FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 20, Nº 1, 2022, pp. 15-21
https://doi.org/10.2298/FUACE211209004C

Original scientific paper

OPTIMIZATION OF 1ST ORDER OF THE TRAVERSE NETWORK OF BELA PALANKA

UDC 528.06(497.11)

Nenad Ćirić

University of Niš, Faculty of Civil Engineering and Architecture, Niš, Serbia

Abstract. *1st order design optimization results of the geodetic network, developed for the purpose of surveying details in municipality of Bela Palanka are presented in the paper.A preliminary analysis of the accuracy and reliability of the 2D network of Bela Palanka-Varos was performed, and then observations were made on the quality of the network with regard to the results obtained by the optimization procedure.The data were processed in NetExpert 2.0. software.*

Key words: *1st order design, optimization, surveying, 2D network, accuracy,reliability*

1. Introduction

Cadastre Municipality of Bela Palanka - Varoš is located in the Pirot District, in the municipality of Bela Palanka. Reconnaissance, stabilization and determination of coordinates of a traverse network for the purpose of surveying details was realized.

Based on the measuring performed for the purpose of calculating the coordinates of the points of traverse network a 1st order optimization was carried out.

The idea was to optimize the network, and based on the results determine the quality of the network regarding the position of the network point, i.e. regarding the plan of observations in the network. A similar problem is described in [1].

2. Optimization in Designing of Geodetic Networks

Optimization is a science whose goal is to determine the "best" solutions to certain mathematically defined problems, which are often physical reality. "Optimum" = "best", which can mean "maximum" or "minimum" depending on the specific case, and both of

Received December 9, 2021 / Accepted February 10, 2022
Corresponding author: Nenad Ćirić
Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18106 Niš, Serbia
E-mail: geosone84bp@yahoo.com

these meanings are mathematically defined [2]. The application of optimization methods is widespread and reaches in almost all areas in which ways of obtaining numerical information have been developed (Science, Engineering, Mathematics, Economics, etc.).

2.1. Classification of the optimization method

Optimization of geodetic network design is classified within different orders (Table 1). The division into orders was performed with respect to the constant and free parameters of the functional and stochastic model, indirect equalization by the method of least squares.

The 0th order design - represents the selection of the optimal coordinate system for the parameters of geodetic networks. When the design matrix and the accuracy of the measured quantities *P* are known, a coffactor matrix of unknown parameters $Q_{\hat{x}}$ or vector of unknown parameters $\hat{x}$ is determined.

The 1st order design - lead to the solution of the optimum design of a geodetic network. For the known accuracy of the planned measuring defined in the form of a difficulty matrix and for the defined accuracy of the unknown parameters $Q_{\hat{x}}$, it is necessary to determine the optimal design, i.e. the optimal measurement plan in the geodetic network *A* (Table 1).

The 2nd order design - leads to the solution of optimal difficulty or accuracy of planned measuring in the network. These data are of great importance for the selection of optimal measurement methods and measuring instruments, because observation of different physical quantities can occur in the network.

The 3rd order design - enables optimal improvement of existing networks in terms of design and accuracy. This most often refers to making the network denser by additional observations or points in parts of the network where the accuracy or reliability is poor.

Table 1 Classification of the optimization method of geodetic networks [3]

Design	Constant parameters	Unknown parameters	Problem solution
0. order	A A	$\hat{x}$, $Q_{\hat{x}}\hat{x}, Q_{\hat{x}}$	Datum
1. order	P, $Q_{\hat{x}}P, Q_{\hat{x}}$	AA	Design
2. order	A, $Q_{\hat{x}}A, Q_{\hat{x}}$	PP	Accuracy
3. order	$Q_{\hat{x}}Q_{\hat{x}}$	$A, P\ A, P$	Quality improvement

Optimization methods are applied in the design of geodetic networks in order to obtain optimal, i.e. the best solutions for design implementation. The optimal geodetic network has high precision and reliability and is designed in accordance with economic conditions [4].

3. Quality of Geodetic Network

In the design process when optimization methods are applied, it is necessary to define the quality criteria of the geodetic network. The quality of a geodetic network usually means accuracy, reliability, sensitivity, economy or some special quality parameters depending on the purpose of the network. The criteria of accuracy of geodetic networks usually refer to the accuracy of points and functions. Global or local accuracy criteria can be defined. Reliability criteria of geodetic networks usually refer to internal and external reliability. Global or local reliability criteria can be defined. Sensitivity criteria of geodetic networks most often refer to the magnitudes of deformations that can be identified for a particular design of the deformation network and the planned accuracy of measuring [5].

