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ANALYSIS ON THE EXPECTED AND REAL QUALITY OF THE HORIZONTAL STAKEOUT

ANALIZA OČEKIVANE I STVARNE KVALITETE HORIZONTALNOG ISKOLČENJA

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ABSTRACT

Horizontal stakeout is a frequently applied geodetic operation. Prior to performing stakeout tasks within surveying projects, it is essential to analyze the expected outcomes of different horizontal stakeout methods. In this study, the prediction of stakeout quality was carried out by computing expected error ellipses for each point intended for stakeout, based on their known project coordinates. The expected error ellipses were derived using stakeout geometry and measurement elements. After all points were staked out, their coordinates were determined through geodetic measurements. This paper presents an analysis of the expected and achieved error ellipses for every point of a residential building project. The expected error ellipses were calculated for two stakeout methods—the polar method and the intersection of the sight lines —after which the results were compared and evaluated.

Keywords: stakeout methods, error ellipses, prediction of quality

SAŽETAK

Horizontalno iskolčenje predstavlja često primjenjivanu geodetsku operaciju. Prije izvođenja zadataka iskolčenja u okviru geodetskih projekata, neophodno je analizirati očekivane rezultate različitih metoda horizontalnog iskolčenja. U ovoj studiji, predikcija kvalitete iskolčenja izvršena je pomoću očekivanih elipsi grešaka za svaku tačku predviđenu za iskolčenje, na osnovu njihovih poznatih projektnih koordinata. Očekivane elipse grešaka dobivene su korištenjem geometrije iskolčenja i mjernih elemenata. Nakon što su sve tačke iskolčene, njihove koordinate određene su geodetskim mjerenjima. U ovom radu prikazana je analiza očekivanih i ostvarenih elipsi grešaka za svaku tačku stambenog objekta. Očekivane elipse grešaka izračunate su za dvije metode iskolčenja — polarnu metodu i metodu presjeka pravaca — nakon čega su rezultati upoređeni i evaluirani

Ključne riječi: metode iskolćenja, elipse grešaka, predikcija kvalitete

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1 INTRODUCTION

Stakeout is a very important geodetic operation during the construction of structures of various types and purposes: residential buildings, business buildings, tunnels, viaducts, roads, etc (Pašalić, 1995; Frankić, 2011). Before starting to build a structure, it is necessary to transfer the geometry of the designed structure to the site where the building will take place (Goršič, Breznikar and Savšek Safić, 2006). During the realization of various engineering structures, there are two groups of geodetic points. The first group consisted of the control network points, whose quality should be such as to ensure the required quality of setting-out. The geometry of the geodetic network depends on the terrain configuration (Hamza et al. 2020) and the location of the designed structure that is to be transferred to the site. In this study, the points of the geodetic network are used for the horizontal stakeout of points of a residential building. These points, defined by the coordinates of the designed building, are belonging to the second group. Setout points are defined by the project and their location in the field is defined by applying an adequate stakeout method. Before the horizontal stakeout of points, it is necessary to determine the quality of the stakeout. The issue of construction stakeout surveys has been investigated very thoroughly in several studies (Baykal et al. 2005; Pirti, 2007; Liu and Yao, 2007; Kala, 2009; Paar et al. 2011; Dąbrowski, 2014; Tuno et al. 2018, etc).

In this paper, two methods of horizontal stakeout were analyzed, using the geodetic network established for residential building construction. The aim was to investigate how the choice of different stakeout methods influences stakeout quality. The quality of the stakeout is analyzed through absolute error ellipses, wherein the stakeout points lie.

2 ESTABLISHMENT OF THE GEODETIC NETWORK

Before horizontal or vertical stakeout, it is necessary to establish a geodetic network. The realization of geodetic control networks is one of the most important tasks for surveying engineers. For this research, a pilot micro-triangulation network was established on the site (Figure 1). The establishment of the control network was carried out in three phases: design, execution and analysis (Pešto and Đidelija, 2018). There are five points in this network, which are forming the three triangles (Figure 1). Due to the terrain configuration, construction and high vegetation, the optimal geometric configuration of the geodetic network was achieved. Work on the network measurements began after the stabilization of points was completed. Measurements in the network were realized by total station Trimble S7. The declared instrument precision is $s_{Hz,V}$ = 1" for angle measurement and s_D = 1 mm; 2 ppm for distance measurement (Ćatić et al., 2022). Before measurements started, testing of the instrument as tachymeter for determining positions of points was done according to the ISO standard 17123-5. Test results confirmed the declared precision by the manufacturer. Measurements in the network involved the measurements of the horizontal directions and slope distances between all points. Analysis of the geodetic network included the correction and reduction of field measurements, detection and removal of gross and systematic errors, adjustment of a geodetic network by the least squares method (parametric model), statistical testing of estimated measurement residuals, and analysis of the quality of the obtained results.

