TESTIRANJE NOVE METODE OBNAVLJANJA KATASTRSKIH NAČRTOV NA SLOVAŠKEM

TESTING OF A NEW WAY OF CADASTRAL MAPS RENEWAL IN SLOVAKIA

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IZVLEČEK

*Največja težava slovaškega katastra je kakovost načrtov. Približno polovica načrtov zahteva ponovno izdelavo. Kakovost druge polovice načrtov prav tako ni visoka in so zanje potrebni lokalni premiki. V dokumentu je obravnavan predlog nove metode obnavljanja katastrskih načrtov – obnova s popravki (*Cadastral Operate Renewal by Correction – RbC*). Ta postopek temelji na transformaciji dela zemljevida z lokalnimi premiki na podlagi novih meritev GNSS in je razdeljen na tri glavne faze – analizo homogenosti, transformacijo in končno kontrolo. Rezultat postopka RbC je obnovljen katastrski načrt brez lokalnih premikov. Nadaljnji cilj tega dokumenta je preizkušanje opisanega postopka na izbrani katastrski enoti in analiza rezultatov. Če se preizkušanje izkaže za uspešno, je lahko ta postopek hitra in cenejša alternativa novim meritvam pri katastrskih načrtih z lokalnimi premiki.*

ABSTRACT

One of the biggest problems in the Slovak cadastre is the quality of maps. Approximately half of them require a new mapping. The quality of the other half is also not high, and they include local shifts. The paper deals with a proposal for a new way of their renewal—Cadastral Operate Renewal by Correction (RbC). This process is based on a transformation of the part of the map with local shifts using a new GNSS measurement. The process has three main stages—homogeneity analysis, transformation, and final control. The result of the RbC process is a renewed cadastral map without any local shifts. Another goal of this paper is to test this process in a chosen cadastral unit and to analyse the results. If the testing is successful, this process could be a fast and cheap alternative to a new mapping in case of these cadastral maps with local shifts.

KLJUČNE BESEDE

vektorski katastrski načrt, lokalni premiki, homogenost načrta, obnavljanje, transformacija

KEY WORDS

vector cadastral map, local shifts, map homogeneity, renewal, transformation

1 INTRODUCTION

The cadastre of real estate in Slovakia is defined as a geometrical and positional determination, recording and description of real estates (Act no. 162/1995 Coll.). The structure and content of the documentation included in the cadastre of real estate is defined in an executive decree. The main parts of the cadastral documentation are surveying information file and descriptive information file (Decree no. 461/2009 Coll.; Gašincová and Gašinec, 2011). The cadastral documentation is managed per cadastral unit. The most important part of the surveying information file is a large-scale planimetric map, called a cadastral map. Its main purpose is to display real estates. The cadastral maps are produced in the system of the Unified Trigonometrical Cadastral Network (UTCN). Nowadays, all the cadastral maps are managed in the digital vector form, so they are called vector cadastral maps (VCMs).

In the Slovak cadastre, there are many data of different quality and origin (Seidlová and Chromčák, 2017). One of the main concerns is the quality of the cadastral map collection. Until 1995, cadastral maps were managed only in the analogue paper form. Between 1995 and 2015, all the analogue maps were replaced by digital vector maps, which are called vector cadastral maps. The update of these maps is interactive with the use of vector geodetic designs (Raškovič et al., 2019). The topic of quality of cadastral maps has been discussed for a long time in Slovakia (Horňanský et al., 2014; Hudecová, 2011; Kyseľ et al., 2018). Low quality and inconsistencies of cadastral data are not a discussed topic just in Slovakia, but they represent a problem also in many other countries (Kaufmann et al., 2009; Lisec and Navratil, 2014; Moharić et al., 2017; Hanus et al., 2018; Mika, 2018; Popov, 2019). In some countries, such as Slovenia, methods for the renewal of older cadastral maps have been proposed (Čeh et al., 2011; Čeh et al., 2012). Currently, only one parameter is used to monitor the cadastral map quality in Slovakia. This parameter is called quality code of a point and it has five values. The value of the quality code of a boundary point is given by its origin, way of determination of its position and its quality (Decree no. 461/2009 Coll.).

