ISSUES OF CADASTRAL MAPS UPDATING AND ACCURACY FOR ESTABLISHING GIS DATABASES OF DETAILED URBAN PLANS

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SUMMARY

Cadastral map, when the Real Estate Cadastre is being produced, initially contains the boundaries of cadastral parcels, buildings, and cultures. After the formation of the Real Estate Cadastre, under the procedure cadastral maintenance, all changes on real estate which are taking place on the ground are being registered; however, the registration is not done ex officio by the administrative authorities. Practice has shown that property rights holders fail to report a vast number of changes that occurred in relation to the registered status in the cadastre to the administrative authority in a timely manner. A particular problem are the differences between areas in graphical and textual GIS database, and all of the issues above represent a major issue in the case of adoption of cadastral maps as conditionally accurate for the creation and implementation of detailed urban plans. The issue persists in operative cadastre over the entire territory of Montenegro, with its emergence and solution being analyzed in detail on the example of the Municipality of Bar.

Key words: Cadastral Map, Detailed Urban Plan, Immovable Property, GIS, database, DCM Bar.

1 INTRODUCTION

The functioning cadastre is a complete record of public and private rights and limitations pertaining to land users and owners, based on the state survey (Kaufmann and Steudler, 1998). It is being implemented through the

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geodetic-cadastral information system with the database holding coordinated land registration and cadastral mapping.

There is a multi-annual trend in Europe to produce studies on spatial data status. Ever since 2001, status is being evaluated and research results are being subsequently published, in the format of European Commission annual reports, which serve as the foundation for decision making on future plans and projects (Aleksić et al., 2014).

The territory of Montenegro, with the area of 1,382,623 ha, is divided into 23 and 796 cadastral municipalities; with approximately 1,300,000 cadastral parcels, according to the cadastral records. The main issue notable in practice is the quality of existing records as a foundation for the new survey. The majority of cadastral municipalities to be surveyed had been covered by the census cadastre, predominantly used for fiscal purposes – cadastral revenue calculation only. Usability and quality of a property register established in such a manner is limited in several manners.

The Directorate for Real Estate (formerly the Direction for Real Estate) had performed several measurement campaigns of WGS coordinates on more than 1300 trigonometric points and polygonal points in towns, from 1997 to 2011 (Real Estate Directorate , 2010). The measurements were performed using static and RTK method. It was estimated that horizontal position accuracy for points measured by the means of static method is approximately 1 cm, and for the network RTK, the accuracy of positioning is better than 2 cm. Data obtained and subsequently processed and implemented in the MontePos system had provided for completing one of the greatest projects in Montenegro in the field of geodesy – the Unique Horizontal Transformation Model. By developing a unique horizontal transformation model, the Real Estate Cadastre data maintenance had became unified, at least regarding the GNSS technology application. The Directorate for Real Estate had published the project results for the official use in 2012, indicating it as mandatory for all GPS measurements over the territory of Montenegro. This provides for a uniform measurement results quality firstly, i.e. independence from contractor, thus reducing and making the scope of works easier for the local units of the Directorate for Real Estate – both in issuing geodetic base data (being significantly destroyed on the ground) and control of geodetic survey documents.

However, this did not solve the poor heritage of cadastral data. Coordinates of trigonometric points used are not independent from each other. The degree of correlation between neighboring points' horizontal position varies depending on the distance between them, as the result of identical measurement procedures and processing methods used for estimating points' coordinates at the time. In general, stochastic links between the points are stronger for the points in close vicinity, decreasing with the greater distance

between the points. Under the further procedure of quality control, the estimate was done for the Helmert similarity transformation parameters, based on the coordinates of all common points. Having that the least squares method was used, resulting corrections were also obtained. Corrections are the measures of congruence between the new and the existing reference system, serving as the test for existence of blunders, i.e. non-congruent coordinates of common points. Corrections per coordinate axis of the existing reference system were used for this purpose.

By excluding these points from the set of common points, conclusions could have been made regarding the territories where they had occurred. Usually, such points were grouped, indicating that they were locally congruent in general, however poorly fitting the trigonometric network of Montenegro. Measurements on the polygonal points in the towns of Montenegro were also performed for the purpose of parameters determination.

It was characteristic that a significant non-congruence of individual polygonal points was determined in the town of Bar. Understanding etiology and exploratory character of this issue requires laying out theoretical and practical foundation of town trigonometric networks.