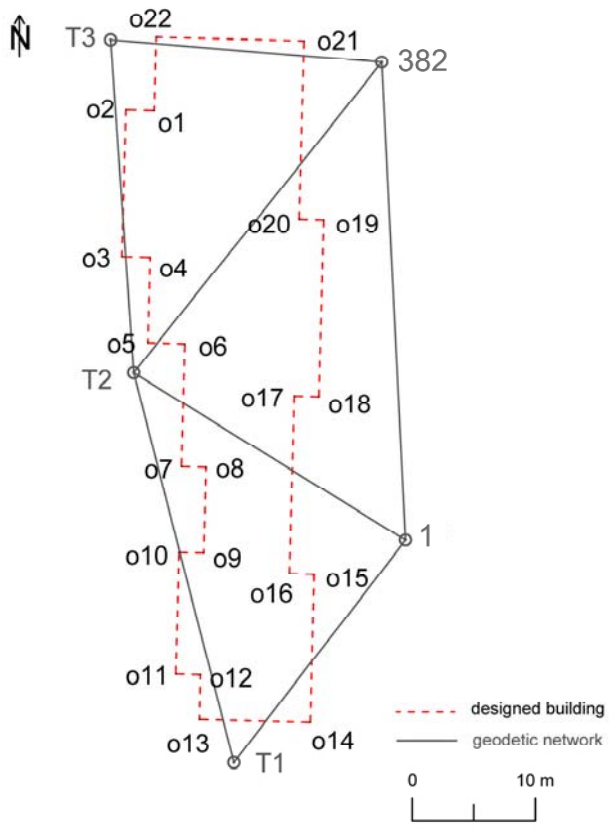

Figure 1. The micro-triangulation network and the designed residential building.

Before the least squares adjustment, all gross errors were identified and removed from the measurements by procedures described in the relevant literature, i.e. (Marjetič et.al., 2012; Soldo and Ambrožič, 2018; Ambrožič et al., 2019). The results of the adjustment are coordinates of all residential building points and their error ellipses. Complete information about the quality of the position of the points of the network is presented by the a-posteriori error ellipses (Mulahusić et al., 2017).

3 STAKEOUT AND ERROR ELLIPSES

Transferring the designed geometry of the structures on site is defined as staking (setting or laying) and is done in horizontal and vertical planes (Tuno et al., 2018). This research will examine two methods of horizontal setting:

(1) horizontal stakeout by the method of the intersection of the sight lines and
(2) horizontal stakeout by the polar method.

The stakeout by the intersection the sight lines is a method that uses two horizontal angles whereas the polar stakeout method uses a horizontal angle and horizontal distance (Figure 2). Using the coordinates of the local trigonometric network and the designed coordinates of the residential

building, all stakeout elements were calculated for both methods.

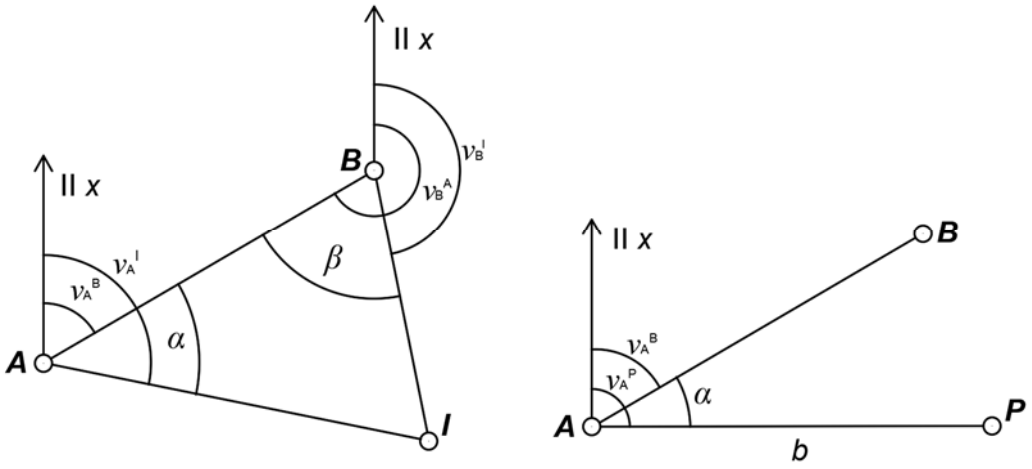

Figure 2. Setting out by the intersection of the sight lines (left) and the polar method (right).

To calculate the horizontal stakeout quality for the intersection method, it is necessary to start from the equation for calculating the coordinates of points using the method of the intersection:

$$y_I = y_A + \Delta y = y_A + \overline{AI}\sin \nu_A^I = y_A + \overline{AB}\frac{\sin\beta}{\sin(\alpha+\beta)}\sin(\nu_A^B + \alpha), \tag{1}$$

$$x_I = x_A + \Delta x = x_A + \overline{AI}\cos \nu_A^I = x_A + \overline{AB}\frac{\sin\beta}{\sin(\alpha+\beta)}\cos(\nu_A^B + \alpha), \tag{2}$$

or for control:

$$y_I = y_B + \Delta y = y_B + \overline{BI}\sin \nu_B^I = y_B + \overline{AB}\frac{\sin\alpha}{\sin(\alpha+\beta)}\sin(\nu_B^A - \beta), \tag{3}$$

$$x_I = x_B + \Delta x = x_B + \overline{BI}\cos \nu_B^I = x_B + \overline{AB}\frac{\sin\alpha}{\sin(\alpha+\beta)}\cos(\nu_B^A - \beta), \tag{4}$$

where:

$\frac{\overline{AI}}{\overline{AB}} = \frac{\sin\beta}{\sin(180° - (\alpha+\beta))} = \frac{\sin\beta}{\sin(\alpha+\beta)}$ … the Law of sines for triangle ABC,

$\frac{\overline{BI}}{\overline{AB}} = \frac{\sin\alpha}{\sin(180° - (\alpha+\beta))} = \frac{\sin\alpha}{\sin(\alpha+\beta)}$ … the Law of sines for triangle ABC,

$\nu_A^I = \nu_A^B + \alpha$ and $\nu_B^I = \nu_B^A - \beta$ … as seen in Figure 2.

