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TESTING THE EFFECT OF UNDERMINING ON POSITIONAL ACCURACY OF THE DIGITAL TECHNICAL MAP OF OSTRAVA IN THE PŘÍVOZ CADASTRAL DISTRICT

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Abstract. Intensive underground exploitation took place in the area of the Ostrava corporate town in recent past. After the coal mining was shut down in 1994 gradual subsidence in the town area has slowed down, however, establishing of the Digital Technical Map of Ostrava (DTMMO) dates back to 1992. When working a seam the original geostatic and tectonic stress state in the surrounding rock mass changes, which is accompanied by rock transformation and displacement from the roof towards the stope. Undermining is manifested in landscape morphology in many different ways that we can divide to continuous and discontinuous deformations. Residual mining effects could therefore have impacted positional accuracy of DTMMO in the last 18 years. The Bohumín 8-9/43 topographic sheet was selected for testing purposes in the Přívoz cadastral district.

Keywords: digital technical map, Ostrava, co-ordinate error, positional error, data analysis, measured objects.

1. Introduction

Works on establishing the Ostrava Town Information System commenced in 1992 and due to the fact that significant part of the area is situated in undermined locations, effort was exerted to remove the undermining effects from the outset. The subsidence disrupted the essential field of points, which was why a polygonal traverse with long courses was led by the VŠB – Technical University of Ostrava in 1992 and 1993 through the town area with connection to triangulation points situated outside the undermined area in the Poruba municipal district and in northern part of the Ostrava corporate town (Žváček 2010). Results of the surveying operations were further used for consequential connection of detail fields of points to the coordinate system. Detail fields of points were then used for detail surveying to establish the DTMMO. The map on the Bohumín 8-9/43 topographic

sheet was originally terrestrially surveyed in 1992 from the new field of points starting from area that was not undermined, and this original state was provided for testing. Residual mining effects and positional errors of the DTMMO could therefore have manifested within the last 18 years.

2. Basic data

Underground exploitation of mineral resources is manifested by surface movements and deformations induced by undermining. Earths movements in the undermined areas cause extensive destruction of land relief, residential places, roads and utility lines. Overall scope of the undermining effects depends mainly on:

– the intensity and nature of the exploitation effects,
– landscape morphology,

– general set of characteristics of objects, facilities and soils located in the mining region.

In our case the continuous landscape deformations are important whose impact in course of several years can negatively affect positional accuracy of DTMMO. Continuous deformations are typical for gradual creation of fluent subsidence basins. Subsidence basin at a continuous areal yield is formed with certain lapse of time and depends on the depth of exploitation, geological composition of the roof, seam thickness and method of exploitation. Scope of the subsidence basin is given especially by depth of the deposit and angle of draw while its shape depends mainly on the deposit dip and on the depth of exploitation.

Vertical movement of a surface point, so-called subsidence, is only a component of general movement of the point aiming to focal point of the stoped space in full area of extraction related to the actual point on the surface. Movement of the surface point therefore deviates in certain angle from vertical direction. We can divide general direction of the movement to its vertical and horizontal components. The general movement is usually not known therefore the v/s relation is useful for practical calculations where v is the horizontal component of movement (shift) and s is the vertical component of the surface point movement (subsidence). Deflection angle from vertical direction is, especially for deep faces, smaller than 15° therefore the horizontal movement is only a fraction of the subsidence. Length of the surface point horizontal movement depends on the point's position within the subsidence basin. We can generally say that the smallest horizontal movements are detected at the outskirts and in the centre of each subsidence basin. The highest values of horizontal movement can, on the other hand, be expected in positions above the face border. In many cases the real measured horizontal movements of subsidence basin points are larger than the theoretically extracted ones. Horizontal component of movement is therefore not extracted from straight general movement of a point in space but from an angular or curvilinear movement. The assumption of angular movement is based on existence of two rock masses varying in their strength or on the shape of curved transaction lines squeezing from the open area of subsidence basin to the narrow space above the stoped-out working. It is difficult to predict the larger movements as the real movement is affected by the non-homogenous composition of the upper wall. Real size of the movements can only be extracted from direct measurements in site.