Nowadays, there are two main types of cadastral maps in Slovakia—numerical maps and non-numerical maps (Decree no. 461/2009 Coll.). The worse part of the cadastral map collection consists of non-numerical maps (57% of maps). Their quality is very low due to their origin (geodetic coordinate system, measurement methods), and the only way for their renewal is a new cadastral mapping. The second group of maps comprises cadastral maps numerical (43% of maps). Their quality is better because all the points were determined using numerical measurement methods, and their coordinates in the UTCN system were recorded, but there are still some problems related to them. This paper deals with these problems of numerical cadastral maps.

The quality of a cadastral map is assessed according to the precision of the original measurement, which is determined based on the values of standard deviation and limit deviations. These criteria are given in the Slovak Technical Norm STN 01 3410 (STN, 1990).

All vector cadastral maps numerical (VCMn) are a result of numerical measurements, and the determined coordinates of points should be accurate. It means that if the position of an existing detailed point is determined in a new measurement, the positional deviation between the new and original coordinates of the point should not exceed value of 0.24 m (Gašincová et al., 2014). However, mistakes were made during the original measurement, and in some locations, the positional deviation exceeds this value. These mistakes were discovered with the rolling out of the GNSS technology, which provides determination of the point position independent of near geodetic control points (Hudecová and Kyseľ, 2020). Since 2013, a special way of updating these maps has been applied (Decree no. 461/2009 Coll., Guideline, 2013). In the locations where local shifts are present, new objects have been transformed into a shifted map using a local transformation, and the original measurement has been stored in the POINTS layer (Figure 1).

Figure 1: VCMn with the POINTS layer (red colour).

Nowadays, there is no concept of renewal of these maps with local shifts in Slovakia, and the objects in the POINTS layer are only stored but not used. The big advantage is that in most cases, the local shift vectors are systematic, which means that the direction and size of the shifts are similar. The renewal by a new cadastral mapping is thus not needed in case of these VCMn with local shifts. The main aim of this paper is to present a new way of renewal of these maps, called Cadastral Operate Renewal by Correction (RbC), and to test it in a selected cadastral unit. The process of RbC could be a fast, effective and reliable way of renewal of VCMn with local shifts.

2 MATERIALS AND METHODS

In this paper, the new process of RbC will be tested in the cadastral unit of Jacovce, Slovak Republic.

Cadastral unit: Jacovce (821781)

Region (Nomenclature of Units for Territorial Statistics – NUTS3): Nitra Region

District (Local Administrative Unit – LAU1): Topoľčany (406)

Area: 10,060,000 m^2

The original cadastral mapping in the built-up area of the cadastral unit of Jacovce was finished in 1981, and the map was in the 1 : 1000 scale. The rural area was mapped in 1989, and the scale of the resulting analogue map was 1 : 5000. Both cadastral mappings were regulated by the Instruction from 1981 (Instruction, 1981). All detailed points in both mappings were determined in the 3rd class of precision, which means that their positional accuracy should be 0.14 m (STN, 1990). This precision is given in regard to the nearest geodetic control points. The maps were reworked to the digital vector form and joined into one VCMn file, which was approved in 2013.

If a new measurement is performed today, the positional deviation between the new control measurement and the original position of a point in the map should not be more than 0.24 m. However, in this cadastral unit, the condition is not fulfilled practically anywhere in the built-up area. This fact is well documented in Figure 2, where the objects in the POINTS layer within the cadastral unit of Jacovce are displayed along with the borders of the cadastral unit and the built-up area. Since 2013, when the POINTS layer was established within the meaning of new regulations, approximately 250 vector geodetic designs for updating the map have been created, and vast majority of them (more than 90%) have included the POINTS layer. The total number of points in the POINTS layer is approximately 2,200.