By applying the Law of propagation of variances and covariances, the precision of determining the y-coordinate of point I, σ_{y_I}, and the x-coordinate of point I, σ_{x_I}, is obtained:

$$\sigma_{y_I} = \sqrt{\overline{AB}^2\left(\frac{\cos(2\beta - \nu_A^B) - \cos\nu_A^B}{\cos(2\alpha+2\beta)-1}\right)^2\sigma_\alpha^2 + \overline{AB}^2\left(\frac{\cos\nu_A^B - \cos(2\alpha+\nu_A^B)}{\cos(2\alpha+2\beta)-1}\right)^2\sigma_\beta^2}, \tag{5}$$

$$\sigma_{x_I} = \sqrt{\overline{AB}^2\left(\frac{\sin(2\beta - \nu_A^B) + \sin\nu_A^B}{\cos(2\alpha+2\beta)-1}\right)^2\sigma_\alpha^2 + \overline{AB}^2\left(\frac{\sin(2\alpha+\nu_A^B) - \sin\nu_A^B}{\cos(2\alpha+2\beta)-1}\right)^2\sigma_\beta^2}, \tag{6}$$

or for control:

$$\sigma_{y_I} = \sqrt{\overline{AB}^2 \left(\frac{\cos(2\beta - \nu_B^A) - \cos\nu_B^A}{\cos(2\alpha + 2\beta) - 1}\right)^2 \sigma_\alpha^2 + \overline{AB}^2 \left(\frac{\cos\nu_B^A - \cos(2\alpha + \nu_B^A)}{\cos(2\alpha + 2\beta) - 1}\right)^2 \sigma_\beta^2}, \tag{7}$$

$$\sigma_{x_I} = \sqrt{\overline{AB}^2 \left(\frac{\sin(2\beta - \nu_B^A) + \sin\nu_B^A}{\cos(2\alpha + 2\beta) - 1}\right)^2 \sigma_\alpha^2 + \overline{AB}^2 \left(\frac{\sin(2\alpha + \nu_B^A) - \sin\nu_B^A}{\cos(2\alpha + 2\beta) - 1}\right)^2 \sigma_\beta^2}, \tag{8}$$

where:

σ_α and σ_β … the standard deviations of angles α and β.

In order to compute the error ellipse of the stakeout, the covariance must also be determined σ_{yx_I}:

$$\sigma_{yx_I} = -\frac{\overline{AB}^2\left\{[\sin(2\nu_A^B)+2\sin(2\beta-2\nu_A^B)-\sin(4\beta-2\nu_A^B)]\sigma_\alpha^2+[\sin(2\nu_A^B)-2\sin(2\alpha+2\nu_A^B)+\sin(4\alpha+2\nu_A^B)]\sigma_\beta^2\right\}}{\cos(4\alpha+4\beta)-4\cos(2\alpha+2\beta)+3}, \tag{9}$$

or for control:

$$\sigma_{yx_I} = -\frac{\overline{AB}^2\left\{[\sin(2\nu_B^A)+2\sin(2\beta-2\nu_B^A)-\sin(4\beta-2\nu_B^A)]\sigma_\alpha^2+[\sin(2\nu_B^A)-2\sin(2\alpha+2\nu_B^A)+\sin(4\alpha+2\nu_B^A)]\sigma_\beta^2\right\}}{\cos(4\alpha+4\beta)-4\cos(2\alpha+2\beta)+3}. \tag{10}$$

To calculate the horizontal stakeout quality using the polar method, it is necessary to start from the equation for calculating the coordinates of points using the polar method:

$$y_P = y_A + \Delta y = y_A + \overline{AP}\sin\nu_A^P = y_A + \overline{AP}\sin(\nu_A^B + \alpha), \tag{11}$$

$$x_P = x_A + \Delta x = x_A + \overline{AP}\cos\nu_A^P = x_A + \overline{AP}\cos(\nu_A^B + \alpha), \tag{12}$$

or for control:

$$y_P = y_B + \Delta y = y_B + \overline{BP}\sin\nu_B^P = y_B + \overline{BP}\sin(\nu_B^A - \beta), \tag{13}$$

$$x_P = x_B + \Delta x = x_B + \overline{BP}\cos\nu_B^P = x_B + \overline{BP}\cos(\nu_B^A - \beta), \tag{14}$$

where:

$\nu_A^P = \nu_A^B + \alpha$ and $\nu_B^P = \nu_B^A - \beta$ … as seen in Figure 2.