The major challenges we are facing today have a critical geographic dimension – especially regarding the natural disasters, climate changes, or urbanization process. Catastrophic earthquake on April 15, 1979 and its consequences on the Montenegrin seaside area, the Municipality of Bar in particular, had imposed the need to use data with greater and more homogenous accuracy in the survey. A local trigonometric network, used for the town survey purpose, commonly named the town trigonometric network, is serving that. It is a part of state trigonometric network, with the link being established by calculating points coordinates in the coordinate system of the state where the city, or most of it, is being situated. The town trigonometric network fundamentally relies on the state trigonometric network and 1st and 2nd order state network, having the shape of triangles with sides length of 1 – 4 km. Part of polygonal lines in Bar is based on the state trigonometric network, and the remaining ones are based on the local network. Data acquisition shows that no official and detailed study on differences in datum of these networks was ever performed. Consequence of their non-congruence are mostly visible in the cadastral maintenance issues. The annual plans of the Directorate for Real Estate of Montenegro recognize the importance of designing resurvey and determination of new polygonal network coordinates in Bar. However, that is yet to be achieved, and the cadastral maintenance will remain difficult and encumbered by many problems directly emerging from the poor data. The problems multiply when using the cadastral maps for developing detail urban plans. The text below provides practical examples depicting possible consequences of taking

parcel data from the local units of the Directorate for Real Estate as conditionally accurate and relevant bases for spatial planning. Although this problem exists all over the territory of Montenegro, the above issues of geodetic networks uniformity in Bar had indicated choice of the examples from the territory of that Municipality. Practical and original solutions are offered, with a prominent explorative character, founded upon the previous results and/or experiences achieved over the territory of ex-YU.

2 PROCEDURE OF CADASTRAL MAPS PRODUCTION AND USE OF THE EXISTING GIS DATABASES

Geographic (geospatial) information is the foundation for local, regional, and global decision-making. The Real Estate Cadastre establishing procedure by the means of the aerial photogrammetric method consists of several phases. The administration organ or contractor delimiters cadastral municipalities, mostly using data from the census cadastre block sketches, produced in 1:10000 scale to identify positions of boundary points defined under the census cadastre production.

Cadastral municipality is a territorial unit that covers a territory of one settlement as a rule, with the law establishing its name, being the fundamental unit for survey performance and production of the Real Estate Cadastre. The administration organ, setting geodetic benchmarks and entering the boundary description in the minutes of boundary demarcation, demarcates cadastral municipality boundary (Law on the state survey and cadastre, 2007).

Before the commencement of acquisition, all owners or property rights holders are obligated to demarcate boundaries of the parcels they use at their own cost, using the visible marks with dimensions prescribed.

Aerial photogrammetric images are the perspective presentation of terrain, meaning that only the point at the center of the image is shown without any deformations. As the distance from the image center grows, deformations increase. Deformations are also a consequence of the acquisition axis slope and the fact that the terrain points are not situated at the same plane, thus the points with the same positions and different heights are projected on the image at different position. Due to that, images are being rendered and ortho-rectified, to remove deformations being a consequence of central projection and acquisition axis slope.

All phases of cadastral maps production are prone to influence of various sources of errors, thus when measuring a value, its “true” value can never be obtained. Measurement errors occur due to the imperfections of measurement equipment, procedures and methods, meteorological

conditions, knowledge of operators, globally categorized as blunders, systematic errors and accidental errors. Blunders mostly occur due to the operator's carelessness or the selection of wrong measuring equipment and may be remedied by the appropriate and correct equipment use in the optimal method, with some of them being removed by statistical tests. Systematic errors are usually the result of imperfections of measuring instruments, methods and external influences, and can be removed or reduced to the acceptable degree by the equipment calibration and selection of the appropriate methods, with the remaining ones being removed by the means of statistical models, being constant or varying in line with a certain rule. Accidental errors result from a great number of factor, differing in value and sign and cannot be mathematically related to the measurement results, thus cannot be eliminated as such. Due to the different errors occurring in all phases of cadastral maps production, presentation of immovable properties on the cadastral maps is not completely true to the immovable properties on the ground.

After completing the aerial photogrammetric acquisition, topographic details recognition on the ground is being performed by zooming in on the aerial photogrammetric image and splitting it into photo-sketches serving as the base for details recognition. Common dimensions of photo-sketches are 40 cm x 40 cm, and the officer identifying details on the ground as acquired and visible at the photo-sketch, so the topographic details may be identified unambiguously providing for acquisition of additional data on immovable properties (e.g. measuring fronts of constructions, designation of fence type). Recognition determines spatial features and inputs them on the photo-sketch to be subsequently shown in the cadastral map. Stereo-plotting procedure provides coordinates of spatial points and production of cadastral maps.