A new mapping would be ineffective in such a situation because the relative quality of the map is sufficient and the shifts were caused only by the low quality geodetic controls. A new process of cadastral map renewal is needed for these maps— Cadastral Operate Renewal by Correction. The fundamental part of this process consists in a transformation of the map geometry to the correct position per partes. The technical part of the process, which is tested in this paper, is very simple and includes three main phases (Kyseľ, 2021).

The first phase is called homogeneity analysis. Its aim is to qualify the local shifts in the map geometry in terms of their frequency, location and size (Hudecová and Kyseľ, 2020). The analysis of homogeneity determines whether the RbC process is practicable. It is examined whether the local shifts occur only in a specific part of the cadastral unit, whether the nature of the local shift vectors is systematic in a particular error location, and whether the error locations could be delimited distinctly. The background for this analysis comprises the objects in the POINTS layer supplemented with the new measurement, where the coverage of the POINTS layer is not sufficient. If an area is proved to be inhomogeneous, it has to be divided into smaller areas which could be homogeneous. If even this does not help, there is no other option but to conduct a new cadastral mapping in the block.

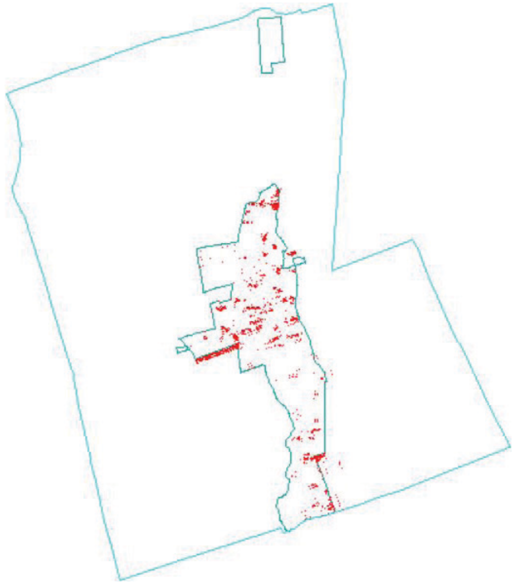


Figure 2: The POINTS layer (red colour) in the cadastral unit of Jacovce.

The main part of the RbC process consists in a transformation of the map geometry to the correct position. A 2D conformal transformation without scale change is used. This type of transformation was chosen because the relative quality of the map geometry is high, and the main goal is to preserve the shape and areas of land parcels. At least two identical points are needed for the transformation, but the ideal number is 4 or 5 points distributed along the perimeter of the transformed area. The parameters are then calculated using the Least Square Method adjustment. The identical points either come from the POINTS layer or are determined in a new measurement. The condition is that their position has to be known both in the shifted system of the map and in the correct system, so the position has to be determined using the active geodetic controls.

The last part of the RbC process is the final control. At this stage, the size and direction of local shift vectors is determined and analysed after the transformation on a set of check points, which were also determined using the active geodetic controls, but they were not used for the calculation of the transformation parameters. It is best to use the points which were used for the initial homogeneity analysis because the local shift vectors can be compared to the state before the transformation. Moreover, during this stage, the areas of the border land parcels are compared to the state before the transformation, and the parcels whose area needs to be corrected are determined. If the process is successful, the result is a correct VCMn produced within a very short time frame.

3 RESULTS AND DISCUSSION

The coverage of the cadastral unit of Jacovce by the POINTS layer was proven to be insufficient, so a new measurement had to be conducted in order to achieve a reliable homogeneity analysis of the VCMn. The measurement was conducted on 6th January 2022 using the GNSS-RTK method with a connection to the SKPOS network. The subject of the measurement were fences, which were accessible from public spaces, so the owners of the parcels did not have to attend the measurement. Approximately 400 new points were determined, which covered the whole built-up area of the cadastral unit (Figure 3, green colour). The testing of the RbC process did not include the rural area of the cadastral unit because the parcel borders are not marked there, and therefore they cannot be measured. In the future, the land consolidation should also be conducted outside the built-up area, which would produce a new cadastral map without any shifts.