By applying the Law of propagation of variances and covariances, the precision of determining the y-coordinate of point P, σ_{y_P}, and the x-coordinate of point P, σ_{x_P}, is obtained:

$$\sigma_{y_P} = \sqrt{\sin^2(\alpha + \nu_A^B)\,\sigma_{\overline{AP}}^2 + \overline{AP}^2\cos^2(\alpha + \nu_A^B)\sigma_\alpha^2}, \tag{15}$$

$$\sigma_{x_P} = \sqrt{\cos^2(\alpha + \nu_A^B)\,\sigma_{\overline{AP}}^2 + \overline{AP}^2\sin^2(\alpha + \nu_A^B)\sigma_\alpha^2}, \tag{16}$$

$\sigma_{\overline{AP}}$ … the standard deviation of distance $\overline{AP}$.

If the Law of propagation of variances and covariances is applied to the control equations (13-14):

$$\sigma_{y_P} = \sqrt{\sin^2(\beta - \nu_B^A)\,\sigma_{\overline{BP}}^2 + \overline{BP}^2\cos^2(\beta - \nu_B^A)\sigma_\beta^2}, \tag{17}$$

$$\sigma_{x_P} = \sqrt{\cos^2(\beta - \nu_B^A)\,\sigma_{\overline{BP}}^2 + \overline{BP}^2 \sin^2(\beta - \nu_B^A)\sigma_\beta^2}, \tag{18}$$

$\sigma_{\overline{BP}}$ … the standard deviation of distance $\overline{BP}$,

the same precisions for determining the y-coordinate of point P, σ_{y_P}, and the x-coordinate of point P, σ_{x_P}, would not be calculated, since all the quantities involved in the equations for calculating point coordinates by the polar method and the control calculation are different. The same precisions for determining the y-coordinate of point P, σ_{y_P}, and the x-coordinate of point P, σ_{x_P}, would be obtained only if the stakeout were performed from the same point (for example, point A), while the orientation point would be different.

In order to compute the error ellipse of the stakeout, the covariance must also be determined σ_{yx_I}:

$$\sigma_{yx_I} = \sin(\alpha + \nu_A^B)\cos(\alpha + \nu_A^B)\,\sigma_{\overline{AP}}^2 - \overline{AP}^2 \sin(\alpha + \nu_A^B)\cos(\alpha + \nu_A^B)\,\sigma_\alpha^2. \tag{19}$$

If the Law of propagation of variances and covariances is applied to the control equations (13-14):

$$\sigma_{yx_I} = -\sin(\beta - \nu_B^A)\cos(\beta - \nu_B^A)\,\sigma_{\overline{BP}}^2 + \overline{BP}^2 \sin(\beta - \nu_B^A)\cos(\beta - \nu_B^A)\,\sigma_\beta^2, \tag{20}$$

the same covariance would not be calculated as with equation (19) – see the comment below equation (18).

The analysis of the stakeout quality in this study is performed based on the calculated error ellipses of the stakeout. An error ellipse is a convenient way of expressing the uncertainty of the position of a point in a graphical format (Figure 3) (Schofield and Breach, 2007). The error ellipses were calculated before stakeout and after stakeout for every point of the residential building according to the following equations:

$$a = \sigma_0 \sqrt{\frac{\sigma_y^2 + \sigma_x^2 + z}{2}}, \tag{21}$$

$$b = \sigma_0 \sqrt{\frac{\sigma_y^2 + \sigma_x^2 - z}{2}}, \tag{22}$$

$$\Theta = \frac{1}{2}\operatorname{atan}\frac{2\sigma_{yx}}{\sigma_x^2 - \sigma_y^2}, \tag{23}$$

where:

σ_0 … the a priori reference standard deviation (typically equal to 1),

$$z = \sqrt{\left(\sigma_x^2 - \sigma_y^2\right)^2 + 4\sigma_{yx}^2}.$$

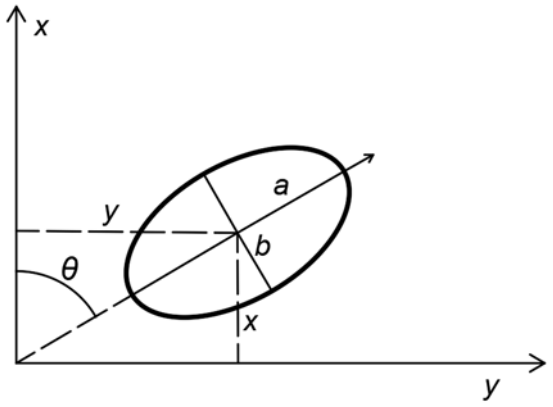

Figure 3. Error ellipse elements.

There were 22 points for the horizontal stakeout (Figure 1). To express the uncertainty of the two-dimensional position of stakeout points before the setting-out process, the predicted error ellipses with an appropriate level of confidence were used. The stakeout using the line-of-sight intersection method was carried out with two Leica Geosystems TC605L instruments which has a declared precision of 5" for angle measurements (Tuno et al., 2010). The polar stakeout was performed with a Trimble S7 total station ($s_{Hz,\,V}$ = 1″ for angles; s_D = 1 mm; 1.5 ppm for slope distances) (Ćatić et al., 2022).