Cadastral parcels areas had been determined in the various manners: from the original measurements, from the measurements graphically taken from the cadastral maps, from cadastral parcel detail points read from the cadastral map or using the planimeter – a device for mechanical calculating of areas. In practice, we are facing numerous examples where difference between parcel area, recorded in property folio, and parcel area, as obtained using the detailed points' coordinates from the cadastral map exceeds the permitted value obtained from the formula (Rulebook on content and method for state survey of immovable properties, draft version, 2015):

$$\Delta = 0.0007 * \sqrt{P} * M \qquad (1)$$

where M is map scale denominator and P is parcel area.

Example 1: *Difference between parcel area in property folio and in cadastral map*

Cadastral parcel No. 746/13 CM Dobre Vode, Municipality of Bar, has the area registered in the property folio of 500 m2, while the area obtained by calculating from detail points' coordinates from the cadastral map is 567 m2, exceeding the permitted difference of 38 m2 for cadastral map scale 1:2500.

Operative capacity and importance of the new IT technologies in geodetic-cadastral records of urban areas is the fact changing the method and dynamics of utilization. GIS with database is the "fuel" accelerating these changes, particularly in the dynamics of registering changes and method of the modern cadastre maintenance (Longley et al., 2005).

On the other hand, data manipulating flows in the cadastral records impose the need to distribute spatial information to the great number of users. User requirements refer to data viewing and searching in the map form, searching through the feature attribute list per certain criteria, layer presentation control and finally generating the appropriate reports and/or base maps.

Regarding the advanced users of these technologies, they mostly cover creating physical and logical data model for spatial information with the integration of available data, and creating the appropriate topology and data analysis. State and local level commonly use the advanced software systems for spatial data management under the ESRI technology (ArcExplorer, ArcMap, ArcCatalog, ArcPad), providing for data manipulation on the local computer or as the fully functional client requesting the GIS data use from the remote server over the internet. For fully functional client, most of the operations related to spatial data manipulation are being performed at the client's side, with server having the role to make the sharable information available. The ESRI ArcIMS serves distribution of maps, data, and metadata by the means of internet. The system is designed for simple creating of maps, development of web pages with interactive maps and WEB-GIS sites administration. The ArcIMS architecture covers presentation, business logic and data level.

Practical use of GIS in the cadastre, Open Source GIS solutions in particular, may increase the error threshold and disturb its standard defined balance. These systems contain numerous modules that the users often use wrongly or apply the models, for the purpose these are not developed, or combine them with data that are not completely consistent. Solution of the problem is for the users of cadastre and its spatial database to become increasingly aware of the spatial data quality issue; especially today when definition of errors and analysis of their propagation or interoperability becomes a routine for modules and tools at disposal of the GIS community.

Furthermore, there is the need to note that an immovable property, i.e. cadastral parcel is not being determined by its area numerically expressed in

the property folio; since that area cannot be identified on the ground without the cadastral map, having that the position, shape and area of a parcel are determined by the boundaries at the cadastral map, shown in a certain scale. In the event when GIS databases contain different area in the property folio and in the cadastral map for a given parcel, the area from the cadastral parcel is the only identifiable and possible to be demarcated on the ground. The logical question follows – why not simply calculate accurate areas of all parcels and enter corrections in property folios, with validation through the GIS database. A legal issue arrises, since the areas registered in property folios were used in legal foundations used for registration of property rights. In the majority of such registration, pursuant the provision of the Real Estate Cadastre data reliability, their accuracy was not questioned. For instance, in the event of immovable property sale, the sale contract always contains the area from the property folio, since only such a contract is a credible document for property rights registration in the cadastral records. If areas calculated from the cadastral maps are to be registered in property folios, the owners would be registered with greater or smaller areas than the ones they had bought, inherited, or being granted by the decision of a governmental organ, etc.