Positional accuracy is one of quantitative parameters of geo-data quality and expresses the anticipated maximum positional deviation of a geo-element from its correct position. We can divide it to positional accuracy in horizontal direction (accuracy of defining the x and y coordinates) and positional accuracy in vertical direction (accuracy of altitude h definition) (Rapant 2006).

The DTMMO has been created since 1994 and DTMMO maintenance and administration has been in operation since the beginning of 2000; it includes geodetic updating, use of documents within granting certificates of occupancy and mutual exchange of data with utility lines administrators. Acquisition and especially updating of the data is conducted with financial participation of the utility lines administrators.

The quality (accuracy) of detail topographic points is expressed by a parameter called the "quality code" (earlier also the "accuracy class"). The quality code depends on standard coordinate error of defining the detail topographic point or on the quality of the original map documents (Table 1).

Table 1. Quality codes of detail points (Český... 2007)

Quality code	According to	
	Accuracy	Origin
	Point whose coordinates were defined with standard coordinate error	Digitalized point from scaled analogue map
3	≤0.14 m	–
4	>0.14 m and ≤0.26 m	–
5	>0.26 m and ≤0.50 m	–
6	≤0.21 m	1:1000, 1:1250
7	>0.21 m and ≤0.50 m	1:2000, 1:2500
8	>0.50 m	1:2880 and others not specified above

When creating the DTMMO the elaborators are required to meet the quality code 3, however, systematic control surveys that would independently verify accuracy of map documents is not carried out.

Position of the Přívoz cadastral district is suitable for testing of residual mining effects that could negatively impact positional accuracy of DTMMO. The Bohumín 8-9/43 topographic sheet in the Přívoz cadastral district was selected in collaboration with the Ostrava City Authority and with DIGIS spol. s r.o., the DTMMO administrator.

3. Surveying methods and data processing

First phase of the in site surveying concentrated on independent definition of coordinates from standpoints using the method of global navigation satellite system (GNSS) from which identical topographic points of DTMMO were consequently measured, intended for the topographic sheet positional accuracy testing. The standpoints were marked by survey pins or by gun-driven nails with metal base. 322 detail topographic points were surveyed in the involved location. The most suitable positions were quoins, fence pillars, gate and gas valves and hydrants, street inlets, poles of overhead lines and public lighting, traffic signs and curb returns.

Bearing of identical points was carried out by the SOKKIA SET 530 RK3 total station, each point in two steps. For each point two bearings were taken while the total station was rearranged between the first and second taking. The selected procedure partly eliminated

gross errors implied by wrong identification of identical points in the field. The process resulted in two sets of coordinates for each identical point and if the difference between coordinates from the first and second taking varied by more than 0.28 m, the taken points were eliminated from further testing. An average was then calculated from the two sets of coordinates that entered into later calculations.

Location around the Church of Virgin Mary on the Svatopluka Čecha square was surveyed. Coordinates of six standpoints chosen with regards to the technology possibilities and limitations were defined by means of GNSS. Five of them were included to control survey and further calculations. In Figure 1 the GNSS points are marked as 600x where x is the sequence number of the appropriate GNSS point. The 5001 point was determined by traverse calculation from the 6001 observation station directed to 6002 and the calculation was checked by taking the bearings in directions to 6001 and 6006 from the 5001 station. The observed directions from individual stations are drawn by dash-and-dot line in Figure 1.

We compare the set of coordinates of identical points gained from direct survey in site with the set acquired by export of identical points' coordinates from the assessed map document. We calculate coordinate difference:

$$\Delta x = x_p - x_n \; ; \; \Delta y = y_p - y_n, \qquad (1)$$

where x_p, y_p are the original coordinates of detail topographic points and x_n, y_n are the newly defined coordinates of identical points.

According to formula (Český… 2007) we determine the mean deviations in u_p position from the calculated coordinate differences:

$$u_p = \sqrt{\frac{(\Delta x^2 + \Delta y^2)}{2}}. \qquad (2)$$

We assume the declared quality code 3 of the map documents is conformable if the mean deviation in position $u_p \leq u_{xy} = 0{,}14$ m (see Table 1) in more than 68.3% of cases while not exceeding the criterion of $2u_{xy} = 0{,}28$ m in more than 4.5% of cases.