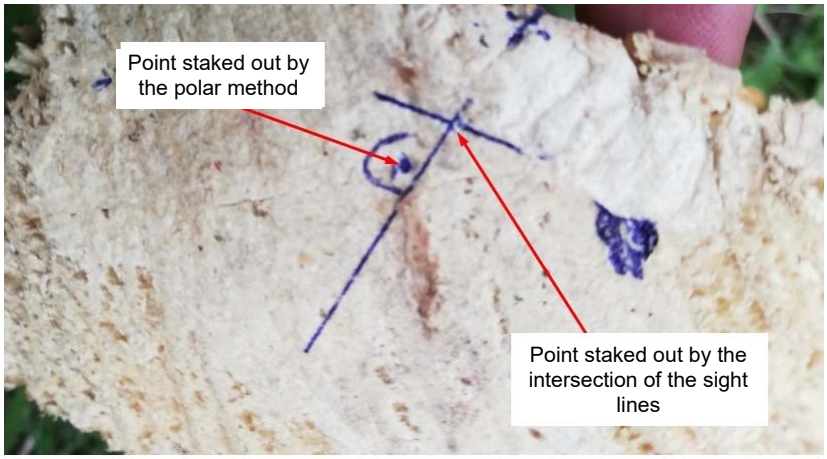

Figure 4. Staked out points on the top of the wooden stake

After the setting-out, every point of the residential building was marked on the ground by a wooden stake. The definitive position of the point was marked on the top of the stake using a pencil. When the process of stakeout was finished it was obvious that the marked positions of points on each wooden stake, that resulted from the two methods of setting-out, are different (Figure 4). All marked points on the stakes were measured from at least three points of the geodetic control network. The points staked out by the polar method and the points staked out by the intersection method were measured separately. Angles and distances were measured using a Trimble S7 electronic tachymeter and a mini prism Leica Geosystems GPM111 (Figure 5).

Figure 5. Mini prism Leica Geosystems GPM111

4 ANALYSIS OF THE RESULTS OBTAINED BY TWO METHODS OF STAKEOUT

First, an a-priori assessment of the quality of determining the stakeout coordinates was carried out using the intersection method and the polar method. Table 1 shows the quality indicators of the stakeout points using the intersection method, calculated according to equations 5–10 and 21–22, for the following pairs of instrument setups: 1 and 382, 1 and T1, 382 and T2, and 382 and T3.

Table 1
Indicators of apriori stakeout quality using the intersection method

Standard error ellipse	**Station 1 and 382**		**Station 1 and T1**		**Station 382 and T2**		**Station 382 and T3**	
Semi-axis of the error ellipse	a	b	a	b	a	b	a	b
Maximum [mm]	3.8	0.6	6.5	0.9	3.8	0.7	3.7	0.8
Minimum [mm]	0.7	0.2	0.4	0.1	0.5	0.0	0.4	0.1
Average[mm]	1.3	0.4	2.0	0.4	1.6	0.4	1.6	0.5

The average value of the semi-major axis of the standard error ellipse is in all cases at least three times greater than the semi-minor axis, indicating inhomogeneous quality in the direction of the coordinate axes. It should be noted that the calculated ellipse is not included in Table 1 for the case where the instrument stations were 382 and T3, and the stakeout point was o22, since for this point the calculated values were a = 80.2 mm and b = 0.1 mm. This is an expected result, as $\alpha = 0° 3' 37.6''$ and $\beta = 0° 12' 9.5''$ (the angle at point o22 is $179° 44' 12.9''$), which represents a very unfavorable intersection.

Table 2 shows the quality indicators of the stakeout points using the polar method, calculated according to equations 15–16 and 19, and 21–22, for the following pairs of instrument stations – orientation: 1 – 382, 382 – 1, T1 – 1, T2 – 382, and T3 – 382.

Table 2
Indicators of apriori stakeout quality using the polar method

Standard error ellipse	**Station 1 and 382**		**Station 382 and 1**		**Station T1 and 1**		**Station T2 and 382**		**Station T3 and 382**	
Semi-axis of the error ellipse	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Maximum [mm]	1.0	0.2	1.1	0.3	1.1	0.3	1.0	0.2	1.1	0.3
Minimum [mm]	1.0	0.0	1.1	0.0	1.1	0.0	1.0	0.0	1.1	0.0
Average[mm]	1.0	0.1	1.1	0.2	1.1	0.1	1.0	0.1	1.1	0.2

Even in the case of the polar staking method, the inhomogeneous quality of the standard error ellipses is noticeable. Better *apriori* staking quality is achieved, which may be a consequence of the more precise instrument used.

From Tables 1 and 2, it is evident that the quality of determining the stakeout coordinates depends on the geometry of the station and the stakeout point.

After all field and office procedures were completed, three sets of point coordinates were obtained: project coordinates of the residential building (y_{Di}, x_{Di}), adjusted coordinates of points staked out by the polar method (y_{Pi}, x_{Pi}) and adjusted coordinates of points staked out by the method of intersection (y_{Ii}, x_{Ii}). Also, three sets of error ellipses were obtained: expected error ellipses for stakeout by the polar method and by the intersection of the sight lines and error ellipses obtained after a stakeout, by adjustment.

The differences between project coordinates and adjusted coordinates obtained after the stakeout were analyzed first.

Figure 6 shows the differences between project coordinates and adjusted coordinates along the *y*- and *x*-axes: $\Delta y_{Pi} = y_{Di} - y_{Pi}$, $\Delta x_{Pi} = x_{Di} - x_{Pi}$ (i.e. the coordinates defined by the project and adjusted coordinates obtained after stakeout by the polar method). It can be seen that differences in *x* coordinates are mostly positive except for points o1, o2, o3, o5, o9, o10 and o22, whose differences are negative. The values of differences of *x* coordinates are in the interval from -6 to 8 mm. Maximum difference of *x* coordinates is 8 mm. The values of differences of *y* coordinates are in the interval from -8 to +6 mm. The maximum difference for *y* coordinates is 8 mm, while the maximum positional deviation $d_{yx} = \sqrt{d_y^2 + d_x^2}$ is 10 mm.

