equipment used was [6]: GPS Spectra Precision Epoch 25 receiver, double frequency (L1/L2), rover RTK+PP – tables 8, 9, 10 and 11.

Table 8. Coordinates inventory of ROMPOS RTK Iasi and VRS - Romania

Point no.	ROMPOS RTK Iasi		ROMPOS RTK RO-VRS	
	X (m)	Y (m)	X (m)	Y (m)
101	635630.4105	671117.0560	635630.3975	671117.0375
109	638369.3395	671214.8815	638369.3365	671214.8700

Based on the observations made by GPS measurement technology, with double frequency, were calculated the new points 101 and 109, by determining the trans-calculation parameters, using 3 old points (Table 9), 4 old points (Table 10), and 28 points of known coordinates (Table 11) disposed on the entire territory of the county of Iasi (Fig. 2).

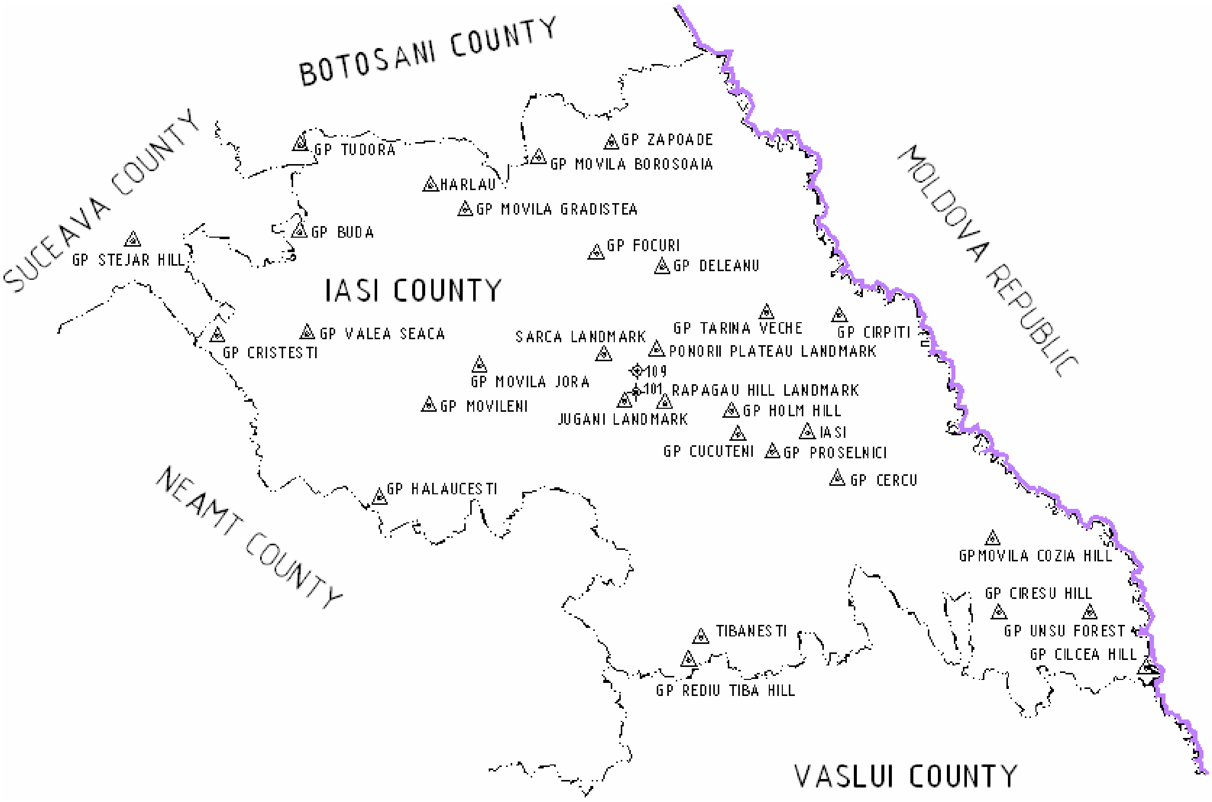

Fig. 2 The disposition outline of stationary points with GPS measurement technology, for determining the trans-calculation parameters on the entire territory of the county of Iasi

Table 9. The calculation of the new points using 3 old points to determine the trans-calculation parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	X (m)	Y (m)
Răpăgău	47.110470	27.182042	634244.966000	674837.099000
Jogani	47.111724	27.141388	634482.680000	669637.604000
Sârca DTM	47.143371	27.121446	640476.955000	666954.714000
101	47.115303	27.152569	635630.438844	671117.092303
109	47.132159	27.153407	638369.327453	671214.871016

Table 10. The calculation of the new points using 4 old points to determine the trans-calculation parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	X (m)	Y (m)
Răpăgău	47.110470	27.182042	634244.966000	674837.099000
Jogani	47.111724	27.141388	634482.680000	669637.604000
Ponorii Plateau	47.144641	27.174096	641065.948000	673807.531000
Sârca DTM	47.143371	27.121446	640476.955000	666954.714000
101	47.115303	27.152569	635630.578156	671117.173375
109	47.132159	27.153407	638369.395222	671214.903157