When assessing the positional deviations we assume normal distribution of the data sets. The assumption has to be verified or disproved by statistic analyses (Neset 1984; Vykutil 1988; Rapant 2002). Suitable tools to assess normality of given data sets are the goodness-of-fit tests. However, before we start to calculate characteristics of the set we have to ensure its homogeneity, i.e. to carry out the outliers test. Suitable tool to assess the outliers in great data sets ($n > 25$) is the Grubb's test. We formulate the H_0 null hypothesis and the H_1 alternative hypothesis:

– H_0: The u_{pi} value is not an outlier,
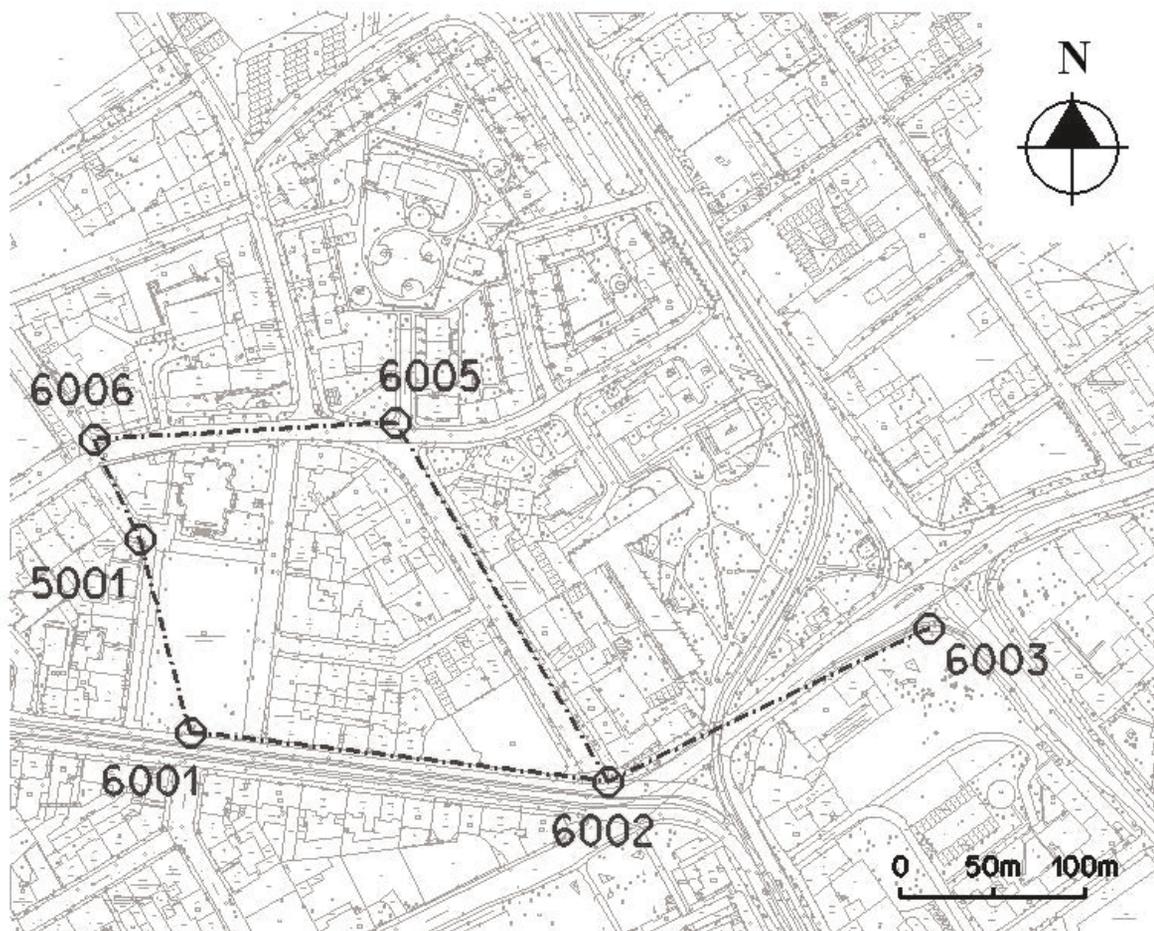– H_1: The u_{pi} value is an outlier.