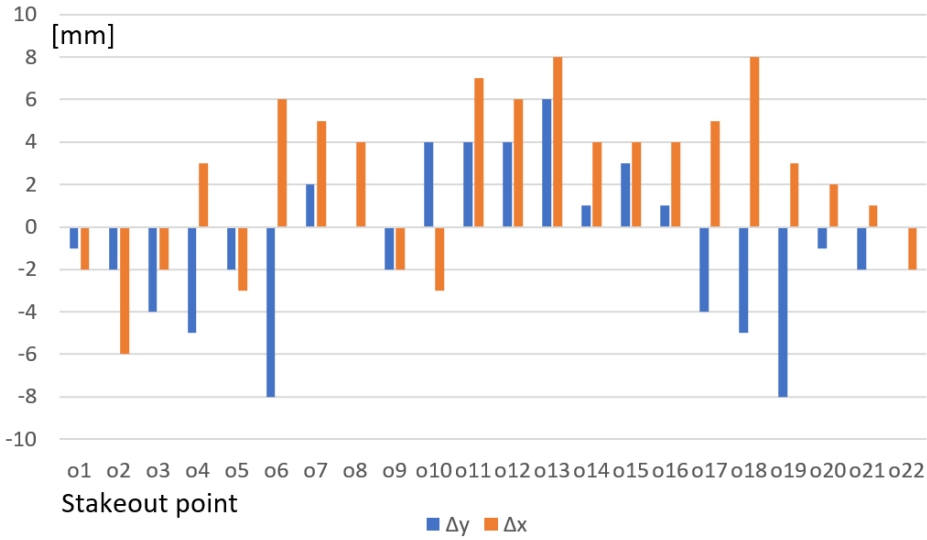

Figure 6. The differences between project coordinates and adjusted coordinates obtained after stakeout by the polar method

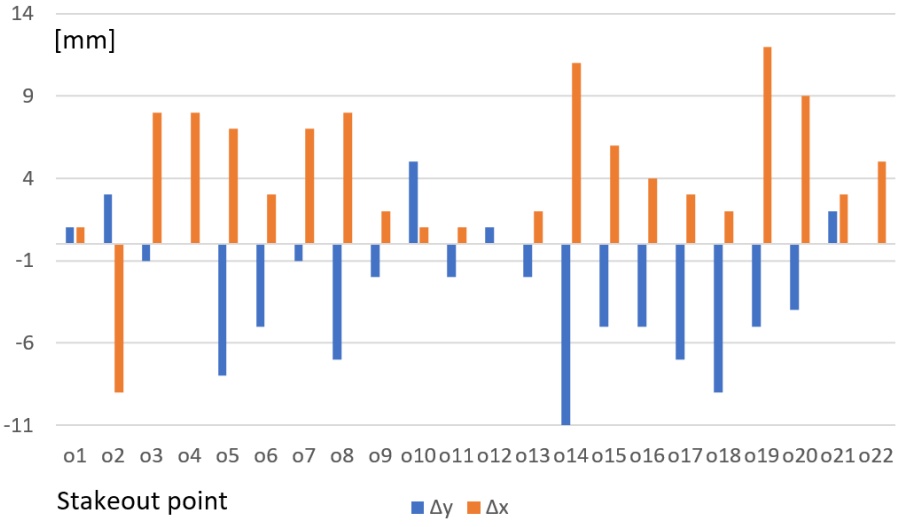

Figure 7. The differences between project coordinates and adjusted coordinates obtained after stakeout by the intersection method.

Figure 7 shows the differences between project coordinates and adjusted coordinates along the *y*- and *x*-axes: $\Delta y_{Ii} = y_{Di} - y_{Ii}$, $\Delta x_{Pi} = x_{Di} - x_{Ii}$ (i.e. the coordinates defined by the project and adjusted coordinates obtained after stakeout by the intersection method). It can be seen that differences of *x* coordinate are positive except for point o2 whose difference is negative. The maximum difference between *x* coordinates is 12 mm, while the maximum difference between *y* coordinates is 11 mm. The maximum positional deviation amounts to 16 mm in this case.

Three sets of error ellipses are shown in Figure 8, while the main statistical indicators are shown

in Table 3. After adjustment, the obtained staking-quality parameters indicate a balanced positional strength for the residential building points. However, the predicted quality is influenced by the configuration of the selected geodetic-network control points and the methodology applied during the stakeout. The average area of the error ellipse that resulted from the adjustment is 12 mm^2, while the average areas of the predicted ellipses for the polar stakeout and stakeout by intersection are 1 mm^2 and 2 mm^2.