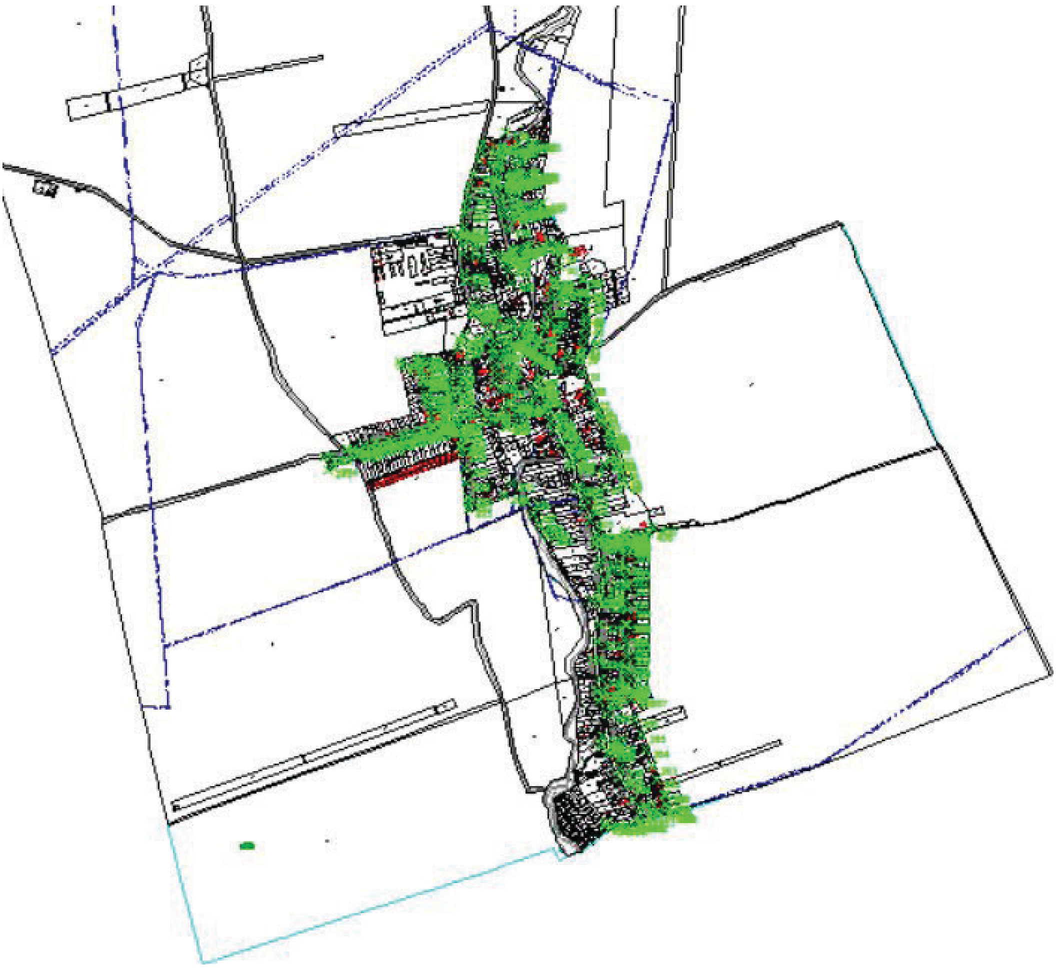


Figure 3: New points (green) measured using the GNSS-RTK method in the cadastral unit of Jacovce.

