

Building the Geodesic Network for the City of Gramsh through GNSS Surveys

¹Bledar Sina, ²Eduart Billoshmi

^{1,2}Faculty of Civil Engineering, Polytechnic University of Tirana, Albania

Abstract - This study presents the methodology and results of establishing a geodesic network for the urban area of Gramsh, Albania, utilizing Global Navigation Satellite System (GNSS) surveys. The development of an accurate geodetic framework is essential for various applications including urban planning, infrastructure development, and cadastral mapping. The research focuses on deploying GNSS receivers strategically across Gramsh to collect precise positioning data, which is subsequently processed using differential correction techniques to achieve centimeter-level accuracy. Ground control points are established throughout the city to facilitate georeferencing and validation of the network. Additionally, quality control measures such as redundancy checks and error analysis are implemented to ensure the reliability of the geodesic network. The resulting network provides a reliable spatial reference system for the city of Gramsh, enabling efficient and accurate geospatial data collection, analysis, and decision-making processes for urban development projects. This study demonstrates the effectiveness of GNSS surveys in establishing geodetic infrastructure in urban environments and highlights their significance in supporting sustainable urban growth and management.

Keywords: GNSS surveys, geodesic network, gps.

I. INTRODUCTION

In the realm of urban development and infrastructure planning, the establishment of a robust geodetic network serves as the cornerstone for accurate spatial referencing and precise positioning. Such networks, built upon advanced surveying techniques and technologies, provide the necessary framework for various applications ranging from land administration and cadastral mapping to civil engineering and urban design. In the context of the city of Gramsh, Albania, a burgeoning urban center nestled amidst the scenic landscapes of the country's interior; the implementation of a modern geodesic network emerges as a critical imperative to support its evolving socio-economic landscape.

Gramsh, located in central Albania, boasts a rich historical heritage alongside its contemporary significance as a hub for agriculture, commerce, and burgeoning tourism. As

the city experiences progressive urbanization and infrastructural expansion, the need for an accurate spatial reference system becomes increasingly pronounced. Historically, the development of geodetic frameworks relied on conventional surveying methodologies, often fraught with limitations in accuracy, efficiency, and scalability. However, the advent of Global Navigation Satellite System (GNSS) technology revolutionized the field of geodesy, offering unprecedented capabilities in precise positioning and geospatial data acquisition.

The utilization of GNSS surveys presents a transformative opportunity for Gramsh to establish a modern geodesic network tailored to its unique geographical and developmental context. By harnessing the signals emitted by satellite constellations such as GPS (Global Positioning System), GLONASS (Global Navigation Satellite System), and Galileo, GNSS receivers can ascertain precise coordinates with remarkable accuracy and reliability. This capability not only streamlines the process of network establishment but also ensures consistency and interoperability with global positioning standards, thereby facilitating seamless integration into broader geospatial frameworks.

The significance of a geodesic network extends beyond mere cartographic accuracy; it underpins a myriad of urban planning and development endeavors critical for the sustainable growth of Gramsh. From delineating property boundaries and optimizing transportation networks to facilitating disaster management and environmental conservation, the spatial reference provided by the geodesic network forms the bedrock upon which informed decisions and strategic interventions are built. Furthermore, in the age of digital transformation and smart cities, the accessibility of precise geospatial data becomes indispensable for innovative solutions ranging from location-based services to augmented reality applications.

Against this backdrop, this study endeavors to elucidate the process of building a geodesic network for the city of Gramsh through GNSS surveys. By delineating the methodology, challenges, and outcomes of this endeavor, this research aims to shed light on the efficacy and applicability of GNSS technology in the context of urban geodesy. Through a

comprehensive examination of surveying techniques, data processing methodologies, and quality assurance protocols, this study seeks to provide insights into the nuances of establishing a reliable spatial reference framework tailored to the specific needs and nuances of Gramsh.

In doing so, this research not only contributes to the academic discourse surrounding geodetic engineering and urban planning but also offers practical implications for policymakers, urban planners, and practitioners tasked with steering the trajectory of Gramsh's development. By harnessing the power of GNSS technology, Gramsh can pave the way towards a future characterized by precision, efficiency, and sustainability in its urban infrastructure and spatial management endeavors.