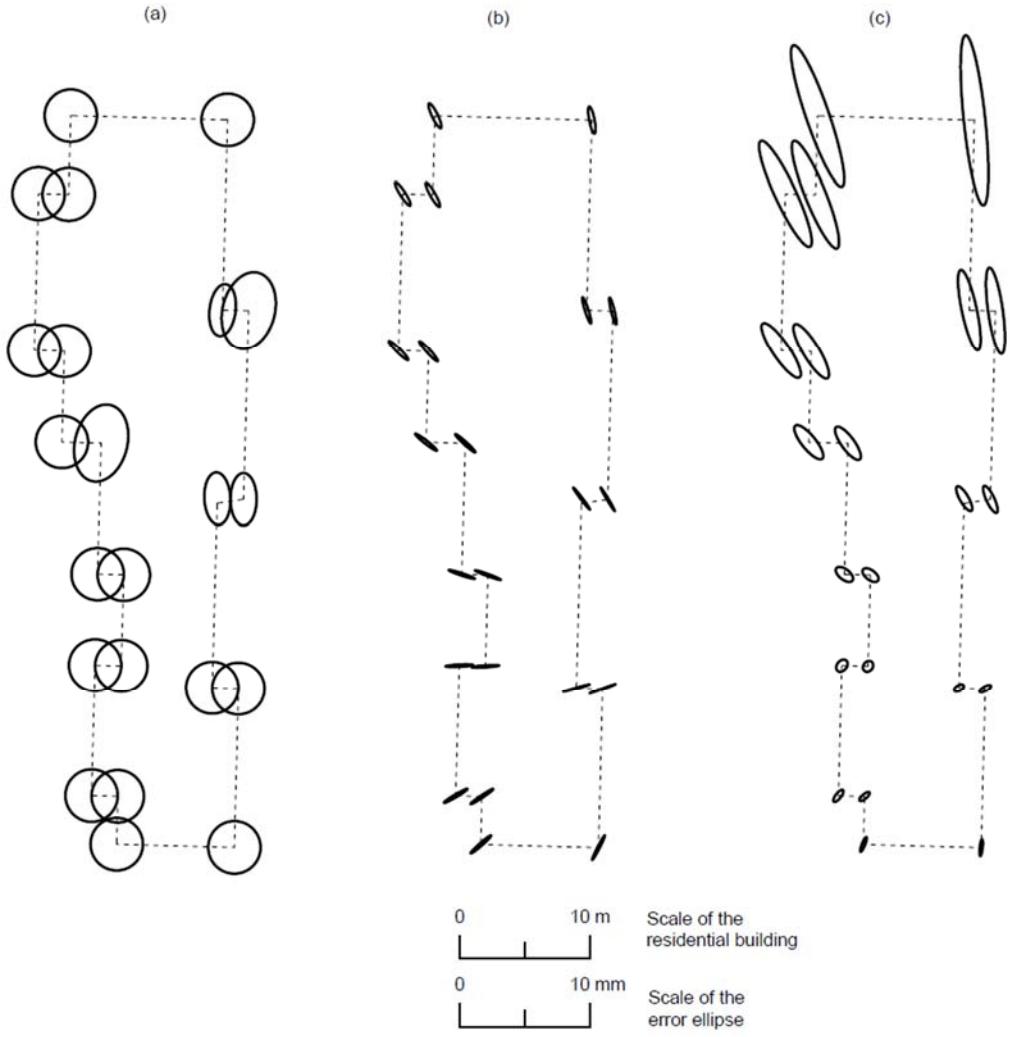

Figure 8. (a) error ellipses obtained after a stakeout by adjustment, (b) expected error ellipses for stakeout by the polar method (instrument station 1 – orientation T1) and (c) expected error ellipses for stakeout by the intersection of the sight lines (instrument setups 1 and T1)

Table 3
Indicators of the predicted and real stakeout quality

Standard error ellipse	Adjustment		Predicted (polar method)		Predicted (intersection method)	
Semi-axis of the error ellipse	a	b	a	b	a	b
Maximum [mm]	3.0	2.0	1.1	0.3	4.5	0.8
Minimum [mm]	2.0	1.0	1.1	0.0	0.5	0.1
Average[mm]	2.1	1.9	1.1	0.1	1.6	0.4

5 CONCLUSION

Stakeout is a very important process during the realization of many projects. For that reason, geodetic experts have to carefully analyze each project they are involved in. In that sense, it is very important to determine the quality of stakeout. Then it is possible, based on the characteristic of the surveying instruments and based on the quality of the geodetic control network, to determine a predicted quality for every point that have to be staked out. Prediction of staking quality can be realized by calculating the expected error ellipses. The input parameters for the calculation of expected error ellipses are staking elements (calculated from the coordinates of the designed structure and coordinates of geodetic control points) and the quality of the geodetic instruments that will be used for the setting-out. This paper aimed to investigate the quality of predicting positional stakeout, based on the expected (a priori) error ellipses and a posteriori error ellipse obtained after stakeout. Different methods of stakeout and different geodetic instruments were considered. The geodetic instrument used for the stakeout by the polar method is Trimble S7 total station, while the Leica TC605L total station was used for the stakeout by the intersection of the sight lines. After the stakeout process, the coordinates for all points marked in the field were calculated by the parametric method of adjustment.

Obtained results of stakeout based on two different methods are not much different. The method of a stakeout by the intersection of the sight lines is more precise than the polar method of stakeout if instruments of the same precision are used. In this research, a more precise instrument was used for the polar method than instruments for the staking by the intersection of the sight lines. The choice of the stakeout method is very important, but many factors have to be considered. Generally, a geodetic expert must analyze the characteristics of available geodetic instruments, the quality of geodetic networks and the financial component of his work.