The first stage of the RbC is a homogeneity analysis of the VCMn. In this phase, the size and direction of local shift vectors were calculated on a set of chosen points, which were a combination of the points from the POINTS layer and those from the new measurement. The analysed area was divided into 22 blocks (Figure 4). The border parcels between the blocks were either publicly-owned parcels, such as streets or water flows, or big field parcels with no registered ownership rights. The borders of the blocks were determined in a manner which ensured that they had the smallest possible size to correct the local shifts in the best way, and there were at least 10 check points measured using the active geodetic controls. In each block, the average values and standard deviations of size (Δp_{AVG}, $\sigma_{\Delta p}$) and direction (α_{AVG}, σ_{α}) of local shift vectors were calculated (Table 1). The size of the positional deviation Δp is represented by the distance between the points in the map and the measured point and is calculated with formula (1)

$$\Delta p = \sqrt{\Delta x^2 + \Delta y^2}, \quad (1)$$

where $\Delta x = x1 - x2$ and $\Delta y = y1 - y2$; where $x1, y1$ are the coordinates of a point from the new GNSS measurement and $x2, y2$ are the coordinates of a point in the original map.

The direction is represented by the azimuth from the measured point to the point in the map in the UTCN coordinate system. The criteria for the homogeneity of a block are the standard deviation of size not exceeding the value of 0.14 m and the standard deviation of direction not exceeding the value of 25 gon. These criteria were determined empirically based on the previous experience.

Figure 4: Division of the cadastral unit of Jacovce into the smallest possible blocks.

Table 1: Homogeneity analysis of the VCMn—small blocks

Block no.	Δp_{AVG} [m]	$\sigma_{\Delta p}$ [m]	α_{AVG} [gon]	σ_{α} [gon]
1	0.41	0.06	332.7242	15.3099
2	0.39	0.05	334.9082	10.0851
3	0.35	0.10	342.1878	12.8078
4	0.30	0.06	331.9855	12.7166
5	0.32	0.04	327.2666	10.1315
6	0.36	0.06	326.0922	11.7582
7	0.37	0.07	312.8513	11.2889
8	0.32	0.04	323.5135	13.9112
9	0.37	0.06	323.6426	9.4341
10	0.30	0.04	321.3865	11.0622
11	0.34	0.03	315.3922	5.8843
12	0.35	0.07	326.1901	15.0453
13	0.38	0.04	312.0059	7.1916
14	0.38	0.04	310.1940	11.1806
15	0.50	0.05	293.5616	7.4026
16	0.52	0.09	304.9894	7.1782
17	0.55	0.06	295.9614	5.3319
18	0.61	0.06	291.3429	5.0863
19	0.39	0.04	280.2391	10.8134
20	0.51	0.09	287.3837	8.0577
21	0.33	0.02	336.0410	4.2518
22	0.31	0.03	341.2984	8.8875

According to the homogeneity analysis (Table 1), the RbC process can be conducted in all 22 analysed blocks. These small blocks would provide the most accurate solution for the RbC because this way, the small changes in the local shifts can be represented better. However, the local shift vectors were similar in some of the blocks, so the situation can be simplified into 3 blocks (Figure 5). Blocks no. 1–14 and no. 21–22 were joined into the new block no. 1, blocks no. 15–18 were combined into the block no. 2, while only the borders of the block no. 19 stay, and they create the new block no. 3. The average values and standard deviations of size (Δp_{AVG}, $\sigma_{\Delta p}$) and direction (α_{AVG}, σ_{α}) of local shift vectors were calculated in each of the joined blocks using the same points as in the first case (Table 2).

Table 2: Homogeneity analysis of the VCMn—joined blocks

Block no.	Δp_{AVG} [m]	$\sigma_{\Delta p}$ [m]	α_{AVG} [gon]	σ_{α} [gon]
1	0.35	0.06	325.4429	14.5019
2	0.54	0.08	293.8177	8.4574
3	0.39	0.04	280.2391	10.8134

Figure 5: Division of the cadastral unit of Jacovce into larger joined blocks.

According to the analysis in Table 2, the RbC process can also be conducted using the larger joined blocks. The next stages of the RbC were tested in both configurations of the blocks.