3.1. Apriori analysis of accuracy of geodetic networks

In the process of designing geodetic networks, in order to obtain numerical values for the purpose of determining the apriori accuracy of the network, it is necessary to determine the design of the network and plan measuring in it. After the analysis of accuracy, it is necessary to compare the obtained accuracy with the defined accuracy in the design specification task. If the accuracy obtained from the apriori analysis is identical or better than the accuracy defined by the design specification, then it can be expected that even after the realization of the entire project, the network will be of adequate quality. Otherwise, if the accuracy requirements from the design specification are not met, changes in the network design, planned measurements or their accuracy are necessary.

If the designed network is of homogeneous positional accuracy, but the accuracy obtained from the apriori analysis is lower than the accuracy defined by the design specifications, then it is necessary to increase the accuracy of the planned measurements. The accuracy of planned measurements is increased by a larger number of measurements or better quality instruments and accessories are planned for measurements that are expected to meet the requirements of defined accuracy. If the designed network does not have a homogeneous positional accuracy, then changes in the measurement plan are necessary, usually by adding new measurements or changing the position of a certain number of points.

After the changes have been made in the design phase, it is necessary to repeat the apriori accuracy analysis and the procedure is repeated until the requirements from the design specifications are met. The procedure of the apriori accuracy analysis is described in [6].

3.2. Apriori analysis of geodetic networks reliability

As reliability indicates the possibility of observing gross errors or determining their impact on the estimates of unknown parameters, if no gross errors are observed, then it is very important to determine its reliability in the network design phase.

If poor reliability is obtained after the apriori analysis, then in order to achieve good reliability in the network, it is necessary to add new planned measurements of quantities and thus increase the number of redundant measured quantities. The best effect is achieved by closing the geometric figures in the geodetic network: triangle, quadrilateral or polygon.

After the change in the measurement plan, it is necessary to do the apriori analysis of accuracy and reliability again. The procedure is repeated until the criteria of accuracy and reliability are met. With adequate software, these calculations take only a few seconds of time. The procedure of the apriori analysis of reliability is described in .

4. OPTIMIZATION OF 2D NETWORK OF BELA PALANKA

4.1. Basic characteristics and position of the network of Bela Palanka - Varoš

The traverse network is located in the area of the cadastre Municipality of Bela Palanka - Varoš. In the geometric sense, the network is designed as a system of 10 closed polygons, interconnected into one whole (Fig. 1).

The traverse network is reconnoitered and stabilized according to the following rules:

- Lengths of individual traverses do not exceed 2 km,
- Traverses are such that the angles between the adjacent traverse sides are approximately 180˚,
- Lengths of traverse sides do not exceed 200 m.

Measurements in the traverse network were performed by total stations, which were previously tested and rectified if necessary. Angular measurement in traverse network were performed in both faces twice, independent of the linear measurement. The lengths of all traverse sides were measured with total stations from the both sides, in both faces, with millimeter accuracy.