The results of this study show the consistency of the a priori and a posteriori error ellipsis. Also, the differences between the coordinates defined by the project and the adjusted coordinates obtained after the stakeout are within the expected limits. Although for the realization of the method by the intersection of the sight lines an instrument of lower quality was used, the final results are practically the same as in the case of the polar method, where the more precise instrument was used. Still, it should be emphasized that the polar method of stakeout requires one geodetic instrument and one or two men (depending on whether the total station is operated remotely or not), while the stakeout by the intersection of the sight lines requires two instruments and a minimum of three men.

References

Ambrožič, T., Mulahusić, A., Tuno, N., Topoljak, J., Hajdar, A., Kogoj, D. (2019). Deformacijska analiza v geodetskih mrežah z robustnimi metodami. *Geodetski vestnik*, *63(2),* 163-178. https://doi.org/10.15292/geodetski-vestnik.2019.02.163-178

Baykal, O., Tari, E., Coşkun, M., Erden, T. (2005). Accuracy of Point Layout with Polar Coordinates. *Journal of Surveying Engineering, 131(3),* 87-93. https://doi.org/10.1061/(ASCE)0733-9453(2005)131:3(87)

Ćatić, J., Tuno, N., Mulahusić, A., Topoljak, J., Đidelija, M., Kogoj, D. (2022). Impact of Rover Pole Holding on the Positioning Accuracy of RTK-GNSS. *Journal of Surveying Engineering*, *148(4),* 05022003. https://doi.org/10.1061/(ASCE)SU.1943-5428.0000404

Dąbrowski, J. (2014). Optimization of setting out controls in aspect of stakeout accuracy of engineering objects. *Geomatics and Environmental Engineering, 8(3),* 27-40. https://doi.org/10.7494/geom.2014.8.3.27

Frankić, K. (2011). *Inženjerska geodezija* (unpublished manuscript). Sarajevo: Univerzitet u Sarajevu – Građevinski fakultet.

Liu, C. Yao, L. (2007). RTK GPS based sea piling engineering: mathematical model and its application. *Survey Review, 39(305),* 193-202. https://doi.org/10.1179/003962607X165168

Goršič, J., Breznikar, A., Savšek Safić, S. (2006). Vloga geodezije pri gradnji manj zahtevnih objektov. *Geodetski vestnik, 50(4),* 654-664.

Hamza V., Stopar B., Ambrožič T. (2020). Deformacijska analiza po postopku Caspary. Deformation Analysis: the Caspary Approach. *Geodetski vestnik*, *64(1),* 68-88. https://doi.org/10.15292/geodetski-vestnik.2020.01.68-88

Kala, V. (2009). Some problems of an as-built survey and setting out accuracy. *Geodezija ir Kartografija, 35(3)*, 73-76. https://doi.org/10.3846/1392-1541.2009.35.73-76

Marjetič, A., Zemljak, M., Ambrožič, T. (2012). Deformacijska analiza po postopku Delft. *Geodetski vestnik*, *56(1),* 9-26. https://doi.org/10.15292/geodetski-vestnik.2012.01.009-026

Mihailović, K., Aleksić, I. (2008). *Koncepti mreža u geodetskom premeru*. Beograd: Privredno društvo za kartografiju Geokarta d.o.o. Beograd.

Mulahusić, A., Topoljak, J., Tuno, N. (2017). *Geodezija za građevinske inžinjere.* Zenica: Univerzitet u Zenici – Politehnički fakultet.

Paar, R., Zrinjski, M., Marendić, A. (2011). Quality Check of Vertical Component using GPS RTK Method and Laser System. *Geodetski vestnik, 55(4),* 689-700. https://dx.doi.org/10.15292/geodetski-vestnik.2011.04.689-700

Pašalić, S. (1995). *Inženjerska geodezija.* Sarajevo: Građevinski fakultet.

Pešto, N., Đidelija, M. (2018). Geodetski radovi pri izgradnji stuba vijadukta "Briješće". *Geodetski glasnik*, *49*, 77-91. https://doi.org/10.58817/2233-1786.2018.52.49.77

Pirti, A. (2007). Performance Analysis of the Real Time Kinematic GPS (RTK GPS) Technique in a Highway Project (Stake-Out). *Survey Review, 39(303),* 43-53. https://doi.org/10.1179/003962607X164989

Schofield, W., Breach, M. (2007). *Engineering Surveying, Sixth edition*. Oxford: Elsevier Linacre House.

Soldo, J., Ambrožič, T. (2018). Deformacijska analiza po postopku München. *Geodetski vestnik*, *62(3),* 392-414. https://doi.org/10.15292/geodetski-vestnik.2018.03.392-414

Tuno, N., Mulahusić, A., Marjetič, A., Kogoj, D. (2010). Pregled razvoja elektronskih tahimetrov Leica Geosystems. *Geodetski vestnik, 54(4),* 643-660. http://dx.doi.org/10.15292/geodetski-vestnik.2010.04.643-660

Tuno, N., Topoljak, J., Ademović, N., Mulahusić, A. (2018). A Simulation Analysis on the Expected Horizontal Accuracy of a Bridge Stakeout. *Tehnički vjesnik*, *25(1),* 285-293. https://doi.org/10.17559/TV-20161115105536

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