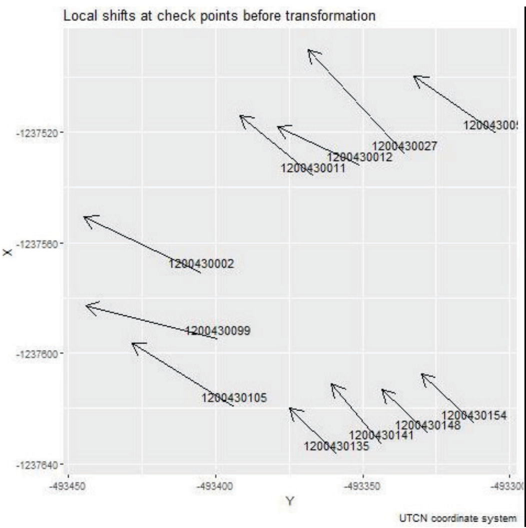
These stages of the RbC process were conducted using a combination of applications "VCMt Precising" and "Correction", which was proven to be reliable and effective for the purposes of this process (Kyseľ, 2021). The second and most important stage of the RbC process is the correction of the VCMn with a transformation in the blocks of parcels, where the first stage showed that they were homogeneous. In this case, all the blocks were homogeneous according to the homogeneity analysis. The transformation parameters were calculated separately for each block using 4 to 5 identical points in each of them, which were distributed around the perimeter of the block. An example of configuration of identical points in one of the blocks (no. 3) is shown in Figure 6. In the second scenario based on the large joined blocks, there were 9 identical points used for the block no. 1, 8 points for the block no. 2 and 4 points in block no. 3. The result of the transformation is a repaired VCMn without any local shifts inside the transformed blocks.

Figure 6: Configuration of identical points (red circle) and check points (green square) in the block no. 3.

The last stage of the RbC process is the final control. The positional deviations Δp and azimuths in the UTCN system α are calculated on a set of check points located between their position determined by a GNSS-RTK measurement and the position in the transformed map. The measured position is taken either from the new measurement or from the POINTS layer. An example of check points configuration in block no. 3 is shown in Figure 6 (green squares). In case of the smaller blocks, there were 10–15 check points in each block. In the second option with the larger joined blocks, all the check points from the first case were used, so there were more than 200 check points in the block no. 1 and approximately 100 points in the block no. 2. The check points used for the final control were the same that were used for the initial homogeneity analysis of the map geometry. The calculated positional deviations should not exceed value of 0.24 m. If this condition is fulfilled at all the check points, the RbC process is considered successful. The average values and standard deviations of positional deviations (Δp_{AVG}, $\sigma_{\Delta p}$) and azimuths (α_{AVG}, σ_{α}) and maximal values of positional deviations (Δp_{MAX}) were determined for each block in case of the small blocks (Table 3) as well as the large joined blocks (Table 4). Results of the "Correction" application include also an arrow graph, which illustrates the local shift vectors before and after the transformation in a particular block. An example of the arrow graph from the block no. 3 is shown in Figure 7.

Table 3: Final control of the RbC process—small blocks

Block no.	Δp_{MAX} [m]	Δp_{AVG} [m]	$\sigma_{\Delta p}$ [m]	α_{AVG} [gon]	σ_{α} [gon]
1	0.24	0.11	0.06	146.8604	119.8904
2	0.16	0.08	0.04	207.9364	167.0356
3	0.24	0.12	0.06	208.1381	142.1052
4	0.19	0.09	0.07	138.2175	98.2180
5	0.12	0.06	0.03	147.3772	100.6835
6	0.17	0.08	0.04	248.4657	121.7595
7	0.24	0.14	0.08	233.7562	69.1246
8	0.17	0.08	0.04	184.5431	157.2860
9	0.20	0.08	0.05	258.1704	58.6228
10	0.14	0.09	0.03	249.8082	42.7609
11	0.09	0.04	0.03	300.5399	104.2134
12	0.16	0.08	0.04	208.1988	128.1507
13	0.16	0.06	0.04	231.7657	104.6111
14	0.17	0.09	0.05	87.5392	73.6622
15	0.15	0.09	0.03	225.9100	83.1996
16	0.18	0.10	0.04	259.0551	134.9314
17	0.21	0.09	0.05	280.1971	108.1555
18	0.17	0.07	0.04	190.0210	72.1937
19	0.12	0.07	0.04	231.5883	166.3152
20	0.19	0.10	0.05	191.6062	89.0856
21	0.05	0.02	0.01	155.0553	57.5922
22	0.10	0.05	0.03	237.6180	112.6937