Fig. 1. Standpoints

Tested criterion of the Grubb's test is

$$T = \frac{\left| u_{pi} - \overline{x} \right|}{s}, \tag{3}$$

where:

u_{pi} – is the mean deviation in point position [m],

$\overline{x}$ – is the arithmetic mean of the data set [m],

s – is the standard deviation of the data set [m].

According to tables of critical values for Grubb's T-distribution we gradually determine the T_k value of critical region for the appropriate n values and we calculate the values of test criterion that we compare with limits of the critical region. If the test implies that an extreme value has to be excluded, all selection characteristics (from the data set without the extreme value) for further calculations (Otipka, Šmajstrla 2006) have to be re-determined.

Gradual exclusion of outliners reduces the n data set but also the value of arithmetic mean, standard deviation and test criterion. The tested criterion for certain tested value is lower than the limit of critical region, which is a reason why we no more disapprove the H_0 hypothesis. We reduce the data set by means of the outlier testing; the data set is now prepared for the test of normality. We therefore formulate the H_0 null hypothesis and the H_1 alternative hypothesis:

– H_0: The tested data set comes from a basic set with normal distribution,

– H_1: The tested data set does not come from a basic set with normal distribution.

Goodness-of-fit tests are divided to two types of models with normal distribution that are specified (we know the value of variance and mean) or non-specified (mean and variance are computed from selection values). The difference between these cases occurs in distribution of the test statistic and also when deciding if the calculated value of the test statistic lies in the critical region. Often used statistic tests are for example the Pearson's test, Kolmogorov – Smirnov, Shapiro – Wilk. The Pearson's test is the best-known and most often used one suitable especially for large sets ($n > 50$), which is also the reason why it was used in this assignment. If $X_1, X_2, ..., X_n$ are independent random variables each of which has the $N(0,1)$ distribution then the random variable:

$$Y = X_1^2 + X_2^2 + ... + X_n^2, \tag{4}$$

has the χ^2 distribution with ν degrees of freedom described as $\chi^2(\nu)$. With increasing number of degrees of freedom the density of the distribution further approximates the shape of density of normal distribution. We divide the data set with n extension to k intervals according to the Sturges's rule:

$$k \approx 1 + 3{,}3 \log n. \tag{5}$$

After testing the outliers we gain a data set whose values vary in certain range. We gain the width of the h class interval by dividing the interval to k classes. We gain the width of the h class interval with the n_j ($j = 1$,

2, ..., k) frequencies, upper limit of the intervals is to be marked as u_{pj}.

We calculate the theoretic class frequencies for data set originated from the basic set with normal distribution $N(\mu, \sigma^2)$. Upper limits of the class intervals must be transferred to values of the standard variable

$$u_j = \frac{u_{pj} - \mu}{\sigma}, \tag{6}$$

where:

μ – mean of normal distribution [m],

σ – standard deviation of normal distribution [m],

u_{pj} – upper limits of individual intervals [m].

In our case we do not know the values of μ and σ therefore we put the value of sample average instead of the μ parameter and the value of sample standard deviation instead of the σ parameter

$$u_j = \frac{u_{pj} - \overline{x}}{s}. \tag{7}$$

For each j we search out the corresponding numerical values of the distribution function of standardizes standard distribution $\varphi(u_j)$. Then we determine the theoretic and absolute class frequencies

$$\pi_j = \varphi(u_j) - \varphi(u_{j-1}) \text{ and } n\pi_j. \tag{8}$$

Necessary condition of the test is that hypothetic frequencies $n\pi_j$ in each class are greater than 5. If the condition is not met the class must be united with the neighbouring class. The test statistic value can then be determined from the following equation

$$\chi^2 = \sum_{j=1}^{k} \frac{(n_j - n\pi_j)^2}{n\pi_j}. \tag{9}$$

The critical region value for normality test on the α confidence level is then

$$\chi^2 > \chi_{1-\alpha}^2 (k - c - 1), \tag{10}$$

where:

k – is number of class intervals,

c – is a parameter which equals 2 for not fully specified models (we anticipate the mean and standard deviation) and $c = 0$ for fully specified models,

$1-\alpha$ – is a distribution quantile χ^2.