II. METHODS AND APPROACH

2.1 Study area

The district of Gramsh is located in the central and southern part of Albania, from Qafa e Shënkolli, Lleshan in the north to Siman (Sqimar) in the south and from Saraseli in the west to the mountain of Valamara, Lenie in the east. According to the statistical data of 2004, this district has 42,616 inhabitants. Most of it lies in the Central Mountain Province, which is called Vërca Province. This part is located on the eastern side of the river Devolli. Its western part lies in the Western Lowlands, known as the province of Sulova, and the area that lies between the river Devolli and Tomorrica lies in the Southern Mountain Province and is known as the province of Tomorrica. This district lies in the middle sector of the river Devolli, which within the district has a length of 49 km, river, which, as we said, together with the river Tomorrica, divides the District of Gramsh into 3 provinces. The district of Gramsh is part of the prefecture of Elbasan. It is bordered by seven other districts which are; Elbasani, Librazhdi, Pogradeci, Korça, Skrapari, Berati and Kuçova, and has an area of 695 km². It consists of a municipality, 9 administrative units and 95 villages. According to the geographical location, it is located in the transitional climate zone, an area that is quite suitable for the development of economic activity. This advantage offered by the geographical position is undermined by the character of the relief, which is generally quite folded. In its entirety, the territory of the district is a valley. The valleys of Devolli and Tomorrica constitute the most paved part of the terrain and where the most fertile soils are found.

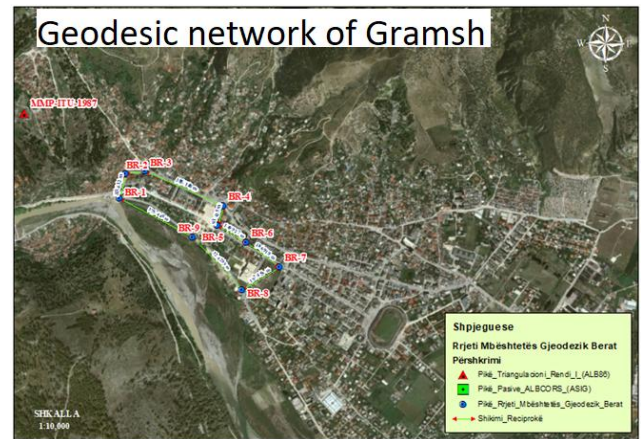


Figure 1: Geodesic network of Gramsh

2.2 Design of GNSS measurements

To determine the points, we initially based on three basic documents, where we pre-determined the positioning of the points of the Gramsh local geodetic support network:

- Topographic map on a scale of 1:25000 (published by the Geographical and Military Infrastructure Institute (former ITU), in the years 1959-1985 (Fig. 2)

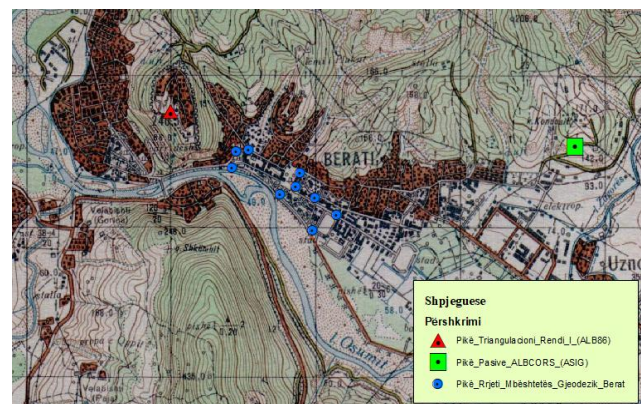


Figure 2: Topographic map of scale 1:25000

The basic criteria that were taken into account for choosing the position of the points:

- The optimal visibility of satellites should not have obstacles above 200 degrees to avoid blocking the satellite signal.
- Elimination of possible reflective surfaces that cause "multipath" of the satellite signal.
- The fixation of new points should be done in places where there are no developments (constructions) and in stable formations such as rock, stone blocks, bridges, etc.
- Avoidance of high voltage poles, unstable or temporary buildings and objects.
- Positioning in suitable places that enable the measurement process.

The preliminary design of the choice of the position of the points was carried out in cooperation with the specialists of the Urban Planning Sector in the Municipality of Gramsh, where together we decided that the local geodetic support network should cover the entire surface of the city.

2.3 Fixation (materialization) of the points of the Gramsh local geodetic support network

After the final definition of the local geodetic support grid points in the city of Gramsh that were determined during the field reconnaissance phase according to the GNSS point design criteria, we started with the grid point fixation phase. The fixing of the network points was mainly carried out along the sidewalks and in positions that are not affected by the developments, according to the urban plan of the Gramsh Municipality. The engineers of Gramsh Municipality, who knew the area in detail, also offered a great help. The fixation of the points was carried out far from the development areas with a distance of 20 - 100 m. Fixing of the points is done with concrete matalic screws (center/mark of the point) with a length of 150 mm and a width of 10 mm.