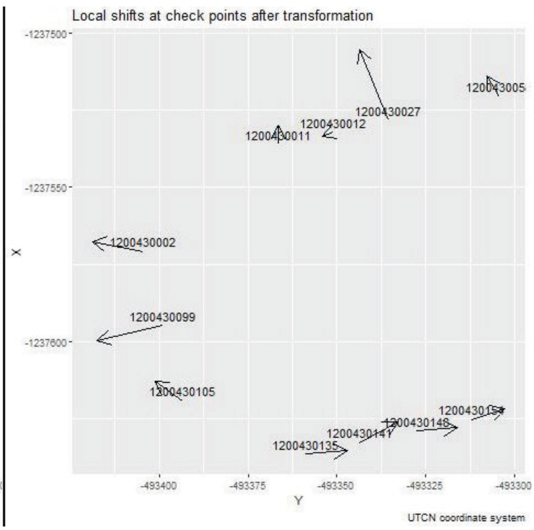


Figure 7: Arrow graph of local shift vectors before (left) and after (right) the transformation in the block no. 3.

Table 4: Final control of the RbC process—large joined blocks

Block no.	Δp_{MAX} [m]	Δp_{AVG} [m]	$\sigma_{\Delta p}$ [m]	α_{AVG} [gon]	σ_{α} [gon]
1	0.24	0.09	0.05	210.5852	100.8680
2	0.24	0.11	0.06	229.7365	86.1017
3	0.12	0.07	0.04	231.5883	166.3152

The final part of the last stage of the RbC process is an analysis of the areas of the parcels through which the borders of the blocks pass. In Table 1 and Table 2, it can be seen the local shift vectors have different properties in each block, so the areas of these border land parcels can change. According to the regulations, the area of a land parcel calculated on the basis of coordinates of points in the map can differ from the value recorded in the cadastral descriptive information file, but the difference (d_p) must not exceed the value of allowed difference (U_p) calculated according to formula (2) (Decree no. 461/2009).

$$U_P = a\sqrt{P} - b, \qquad (2)$$

where P is area of a land parcel recorded in the cadastral descriptive information file, and a, b are coefficients, which acquire values according to the scale of the original analogue map given by the Annex no. 14 to the Decree no. 461/2009 (Decree no. 461/2009).

For the original map scale 1:1000 in our case of cadastral unit of Jacovce, the acquired value of the coefficient a from the Annex no. 14 is 0.42 and the value of the coefficient b is 0.40. For example, for the land parcel area P = 1000 m2 the allowed difference Up is equal to 13 m2.

The areas of the border parcels were calculated after the transformation of the map and compared to the values recorded in descriptive files of the cadastre. The analysis for both options is shown in Table 5.

Table 5: Analysis of the border parcel areas after the transformation

	Small blocks	Large blocks
Total no. of border parcels	53	31
No. of parcels $d_p \le U_P$	40	18
No. of parcels $d_p > U_P$	13	13
- of which no. of parcels with recorded ownership rights	6	8
- of which no. of privately-owned parcels with recorded ownership rights	3	4
- of which no. of parcels with ownership rights not recorded	7	5