In the case of united classes their total number will decrease, which implies that a k_r parameter for reduced number of classes enters the calculation of critical region:

$$\chi^2 > \chi_{1-\alpha}^2 (k_r - c - 1). \tag{11}$$

When we compare the test statistic and the computed critical region, we detect if the test statistic value falls into the critical region. If the value falls into the critical region, we reject the H_0 null hypothesis that the tested data set comes from the basic set with normal distribution and we accept the alternative H_1 hypothesis.

4. Evaluation of surveyed data

The most frequently surveyed objects in the location were gate and gas valves, quoins, street inlets and manholes with round covers. Other often measured objects and topographic elements were public lighting lamps, traffic signs, curb returns, hydrants and others listed in Table 2.

Table 2. Number of various types of surveyed objects in the Přívoz cadastral district

Type of the object	Number
Valve (gas or gate)	70
Quoin	54
Street inlet	44
Manhole with round cover	38
Public lighting lamp	28
Traffic sign	22
Curb return	18
Hydrant	10
Manhole with square cover	9
Corner of dwarf wall	8
Others	21

The item "others" includes for example poles of overhead lines and other topographic elements of DTMMO such as traffic lights, tram conduction poles or fence pillars. Aboveground marks of service lines in this location comprise approximately two thirds of the overall number of surveyed objects. It results from lower number of suitable, well-identifiable topographic elements and higher density of service lines and therefore also their marks.

279 control-measured points (86.65%) meet the $u_p \leq u_{xy} = 0,14$ m criterion and 25 points (7.76%) lies in the interval $u_p > 2u_{xy}$. Early results indicate that the first criterion $u_p \leq u_{xy}$ is met while the second criterion $u_p > 2u_{xy}$ is slightly exceeded. The next step to assess the coordinate differences is to look closely at identical points where u_p exceeds the value of $2u_{xy}$. Distribution of these points within the involved area does not create any significant aggregation and they are not of a single kind either. They include the aboveground marks of service lines (gate or gas valves, street inlets, a hydrant, a lamp), quoins, traffic signs and traffic lights (Table 3).

Where possible the identical points were measured together with their height component. The height component is not mentioned for all tested points and should only serve for information. Information about the height deviation – or about the coordinate deviation in *Z*-axis – can be used to assess positional deviations for the 25 points exceeding the $u_p > 2u_{xy}$ criterion. With respect to the theoretic considerations regarding mining effects on a surface points' general movement, we can anticipate that vertical component of movement will significantly prove in the size of coordinate deviations of tested identical points meeting the $u_p > 2u_{xy}$ criterion. However, the *Z*-axis coordinate deviations in relation to *X* and *Y*-axis deviations are negligible, except for the 141 point. Slight exceeding of given criteria can be caused by relatively old

date of map documents or by randomly higher error rate in the involved location that would be alleviated if larger area was surveyed. It should be reminded that the map documents originate in 1992 and timeliness of the map documents can play a significant role in exceeding the $u_p > 2u_{xy}$ criterion for greater number of tested points.

The outliers test was then made for the set of positional deviations according to the (3) formula. 27 extreme values were eliminated that did not enter the following normality testing of the data set. Final number of the data set elements was reduced to $n = 289$. Mean value of the data set is $\bar{x} = 0.06$ m and its standard deviation amounts to $s = 0.04$ m.

The reduced data set with $n = 289$ was divided to $k = 9$ intervals according to the (5) formula and as the outliers testing gave us a data set whose values vary in the range of <0; 0.19>, we will get the $h = 0.02$ width of the class interval by fractioning the highest value by the k parameter and by rounding the result to centimetres. Then the test statistic calculation was carried out according to the (7), (8) and (9) formulas. In course of computing the last class was united with the neighbouring class because of its insufficient frequency as seen in Table 4. After summing-up values in the last column of Table 4 we get the test characteristic $\chi^2 = 40.61$. Value of critical region for the normality test on the $\alpha = 0.05$ level of confidence for reduced number of classes according to the (11) formula is $\chi^2(5) = 11.1$. The acquired results prove that it is not a set with normal distribution. We therefore reject the H_0 null hypothesis that the tested data set comes from a basic set with normal distribution and we accept the alternative H_1 hypothesis.