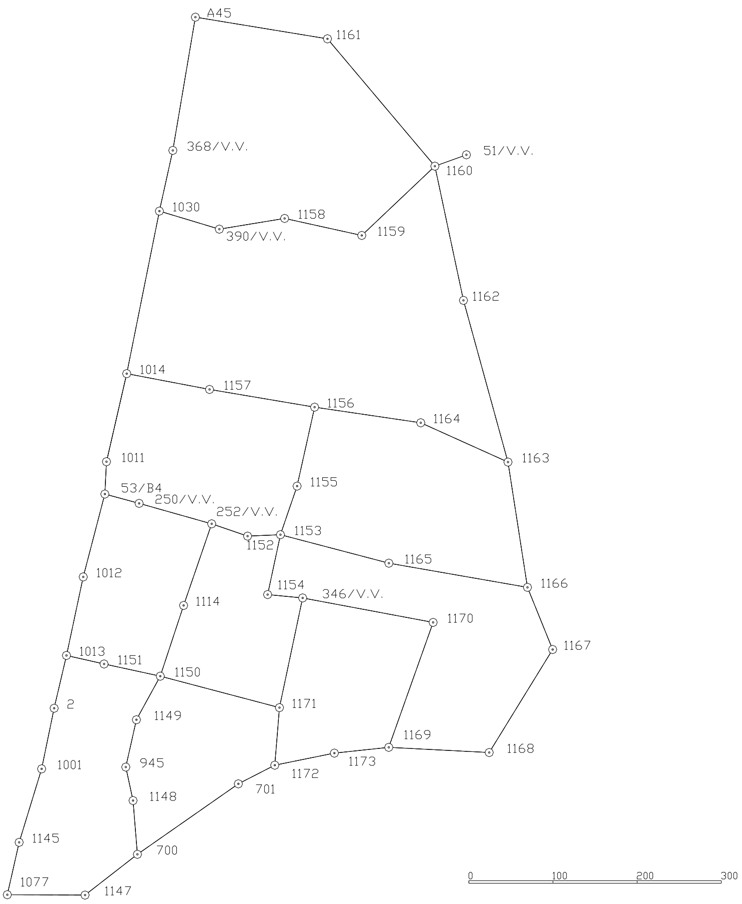

Fig. 1 Sketch of the traverse network of Bela Palanka - Varoš

Coordinates of traverse points were calculated based on the results of measuring horizontal angles (derived from the values of measured directions), the length of traverse sides in the National Coordinate System (obtained on the basis of mean values of measuring lengths back and forth and reduced to projection) and approximate coordinates of points.

4.2. 1st Order Optimization of 2D network of Bela Palanka - Varoš

As already mentioned, within the 1st order design optimization a prior analysis of accuracy and reliability of geodetic network is implemented [8]. It is necessary to determine the optimum design, i.e. optimum measurement plan in the geodetic network , for the known accuracy of the planned measuring defined in the form of the difficulty matrix and for the defined accuracy of unknown parameters $Q_{\hat{x}}$.

After determining the temporary values of coordinates, defining the plan of measured parameters and as well as the accuracy of measuring them in the network, a design matrix and covariant matrix of measured parameters K_l were determined.

Based on the matrix $K_{\hat{x}}$ elements, a complete prior analysis of accuracy of point and functions in a geodetic network was performed.

For the purpose of a prior analysis of a geodetic network, 2D equalization was performed. The data were processed in NetExpert 2.0. software. The network was equalized as free, whereby the total number of points is 48, the number of assigned points 0. In total, there was 171 measured parameters, 58 sides and 113 directions.

The solution was analyzed according to the following criteria:

- The ratio of the major and minor semi-axis of the error ellipse should be in the range of values:

$$1 \le A/B \le 2 \tag{1}$$

- Standard deviations of equalized measurements should be within the following range:

$$\sigma_d \le 5'' \tag{2}$$

$$\sigma_l \le 5mm + 5ppm \tag{3}$$

- Coefficients of internal and external reliability should be within tabular values, which, for the traverse network, are:

$$0.1 \le r_{ii} \le 0.1 \tag{4}$$

- Positional accuracy of traverse points, from the apriori analysis must be consistent with the accuracy defined as the given criterion:

$$\sigma_{pos} \le 15mm \tag{5}$$

- The accuracy of measured values, unknown parameters, position accuracy of the points and parameters of error ellipses are explained in [6] and [7].

4.3. Optimization results of the network of Bela Palanka - Varoš

Apriori analysis of the accuracy and reliability of point and functions in geodetic network has been carried. Table 2 gives data on the quality of the network of Bela Palanka - Varoš: the estimation of the accuracy of the coordinates of the geodetic network, ratio of semi-axes of the standard error ellipses, the estimation of the accuracy of measured values. The obtained coefficients of internal and external reliability are in the range with the values obtained empirically and which are recommended in designing of geodetic networks.

Table2 Data on the quality of the traverse network Bela Palanka - Varoš

	min	max	average
s(direction)	4,19	5	4,59
s(linear)	3,7	5,7	4,7
s_Y	3,2	7,6	4,8
s_X	3,4	8,1	5,2
s_{pos}	4,8	11,1	7,2
A/B	1,03	1,88	1,29

Figure 2 shows the ellipses of standard errors of the traverse network Bela Palanka -Varoš.