3 ANALYSIS OF THEORETICALLY DEFINED VALUES OF PARCEL BOUNDARY POINTS POSITION DISCREPANCY AGAINST THE EMPIRICALLY OBTAINED RESULTS

Scale for the cadastral maps production (i.e. projected accuracy of parcel boundary points position accuracy) depends of the terrain grade. There are four terrain grades: grade A, grade B, grade V, and grade G; with the land being classified pursuant to the development degree, distance from towns, infrastructure, etc. Depending from the terrain grade, maps were produced in the appropriate scale, as shown in the table below (Rulebook on content and method for state survey of immovable properties, draft version, 2015).

Table 1: Map scales per terrain grades

Terrain grade	A	B	V	G
Map scale	1:500	1:1000	1:2000	1:2500
	1:1000	1:2000	1:2500	1:5000

For each map scale, the Rulebook on Content and Method for State Survey of Immovable Properties determines standards for positions of parcel boundary points and other detail points, as shown in the table below:

Table 2: Standards for boundary points positions depending on the map scale

Map scale	1:500	1:1000	1:2000	1:2500	1:5000
Standard for parcel boundary points position (m)	0.05	0.10	0.15	0.20	0.25
Standard for other detail points position (m)	0.08	0.15	0.20	0.25	0.30

Therefore, if there was a fence, wall or other topographic detail surveyed on the ground at the moment of aerial photogrammetric acquisition, recognized in photo-sketch and shown in the cadastral map by a line, and subsequently surveyed in the field using another method, the difference in position of parcel boundary point surveyed against boundary line position in the cadastral map should not exceed the values shown in the table above.

Apart from the errors in the procedure of the Real Estate Cadastre establishing and the cadastral maps production, erroneous positions of cadastral parcels boundaries are a consequence of not adhering to the regulations under the Real Estate Cadastre maintenance procedure, primarily when performing cadastral parcels subdivision based on measurement of fronts (Đurović, 2011).

Example 1: *Boundary position discrepancy in the field against its position in the map as the result of the errors in the procedure of the Real Estate Cadastre establishment and cadastral maps production*

Practical example refers to the boundary line between cadastral parcels No. 2142 and 2143/1, CM Polje. Boundary line between the two parcels was established from the aerial photogrammetric acquisition in 1987, used for production of cadastral maps, scale 1:1000. Parcel boundary points position standard for map scale 1:1,000 is 0.10 m, i.e. 10 cm. Based on the detail points acquisition over the existing concrete wall on the ground using polar method, coordinates of points in state coordinate system were calculated, unambiguously determining its position. After mapping the points on the cadastral map, it was determined that the existing wall on the ground has positional deviation of 0.43 m against the position of cadastral boundary between the percels No. 2142 and 2143/1, CM Polje.

In theory, this discrepancy may be due to land usurpation or error in the cadastral map production procedure. For the reason above, the photo-sketch (zoomed part of aerial photogrammetric map) was viewed, containing a clear designation that at the time of acquisition, the boundary line between the parcels No. 2142 and 2143/1 coincided with metal fence on concrete wall, with the auxiliary building being present in the southeast of the parcel No. 2143/1, still existing on the ground. This indicates that the wall was not

moved since the time or aerial photogrammetric acquisition, thus the boundary line discrepancy between the ground and cadastral boundary is the consequence of the cadastral map production procedure, meaning that the boundary point position discrepancy is 0.43 m instead of 0.10 m permitted.

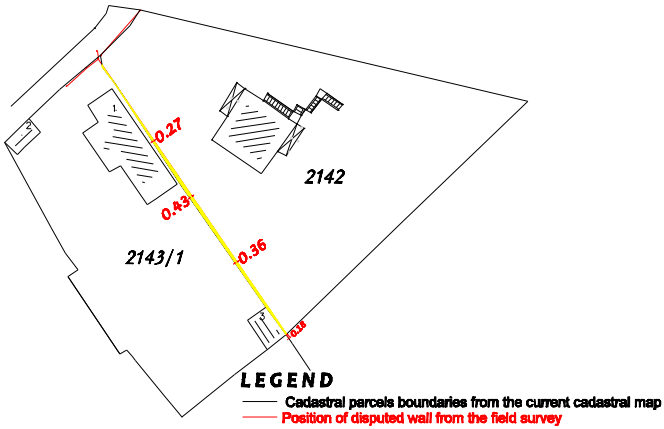

Figure 1: Presentation of cadastral parcels No. 2143/1 and 2142 CM Polje, Municipality of Bar

Example 2: *Discrepancy of boundary position on the ground against its position on the map resulting from errors (lack of officer's skills) in parcel subdivision under the Real Estate Cadastre maintenance procedure*

The Real Estate Cadastre maintenance involves registration of changes that had occurred after the Real Estate Cadastre establishing, by performing detailed survey by the means of polar, orthogonal or lately GPS method on the spot, producing survey sketch, and use it to map changes in the cadastral map working original and register accordingly in the cadastral records – property folio, after passing a resolution on enforceability.