Figure 3: The center of the point

Before fixing the points in their centers, a modification of their head is made, opening a hole with a diameter of 3-4 mm in the center, in order to easily place the thread in the center of the center. The working tools that were used for fixing the points are: battery drill, two-mix strong solution that replaces the preparation of mortar for concreting the points, hammer, etc. GNSS surveys of 12 points of the Berat local geodetic support network were carried out according to the following criteria:

- The survey strategy should be implemented according to the multi-station concept (three receivers that simultaneously track satellite data).
- The time of observations for each session should be 30-45 minutes.
- Measurements are carried out according to the "Fast static" service.
- The data collection speed should be 5 seconds.

For control, improvement of field accuracy and reliability of GNSS observations, the following surveys were carried out:

- At the classic network point ALB86 "MMP-ITU-1987", which is located in Berat Castle, multiple re-surveys have been carried out.
- At two points of the network (BR-7 and BR-1) re-inspections (re-occupancy) were carried out, being inspected twice.
- At the passive point of KRGJSH networks "D29HaHpVG" in a session lasting 60 min.

For the processing of GNSS measurements, we are based on the 5 reference stations of the ALBCORS global positioning system.

The process of GNSS measurements was carried out on May 22, 2021, where at 9:30 the first session of GNSS observations was started by the working group consisting of 3 people distributed in the points of the local geodetic support network Gramsh and so that the observations to start simultaneously, intergroup mobile communication was used.

During the inspection process, a special care was shown in the leveling (positioning of the bubble in the center of the vertical level) of the chalon by means of the bipod, as well as in order to avoid multipaths, parking of cars nearby was not allowed. GNSS antennas (minimum 10 m). Also, during the GNSS surveys for the 12 points of the Gramsh local geodetic support network, the basic data required by the GNSS field measurements form referred to "Guidelines no. 3, dated 06.09.2013" ASIG (Tab. 2.5 a), as well as some additional data such as:

1. Number of satellites,
2. Values of GDOP and PDOP,
3. Points measured in each session session,

The processing and compensation of GNSS data was carried out through the program "Trimble Business Center" (TBC) where the coordinates of the GNSS measured points of the local geodetic support network BERAT were calculated based on the coordinates of 5 (five) reference stations of the positioning system global ALBCORS. The program defines network compensation as "Solving the simultaneous equations designed to close the fast-static service network via the weighted sum of squares of the residuals of the observations".

In the following we describe the steps of processing GNSS observations in the fast-static service.

Identification of inappropriate baselines

During network compensation, we can only use independent baselines (which are formed by direct field measurements), so the dependent, unwanted baselines must be excluded first.

For a survey session, the number of independent baselines (b) is calculated as one less than the number (n) of receivers used in the session:

$$b = n - 1$$

The number of dependent lines, Nv can be calculated as:

$$Nv = (n - 1) \cdot (n - 2)/2$$

The total number of baselines, Nt can be calculated as:

$$Nt = n \cdot (n - 1)/2$$

In this diploma project, in 1 session, GNSS surveys were carried out with three Trimble R8 receivers simultaneously at the points of the support network, as well as GNSS surveys from 5 reference stations of the ALBCORS system, so referring to the equations above, it results.

In order to satisfy the accuracy standards, only independent baselines can be taken into consideration, but for carrying out controls of closures in geometric figures, dependent baselines are necessary, especially for control services (geodesic support networks), therefore in this project not all the dependent lines are excluded, but only those that, after being cleaned from "bad" data and from misbehaving satellites, have come out of the After importing the data, we define as strong points (control) the 5 reference stations of ALBCORS: Berat, Çorovodë (Skrapar), Fier, Lushnje, Gramsh. Before processing the baselines, we define some parameters in TBC: the data collection interval during GNSS surveys: (5-sec), the GPS and GLONNAS satellite systems, the gradient 200, the way to calculate the position of each point using the weighted average of of all observations: "Weighted Mean of All Observation". Knowing that the processing of the baselines produces a vector between the stations, with data at the same time, as a start we select all the baselines that were produced in the first session by the three receivers that have observed simultaneously at the points of the local geodetic support network Berat and from the 5 stations ALBCORS system reference:

- Session I: (duration 9:30 ÷ 10:30)
- Targeted points: MMP-ITU-1987 - BR-2 - BR-3 as well as 5 ALBCORS bases

4. So, we activate the baselines created in the first session and deactivate the baselines of the other 5 sessions.

III. RESULTS AND DISCUSSIONS

To carry out this transition, the following formulas are used,

Where

- N - radius of curvature of the first vertical and is calculated;
- E - eccentricity of the ellipsoid and
- F - is polar compression of the ellipsoid.