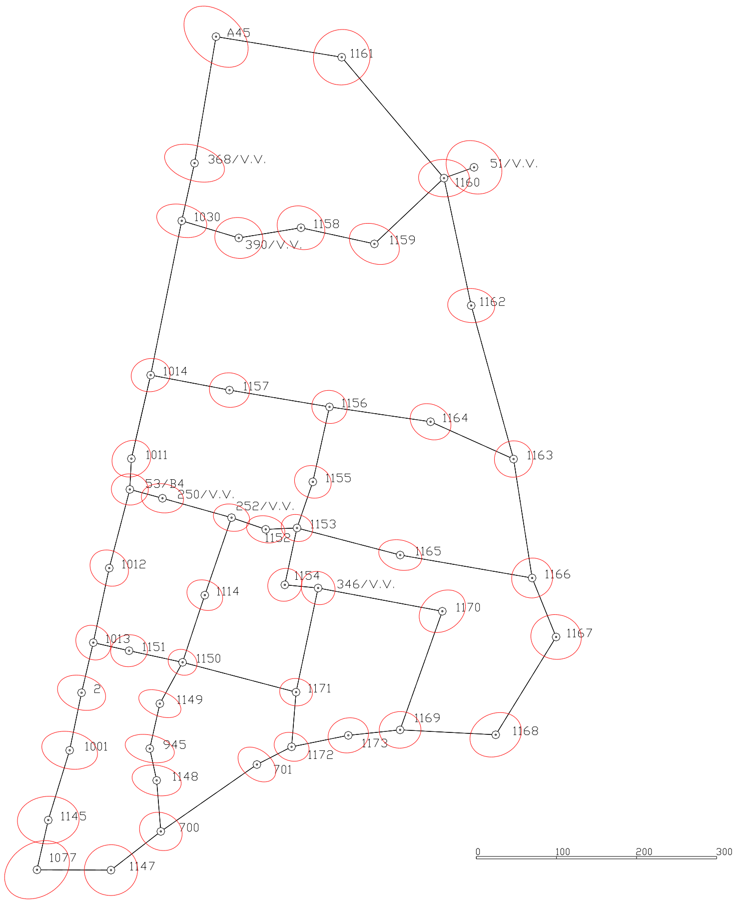

Fig. 2 Standard error ellipses of the network of Bela Palanka - Varoš

4. CONCLUSION

The quality of the existing geodetic network on the territory of the cadastral municipality of Bela Palanka - Varoš was analyzed. Based on the results obtained by the preceding analysis of accuracy and reliability, the following was concluded:

- The network is homogeneous. The ratio of the major and minor semi-axis of the error ellipse is in the defined range of values ($1 \leq A/B \leq 2$).
- The obtained positional accuracy from the preceding analysis of the traverse points agrees with the accuracy which was defined by the design specifications ($\sigma_{pos} \leq 15mm$).
- Standard deviations of measured values are in the defined range ($\sigma_d \leq 5''$ and $\sigma_l \leq 5mm + 5ppm$).
- The obtained coefficients of internal and external reliability are in the range with the values obtained empirically and which are recommended in designing of geodetic networks.

Therefore, by 1st order optimization of the traverse network of Bela Palanka - Varoš, it can be concluded that the network serves its function in terms of the position of points of the geodetic network and measurement plan in it, i.e. that the network has an optimal design.

REFERENCES

1. G. Marinković, T. Kuzmić and M. Trifković, Optimization of geodetic network for the restoration of surveying in cm Vojvoda Stepa, Journal of facultaty of civil engineering, vol. 33, pp. 85-100, 2018.
2. S. Opricović, Sistem optimization, Faculty of Civil Engineering, Belgrade, 1992.
3. G. Schmitt, Optimization of geodetic networks, Rev. Geophys. Sp. Phys., vol. 20, no. 4, pp. 877-884, 1982.
4. M. Eshagh and M. A. Alizadeh-Khameneh, The effect of constraints on bi-objective optimisation of geodetic networks, Acta Geod Geophys, vol. 50, no. 4, pp. 449-459, 2015.
5. S. Radojčić, Koncept pouzdanosti geodetskih mreža, Vojnoteh. Glas., vol. 2, pp. 179-187, 2010.
6. K. Mihailović andI. Aleksić, Concepts of networks in a geodetic survey, Geokarta d.o.o., Belgrade, 2008.
7. W. F. Caspary, Concepts of network and deformation analysis, Sydney, Australia: Monograph 11, School of Surveying, The University of New South Wales, 2000.
8. I. Aleksić, Lecture on PhD studies, Belgrade, 2010.
9. S. Opricović, Multicriteria system optimization in Civil Engineering, Faculty of Civil Engineering, Belgrade, 1998.
10. A.R. Amiri-Simkooei, J. Asgari, F. Zangeneh-Nejad and S. Zaminpardaz, Basic Concepts of Optimization and Design of Gedetic Networks, Journal of Surveying Engineering, vol. 138, issue 4, pp. 172-183, November 2012.

OPTIMIZACIJA 1. REDA POLIGONSKE MREŽE BELA PALANKA

U radu su predstavljeni rezultati optimizacije dizajna prvog reda, geodetske mreže razvijene za potrebe snimanja detalja na području opštine Bela Palanka. Urađena je prethodna analiza tačnosti i pouzdanosti 2D mreže Bela Palanka - Varoš a zatim su data zapažanja o kvalitetu mreže s obzirom na rezultate dobijene optimizacionim postupkom.Podaci su obrađeni u programu NetExpert 2.0.

Ključne reči: *dizajn prvog reda, optimizacija, snimanje, 2D mreža, tačnost, pouzdanost*