A certain number of survey sketches serving as the base for cadastral parcel subdivision do not contain detail points coordinates for newly formed cadastral parcel – lengths of parcel fronts are shown only, depicting parcel geometry, without determining its position in the state coordinate system. This does not provide for precise and unambiguous immovable property position determination, having that the survey was done using the tape (which provides for measuring slanted area only, not horizontal area (reduced to a plane)). Commonly, due to the lack of knowledge or effort, altitude differences were also not measured, thus the slanted areas only remained.

At the location named "Zeleni pojas", settlement of Susanj, Bar, cadastral parcels No. 832 and 825, CM Susanj, subdivided to establish several hundreds of parcels inside their boundaries, parcel subdivision was performed exclusively by measuring front lines of the parcels on the ground, although ground has significant slope. Predominantly for that reason, there were major (up to several meters) discrepancies between the boundary position on the ground and in the cadastral map.

Example 3: *Practical example of cadastral parcel boundaries deviation against their actual position on the ground (1)*

Detail points of cadastral parcel No. 832/125, CM Susanj were surveyed, and after being mapped on the cadastral map, the analysis of boundary position on the ground was analyzed against their position in the cadastral map. Figure 2 shows boundaries of the cadastral parcel No. 832/125, with red showing the position of boundaries from the current state acquisition on the ground, and black showing position of boundaries from the current cadastral map. Discrepancies at the characteristic were also shown, reaching 5.96 m, and the parcel was "shifted" towards northeast.

This provides for adjusting boundaries on the ground and cadastral map under the DUP parcels subdivision and resolving property rights relations. Had the processing officer established the urban parcel to match the owners – cadastral parcel, there would be no possibility to adjust boundaries, thus the owner of the cadastral parcel No. 832/125 would hold a part of neighboring parcel in his property at the southwest, while the part of property between the red and the black line at the northwest would be outside his property, although he is registered as the owner.

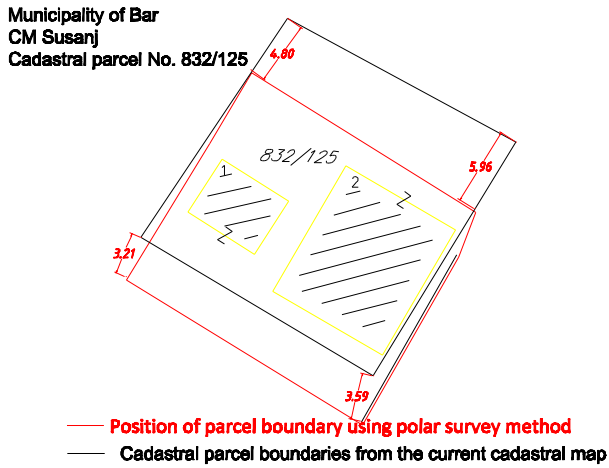

Figure 2: Boundaries of cadastral parcel No. 832/125 CM Susanj

Example 4: *Practical example of cadastral parcel boundaries deviation against their actual position on the ground (2)*
The same location provides an example where the position of road is fully wrongly shown in the cadastral map, so when its position is demarcated on the ground from the coordinates, its position "crosses" the existing buildings, with the road factually existing on the ground, however behind the building's northeast side.
Figure 3 shows position of the cadastral parcel No. 825/171, CM Susanj, with blue line showing the factual position from polar method survey on the ground and black line showing position in the cadastral map. In the northeast of the parcel, there is a road, which, according to the data from the cadastral map, "crosses" the existing, surveyed buildings.
Pursuant to the positions of the existing immovable property boundary on the ground and the boundary positions of the cadastral parcel No. 825/171 in the cadastral map, conclusion emerges that the property owner holds in the field the yellow marked area under his property without being registered as the property rights holder; it is registered as the part of non-categorized road pursuant to the cadastral data instead (although the road is actually situated above), while the area in green is outside the fenced property of the immovable property owner, although he is registered as property rights holder for that part of parcel.