The calculation of (X,Y,Z) according to these formulas cannot be done without knowing the geometric parameters of the reference ellipsoid (a, f,e).

For the GRS80 ellipsoid these parameters are:

- a = 6 378 137 m;
- f = 0.003 352 810 681 183 637 418 and 1/f = 298.257 222 100 882 711 243;
- e2 = 0.006694380022903415...

(b) The reverse transition, from (X,Y,Z) to is not done directly, but requires the implementation of a procedure of successive approximations through the steps shown below;

- Dividing the second equation by the first equation of the

equations (*) we find: $\lambda = tg^{-1} \left(\frac{y}{x} \right)$

- The ellipsoidal width is obtained through a process of successive approximations starting from an initial value of the width according to the following steps:

1. Calculate the approximate width:

$$\varphi_0 = \arctan \left(\frac{z}{p(1 - e^2)} \right) \quad \text{where: } p = \sqrt{x^2 + y^2}$$

2. According to the approximate width, we calculate the approximate radius of curvature of the first vertical

$$N_0 = a / \left(1 - e^2 \sin^2 \varphi_0 \right)^{1/2} \quad \text{and the approximate ellipsoidal height and from them the width of the first approximation according to the equation:}$$

$$\varphi = \arctan \frac{z}{p} \left(\frac{N_0 + h_0}{N_0 (1 - e^2) + h_0} \right)$$

3. Further, action (2) is repeated in successive approximations until the width found in the last approximation with that found in the penultimate approximation is a small acceptable size for the accuracy we require in the calculation.

4. With the width found in the last approximation, calculate the final radius of curvature of the first vertical N and the final ellipsoidal height according to the equation:

$$h = \frac{P}{\cos \varphi} - N$$

The obtained geospatial data (coordinates of 6 points) will serve various public and private institutions that work in the field of Geodetic, GIS, Geophysical, Geographical studies, civil constructions in function of the development of the city of Gramsci.

The project will be donated to Gramsh Municipality.

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Vertical Spatial Coordinates ETRS89/ETRF2000							
Nr. S esio ne	Point identifica tion	X (GRS80) (m)	Y (GRS80) (m)	Z (GRS80) (m)	ΔX (m)	ΔY (m)	ΔZ (m)
1	MMP-ITU-1987	4551606.16	1651720.79	4138049.76	0.011	0.006	0.01
	BR-2	4551493.29	1652162.97	4137729.13	0.011	0.006	0.009
	BR-3	4551454.15	1652242.53	4137735.89	0.012	0.007	0.011
2	MMP-ITU-1987	4551606.15	1651720.79	4138049.75	0.012	0.005	0.01
	BR-4	4551426.29	1652607.42	4137615.74	0.011	0.005	0.009
	BR-5	4551489.86	1652600.51	4137547.63	0.01	0.005	0.008
3	MMP-ITU-1987	4551606.14	1651720.78	4138049.75	0.007	0.004	0.007
	BR-6	4551492.62	1652738.57	4137489.22	0.007	0.004	0.006
	BR-7	4551508.59	1652905.36	4137406.38	0.007	0.004	0.006
4	MMP-ITU-1987	4551606.16	1651720.78	4138049.76	0.009	0.005	0.009
	BR-7	4551508.58	1652905.36	4137406.38	0.009	0.005	0.008
	BR-8	4551629.47	1652770.65	4137327.45	0.008	0.004	0.007
5	MMP-ITU-1987	4551606.13	1651720.78	4138049.72	0.007	0.004	0.007
	BR-9	4551559.46	1652509.69	4137506.81	0.007	0.004	0.007
	BR-1	4551564.49	1652158.91	4137640.54	0.007	0.004	0.007
6	MMP-ITU-1987	4551606.15	1651720.79	4138049.75	0.006	0.004	0.006
	BR-1	4551564.51	1652158.93	4137640.57	0.006	0.004	0.006
	D 29HaHpV G	4550716.71	1654365.07	4137793.07	0.004	0.003	0.004

IV. CONCLUSION

The local geodetic support network in the city of Gramsh will serve as a basic reference for the support of all geodetic pumice based on the official KRGJSH framework.

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