Table 3. Points with positional deviation $u_p > 2u_{xy}$ in Přívoz cad. district

Point no.	Δy	Δx	Δz	Note
19	0.32	0.30	–0.10	Traffic sign
26	0.30	0.42	–0.03	Traffic sign
31	–0.30	–0.51		Street inlet
61	0.44	0.21	–0.03	Gate or gas valve
64	–0.57	–0.02	–0.05	Street inlet
87	–0.52	–0.30		Gate or gas valve
98	–1.65	4.20		Quoin
99	0.40	0.83		Quoin
100	0.17	0.82		Quoin
101	–0.09	0.63		Quoin
102	0.03	0.78		Quoin
136	0.76	0.19		Gate or gas valve
141	0.92	0.73	–1.68	Gate or gas valve
194	0.21	–0.38	–0.04	Traffic sign
205	0.96	0.23	0.10	Traffic sign
231	–0.26	0.36	–0.05	Hydrant
232	1.02	–0.22	–0.07	Traffic lights
236	–2.25	–0.82	–0.13	Traffic sign
246	2.20	0.00	–0.06	Quoin
251	–0.60	0.05		Quoin
270	0.73	0.15	–0.14	Traffic lights
271	–0.13	0.61	–0.13	Traffic lights
319	0.30	–0.44	–0.18	Gate or gas valve
320	0.29	–0.33	–0.08	Public lighting lamp
322	0.45	–0.62	0.00	Street inlet

Table 4. Calculation schema of test statistic χ^2 for positional deviations in Přívoz cad. district

u_{pj}	n_j	u_j	$\varphi(u_j)$	π_j	$n\pi_j$	$n\pi_j$	n_j	$\dfrac{(n_j - n\pi_j)^2}{n\pi_j}$
0.02	49	−1.07	0.142	0.142	41.04	41.04	49	1.54
0.04	71	−0.55	0.291	0.149	43.06	43.06	71	18.13
0.06	62	−0.02	0.492	0.201	58.09	58.09	62	0.26
0.08	37	0.50	0.691	0.199	57.51	57.51	37	7.31
0.10	31	1.03	0.848	0.157	45.37	45.37	31	4.55
0.12	15	1.55	0.939	0.091	26.30	26.30	15	4.86
0.14	14	2.07	0.981	0.042	12.14	12.14	14	0.28
0.16	7	2.60	0.995	0.014	4.05	5.50	10	3.68
0.19	3	3.39	1.000	0.005	1.45			

Table 5. Calculation schema of test statistic χ_y^2 for the Y coordinate axis (Přívoz cad. district)

Δy_j	n_j	y_j	$\varphi(yj)$	π_j	$n\pi_j$	$n\pi_j$	n_j	$\dfrac{(n_j - n\pi_j)^2}{n\pi_j}$
−0.24	5	−2.69	0.004	0.004	1.21			
−0.18	4	−1.87	0.031	0.027	8.15	9.36	9	0.01
−0.12	34	−1.06	0.145	0.114	34.43	34.43	34	0.01
−0.06	75	−0.24	0.405	0.260	78.52	78.52	75	0.16
0.00	111	0.57	0.716	0.311	93.92	93.92	111	3.11
0.06	57	1.38	0.916	0.200	60.40	60.40	57	0.19
0.12	10	2.20	0.986	0.070	21.14	25.37	16	3.46
0.18	4	3.01	0.999	0.013	3.93			
0.21	2	3.42	1.000	0.001	0.30			

Next step in testing the identical points' positional deviations was the independent testing of coordinate deviations separately for axis Y and X. Outliers test was first made for each of the sets followed by the data normality testing. Number of extreme values of the Y-axis coordinate deviations amounted to 19 while values $\Delta y = -0.30$ m and $\Delta y = 0.21$ m form the interval that the coordinate deviation values for data normality testing fall to. Number of values belonging to this interval is $n_y = 302$. The mean for the Y coordinate axis is $\Delta y = -0.04$ m, standard deviation is $s_y = 0.07$ m. Number of classes $k = 9$ was calculated according to the (5) formula and the $h = 0.06$ width of the class interval according to the (12) formula:

$$h = \frac{(\Delta x(y)_{max} - \Delta x(y)_{min})}{k}. \tag{12}$$

Test statistic was calculated according to formulas (7), (8) and (9) as shown in Table 5. Because of insufficient frequency in the first class and in the last two classes, they were united with their neighbouring classes. Thus the number of classes was reduced to $k_r = 6$. After summing-up the values in the last column of Table 5, we get the value of test characteristic $\chi_y^2 = 6.94$ for coordinate deviations in the Y-axis. Value of critical region for the normality test on the $\alpha = 0.05$ level of confidence for reduced number of classes according to the (11) formula is $\chi^2(3) = 7.8$. The χ_y^2 test characteristic does not fall to

the critical region and we therefore fail to reject the H_0 null hypothesis that the tested data set of Y-axis coordinate deviations comes from a basic set with normal distribution (Fig. 2).

The same procedure of the data normality testing was carried out for the set of X-axis coordinate deviations. First the outliers test was conducted and 21 values were eliminated. The reduced data set has the scope of $n_x = 300$. Mean of the X-axis coordinate deviations is $\Delta x = 0.01$ m, standard deviation is $s_x = 0.07$ m. Limit values of the reduced interval of coordinate deviations that were not evaluated as extremes are $\Delta x = -0.22$ m and $\Delta x = 0.23$ m. The <−0.22; 0.23> interval was divided to 9 classes, while the k value was calculated from the (5) formula and the class interval width according to the (12) formula, i.e. $h = 0.05$. Test statistic for X-axis coordinate deviations was calculated according to formulas (7), (8) and (9) as shown in Table 6.

Because of insufficient frequency in the first and last classes, they were united with their neighbouring classes. Thus the number of classes was reduced to $k_r = 7$. After summing-up the values in the last column of table 6, we get the value of test characteristic $\chi_x^2 = 18.51$ for coordinate deviations in the X-axis. Value of critical region for the normality test on the $\alpha = 0.05$ level of confidence for reduced number of classes according to the (11) formula is $\chi^2(4) = 9.5$. The χ_y^2 test characteristic falls into the critical region and we therefore reject the H_0 null

hypothesis that the tested data set of *X*-axis coordinate deviations comes from a basic set with normal distribution and we accept the alternative H$_1$ hypothesis (Fig. 3).

Coordinate differences of the surveyed identical points in relation to the points exported from DTMMO were plotted into a graph. The mean of coordinate differences in *Y*-axis lies in slightly negative values, mean of *X*-axis coordinate differences nears zero, which can also be approximately assessed from Figure 4.

Table 6. Calculation schema of test statistic χ_y^2 for the X coordinate axis (Přívoz cad. district)

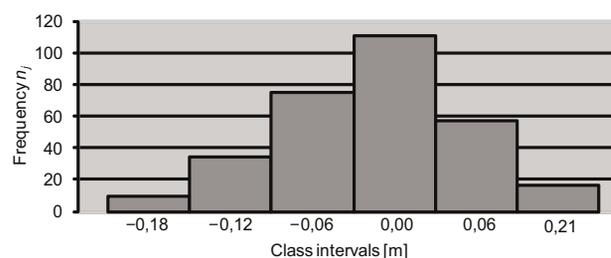| Δx_j	n_j	x_j	$\varphi(x_j)$	π_j	$n\pi_j$	$n\pi_j$	n_j	$\dfrac{(n_j - n\pi_j)^2}{n\pi_j}$
−0.17	5	−2.56	0.005	0.005	1.50			
−0.12	7	−1.85	0.032	0.027	8.10	9.60	12	0.60
−0.07	20	−1.13	0.129	0.097	29.10	29.10	20	2.85
−0.02	69	−0.42	0.337	0.208	62.40	62.40	69	0.70
0.03	101	0.29	0.614	0.277	83.10	83.10	101	3.86
0.08	66	1.01	0.844	0.230	69.00	69.00	66	0.13
0.13	16	1.72	0.957	0.113	33.90	33.90	16	9.45
0.18	10	2.43	0.992	0.035	10.50	12.60	16	0.92
0.23	6	3.15	0.999	0.007	2.10			