If Tables 1 and 2 are compared to Tables 3 and 4, it can be seen the RbC process was successful in all blocks in both situations. After the homogeneity analysis, the values of local shift vectors size varied from 0.30 m to 0.60 m, and the standard deviations of their size and direction were low, which meant that their nature was systematic. After the transformation, the maximum average value of local shift vectors size in a block is 0.11 m. In some blocks, the maximum value of positional deviations is 0.24 m, which is a marginal value, but it still meets the requirements. The standard deviation of azimuths after the transformation is high, which means that the systematic nature of local shifts was eliminated, and the positional deviations between the transformed map and the measurement are caused only by stochastic errors of the original and new measurements. This fact is also visible in Figure 7. In Table 4, it can be seen that the average values of positional deviations are well below the marginal value, and the local shifts were eliminated in the whole built-up area of the cadastral unit of Jacovce using only 3 blocks. The use of smaller blocks is probably more accurate because the local shifts can be represented in a more detailed way, but the results are not dramatically worsened by joining the blocks. This means that the process could be very simple and fast. Table 5 shows that there are no dramatic changes in the areas of the parcels which create the border between blocks. In both alternatives, d_p exceeded the maximum allowed value only in case of 13 parcels in the whole cadastral unit, which would need a correction. However, a big part of them does not have the ownership rights recorded in the cadastre, so the areas could be corrected without any problem. In the other group where the ownership rights are recorded, a half of parcels are publicly-owned in both cases. The correction of these areas would be painful for their owners, but they would be rewarded by a better quality of the recording of their real estate. Overall, the testing of the RbC process in the cadastral unit of Jacovce can be assessed very positively, and it could be used in other cadastral units with a VCMn with local shifts. However, before the implementation of this process into the surveying practice, more testing is needed.

The new measurement was conducted using the GNSS-RTK method, and therefore only the fences could be measured. However, in Slovakia, it often happens that the fence is not built on the property border, so these points are not as reliable for the RbC process as other points, such as corners of buildings. Nevertheless, it is a compromise to ensure higher effectiveness of the method, as the corners would have to be measured with a total station, which would take more time. Alternatively, the building corners could be determined using the UAV photogrammetry. However, the effectiveness of this method in the RbC process has not been assessed yet. In the past, boundary stones were used for the reliable signalization of the boundaries, but nowadays they are no longer used and most of the historical stones have been destroyed, so they also cannot be used for this process.

The main advantage of the RbC process is that the map geometry could be renewed in a short time with minimum costs, while only the parts of the cadastral unit with local shifts would be renewed, contrary to a new mapping, which is conducted in the whole cadastral unit. Other advantage is that the surveying works can be conducted without the presence of the parcel owners.

The disadvantage of this process is that it is applicable only for the VCMn where, according to the homogeneity analysis, the error areas can be delimited distinctly, and a new additional measurement is needed in most of the cadastral units in order to determine identical and check points. If the homogeneity analysis results in a conclusion that a block is not homogeneous, there is no other option but a new cadastral mapping. However, the process could be a cheap and fast alternative to a new mapping in the VCMn with local shifts.

4 CONCLUSIONS

In Slovakia, there can be local shifts in the VCMn. Their presence is indicated by the objects in the POINTS layer. This layer is included approximately in 40% of all VCMn, but that does not mean that the shifts cannot be found in other maps. A new cadastral mapping would be ineffective in these cadastral units because local shifts usually occur only in a part of the cadastral unit, and the relative quality of the map geometry is high. In the paper, a new way of cadastral map renewal was proposed, called Cadastral

Operate Renewal by Correction (RbC). This process was also tested in the cadastral unit of Jacovce, where there are local shifts in the VCMn.

The first stage consisted in the homogeneity analysis, which showed that there were local shifts in the whole built-up area, and this whole area was suitable for the RbC process. In subsequent stages, two alternatives were used, one with the smallest possible blocks of parcels and one with larger blocks, which were created by joining small blocks with similar properties of local shift vectors. The map was transformed to the correct position, and a final control was conducted on a set of check points in each block. This analysis showed that the RbC process was successful in all the blocks. The result was a correct VCMn in the whole built-up area of the cadastral unit with corrections needed only in a few areas of parcels. The advantages and disadvantages of this process were also described. The RbC could be a cheap and fast alternative to cadastral mapping in case of VCMn with local shifts.

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