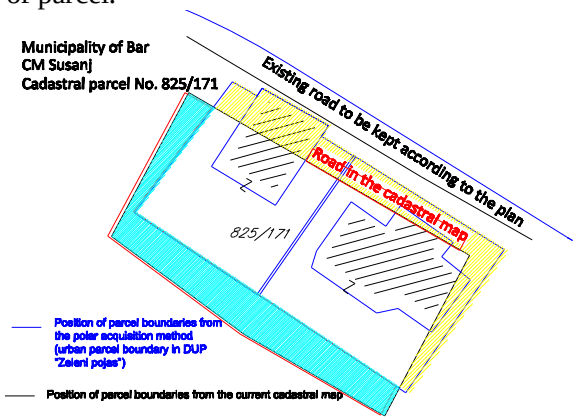

Figure 3: Boundaries of cadastral parcel No. 825/171 CM Susanj

Accepting cadastral boundaries as conditionally accurate and planning the road at the position of the road shown in the cadastral map would invoke the situation to trace the road over the existing buildings, and such buildings could not be registered in the cadastre. Having that these non-congruencies of immovable property boundaries are not a consequence of boundaries moving and usurpation on the ground, and are caused by erroneous mapping

in the cadastral map, great damages would be imposed to the property owners, caused by the fault of governmental organs, and not their own fault. For that reason, the need for accurate and precise determination of current situation is obvious prior to drafting the planning documents, to avoid the problems when implementing the plan.

The examples above indicate that the position of cadastral parcels boundaries shown in the cadastral map cannot be accepted as a priori accurate; instead, for the purposes of detailed urban plans production, there is a need to provide quality and updated geodetic base maps. However, due to the lack of financial means, practice usually opts for alternative solutions, meaning the use of existing cadastral and topographic maps, along with the data collected by authorized geodetic organizations in the Real Estate Cadastre maintenance procedure.

4 CONCLUSIONS

Practice daily imposes the problems caused by the low quality of data in the cadastral records. The lack of financial resources often imposes the necessity to use the existing cadastral and topographic maps as the only available data on immovable properties, topographic features and relief, used as the foundation for urban planners to plan space and draft proposals for establishing urban parcels, roads and other various purpose areas.

The major challenges we are facing today have a critical geographic dimension – especially regarding natural disasters, climate change, or uncontrolled urbanization process. Shortcomings of cadastral records and non-precision in the existing GIS databases, described in the paper as the causes of problems when drafting and implementing urban plans, may be divided into three categories: outdated cadastral data reflected by a vast number of changes that had occurred on the immovable properties on the ground and not being registered in the cadastral map and the cadastral records, inaccurate positions of cadastral parcel boundaries, topographic details and difference between the areas registered in the property folios against the areas obtained by calculating from the cadastral map. More precisely, there is the need to resolve the issue of data quality in the spatial cadastral database – not only in the data domain (thematic, spatial, and temporal), but more importantly – for the data quality components (origin, accuracy, resolution, completeness, consistency).

Operative capacity and importance of the new IT technologies in geodetic-cadastral records of urban areas is the fact changing the method and dynamics of utilization. GIS with database is the “fuel” accelerating these changes, particularly in the dynamics of registering changes and method of

the modern cadastre maintenance. The majority of parcels, out of some 1,300,000 in Montenegro, suffer the issue of non-congruence of data in graphical and textual database. This is the fact that complicates and imposes operative complexity of the relation: services – cadastral database – user. Due to the noted problem of non-uniform geodetic networks in Bar, the paper analyzes several examples and offers solutions for the territory of this Municipality.

Procedure of cadastral parcels subdivision pursuant to the planning project provides for resolution for the issue of cadastral parcel boundaries position discrepancies against the position of the fences existing on the ground, providing that the planning officer receives updated and quality cadastral – topographic maps prior to commencing parcel subdivision planning. Otherwise, if cadastral positions of immovable properties boundaries and topographic features are to be accepted, the possibility to coordinate the existing situation in the field and the status in the cadastral records is being eliminated.

The issue of non-congruence between the parcel areas registered in the property folio and the areas obtained by calculating from parcel detail points coordinates from the cadastral map must be solved initially in the cadastre, since it cannot be resolved in the planning documents drafting phase. One of the methods is to perform adjustment of parcel areas in property folios to the parcel areas in the cadastral map by correcting the areas in the property folios, in line with the areas calculated from the map. Justification of such an approach is in the fact that the numerical area shown in the property folio is an abstract data, having no significance on its own unless it is congruent with the area on the cadastral map, being identifiable as such on the ground.

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