Fig. 2. Frequency distribution histogram for the Y-axis coordinate deviations (Přívoz cad. district)
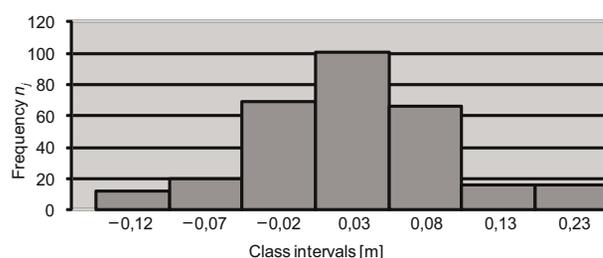

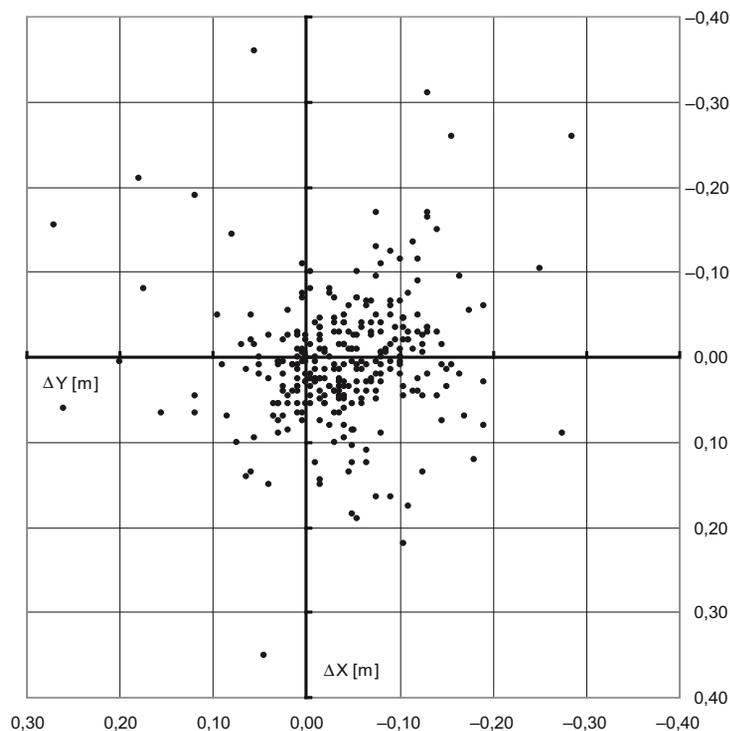**Fig. 3.** Frequency distribution histogram for the X-axis coordinate deviations (Přívoz cad. district)

Fig. 4. Coordinate differences of surveyed identical points in relation to DTMMO in Přívoz cad. district

5. Conclusions

The Přívoz cadastral district lies in an area that was affected by mining effects in recent history. The Ostrava City Authority in collaboration with DIGIS spol. s r.o. selected the location around the Church of Virgin Mary on the Svatopluka Čecha square on the Bohumín 8-9/43 topographic sheet as suitable for positional accuracy testing of DTMMO. First geodetic surveys for DTMMO creation started as early as in 1992 and this original digital map could have been affected by residual mining effect in later years. Survey of identical topographic points was carried out in this location with independent connection by the GNSS technology and statistic analysis of surveyed data was elaborated.

Normality of tested data was confirmed only for differences in the *Y* axis. Percentage ratio of identical points complying with the $u_p \leq u_{xy} = 0.14$ m criterion nears 87%. Greater number of points with positional deviations $u_p > 2u_{xy}$ is probably caused by old date of the provided map document produced in 1992. Impact of residual mining effects on accuracy of the original DTMMO from 1992 – due to standard deviations' values and means of coordinate differences in *X* and *Y* axis and positional deviations – was not proved.

The executed survey, calculation and analytic works presented in this article comprise a part of a more extended work concerning testing of DTMMO positional accuracy in four different locations within the area of the Ostrava statutory town. All locations were selected in collaboration with the Ostrava City Authority and DIGIS spol. s r.o. and are typical for the nature of their development, origin of topographic sheets and possibly also for prediction of residual mining effects that can negatively affect positional accuracy of DTMMO and therefore increase the cost of regular updating of digital map documents in the area of Ostrava.

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