Table 11. The calculation of the new points using 28 old points to determine the trans-calculation parameters

Number / Point name	Geographic coordinates		STEREO '70 rectangular coordinates	
	φ	λ	X (m)	Y (m)
GP CERCU	-	-	624493.8567	697142.0401
GP HOLM HILL	-	-	633189.0110	683396.1420
…	…	…	…	…
GP BUDA	-	-	656269.6880	627730.0220
GP TUDORA	-	-	667477.7850	627855.4900
101	47.11530282	27.15256928	635630.4114	671117.0497
109	47.13215876	27.15340665	638369.3443	671214.8787

Following the measurements by GPS methods were obtained five sets of Stereographical 1970 plane rectangular coordinates, presented in Tables 12, 13, 14 and 15 [4, 7].

For the comparative study were calculated the differences between new points coordinates obtained by the classical determination method and coordinates obtained from GPS measurements (Tables 12, 13 and 14), respectively between ROMPOS RTK Iasi and ROMPOS RTK RO-VRS, Romania (Table 15).

Table 12. Comparison table classic measurements – 4 points calibration GPS control

Point no.	Determinations from classic measurements		Determinations with 4 control points for calibration		Differences		Vector
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)	
101	635630.537	671117.209	635630.578	671117.173	0.041	-0.036	0.055
109	638369.177	671214.886	638369.395	671214.903	0.218	0.017	0.218

Table 13. Comparison table classic measurements – 28 points calibration GPS control

Point no.	Determinations from classic measurements		Determinations with 28 control points for calibration		Differences		Vector
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)	
101	635630.537	671117.209	635630.411	671117.050	-0.126	-0.159	0.203
109	638369.177	671214.886	638369.344	671214.879	0.167	-0.007	0.167

Table 14. Comparison table classic measurements – GPS ROMPOS RTK Iasi

Point no.	Determinations from classic measurements		ROMPOS RTK Iasi		Differences		Vector
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)	
101	635630.537	671117.209	635630.411	671117.056	-0.126	-0.153	0.198
109	638369.177	671214.886	638369.340	671214.882	0.163	-0.004	0.163

Table 15. Comparison table GPS ROMPOS RTK Iasi – ROMPOS RTK RO-VRS - Romania

Point no.	ROMPOS RTK Iasi		ROMPOS RTK RO-VRS		Differences		Vector
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)	
101	635630.411	671117.056	635630.398	671117.038	-0.013	-0.018	0.022
109	638369.340	671214.882	638369.337	671214.870	-0.003	-0.012	0.012

4. Conclusions

After the compared study of determinations from the thickening and lifting network by triangulation-trilateration classical methods and GPS measurements, there were not found major differences. Thus we can say that in areas where support geodetic network exists and is easily accessible, it can be used to obtain a network of thickening and lifting of satisfactory accuracy, with minimal costs. In areas where the density of the points of support network does not provide opportunities for traditional measurements, GPS technology can achieve this by different measurement methods, obtaining new points with high precision.

The economic efficiency, defined by high productivity and low costs, is higher then intersections whether GPS devices are their own or not, or if measurements are executed by custom by a specialized company. In addition, if the works that will be executed later will be continued with total stations, it can be counted on a lower density network, which greatly reduces the cost of works.

References

1. Dragomir P.I., Rus T., Dumitru P., Integration of GPS Permanent Stations National Network in EUPOS European Network. Modern technologies for the 3rd Millennium Conference, Oradea, 2005

2. Dragomir P.I., Rus T., Dumitru P., Modernization of GPS permanent stations national network of Romania. Journal of Geodesy, Cartography and Cadastre, Works presented at Land and Survey measurements Symposium, vol. 14, nr. 1-2, Bucharest, 2005

3. Moldoveanu C., Support geodetic networks-module. References and Coordinates Systems. Publishing CONSPRESS, Bucharest, 2002

4. Neuner J., Săvulescu C., Moldoveanu C., Study regarding the possibility of determination of the coordinates in 1970 stereographic projection using GPS technology. Journal of Geodesy no.1-2, Bucharest, 2002

5. Neuner J., Global positioning systems. Publishing MatrixRom, Bucharest, 2000

6. Nistor Gh., Andrei O., Chirilă C., GPS technology to achieve space geodetic network in Romania. State Agrarian University of Moldavia, Scientific papers, vol. 13, Cadastre, territorial planning, environmental engineering, Chisinau, 2005

7. Nistor Gh., Sălceanu Gh, Implementing GIS technology in making urban-real estate informational system of a city. University „1 December 1918" Alba Iulia, RevCAD – Journal of Cadastre, 2008

8. Păunescu C., Mocanu V., Dimitriu S., GPS Global positioning system. Publishing MatrixRom, 2006

9. ROMPOS, Romanian Position Determination System. Brochure published by Cadastre and Land Registration Office, September 2008

*10.***, European Position Determination System - Technical Standards. Revised 2nd Edition, 24 April 2008, Resolution of the International EUPOS® Steering Committee, 13th Conference, Bucharest, Romania, 2008*