"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
*http://enviro.vgtu.lt*

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.174
DOI: https://doi.org/10.3846/enviro.2017.174

# Evaluation of the Possibilities to use the Photogrammetric Method to Determine the Course of Boundaries of Cadastral Parcels during the Modernization of the Cadastre

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**Abstract.** In Poland, there are still many cadastral districts with the outdated database of the real estate cadastre. The situation which is particularly unfavorable occurs in southern Poland, on the territory of the former Austrian cadastre. This study presents a procedure for the comprehensive modernization of the real estate cadastre, carried out in numerous cadastral districts in the years 2014–2015, as part of the national project: Development of an Integrated Real Estate Information System. The modernization of the cadastre carried out in Gorlice district, province of Malopolska, served as an example to analyze the difficulties associated with the transformation of the analog materials and cadastral documents contained in the geodetic and cartographic documentation center database, often dating back to the times of the Austrian partition, into cadastral data in the electronic form, valuable in terms of accuracy and quality.
The article presents the stages of determining the course of parcel boundaries, performed with the use of modern photogrammetric method. This method significantly accelerates the works related to the modernization, however, it is not flawless. Nevertheless, this is the method of the future, which definitely shortens the task performance time.
The conclusions which were formulated therefrom can accelerate and streamline the modernization process of the cadastre using photogrammetric measurements to determine the course of boundaries of the cadastral parcels in the subsequent modernizations of the cadastre, as planned in Poland.

**Keywords:** boundaries of cadastral parcels, modernization of the cadastre, photogrammetry, real estate cadastre.

**Conference topic:** Technologies of Geodesy and Cadastre.

## Introduction

Pursuant to the Regulation on the register of land and buildings (Regulation of the Minister… 2001), after its amendment in 2013 and in 2015, modernization of the cadastre involves some technical, organizational and administrative actions to be taken by the district governor. The main aim of the modernization is to create a full set of cadastral data, presented in electronic form as a database (Janus *et al.* 2016; Siejka 2016). Therefore, the modernization involves the supplementation of the existing cadastral database, and the cadastral data which was included in the database before the modernization are modified and updated. Having completed the modernization process, the cadastral data should be up-to-date and consistent with applicable legal regulations (Busko, Meusz 2014).

This study is mostly devoted to the procedure of determining the course of boundaries of cadastral parcels using photogrammetric method. This is the method which is commonly used today by contractors of modernization works. The paper presents its advantages, as well as problems which might occur while determining the boundaries. The choice of measurement methods and technologies used is of great importance and should be made with regard to the expected measurement accuracy, but taking into account the economics of the measurement project and optimizing the time devoted to surveying (Busko *et al.* 2014).

In the southern and south-eastern Poland, there are still numerous cadastral districts in which the existing materials and documents date back to the former Austrian partition (Busko, Przewiezlikowska 2016). The modernization process allows to transform them into the cadastral data contained in electronic form, valuable in terms of accuracy and quality, also very important in terms of real estate management, as well as for conducting analyses and real estate transactions (Jasinska 2014; Noszczyk, Hernik 2016). Currently, Poland is involved in the implementation of the project of the Integrated Real Estate Information System – ZSIN. The construction of ZSIN was commenced in Poland in 2013, when the agreement was signed for co-financing of this project from the Operational Programme Innovative Economy 2007–2013, as part of the priority axis 7 "Information Society – establishment of electronic administration". In order to create ZSIN, 72.4 million zlotys were allocated, including 61.5 million zlotys from the European Union grants, which accounted for almost 85% of the total cost of this project.

The object, which in 2015 was subjected to the cadastral modernization procedures (which form the basis of this study), is situated in the Malopolska province and is part of the Gorlice district. It consists of 11 cadastral districts, marked in green in Figure 1.

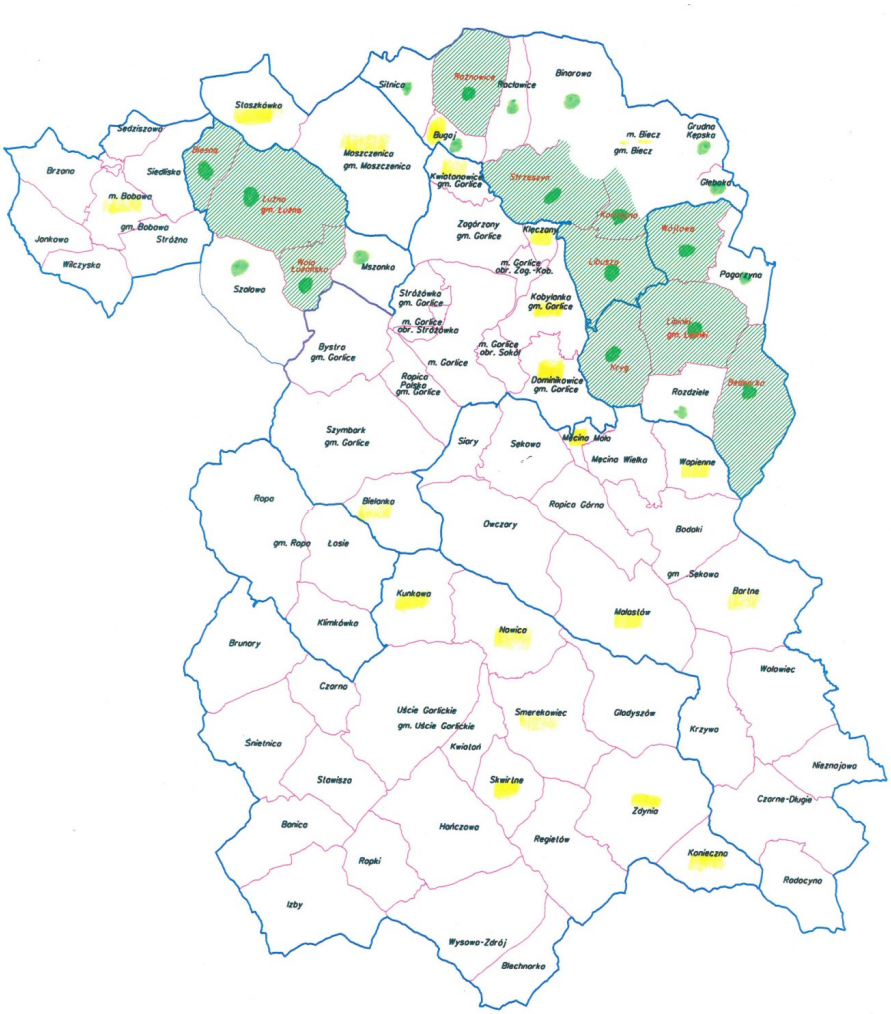


Fig. 1. Gorlice district with the marked cadastral districts which were subjected to the modernization procedure

## Materials and methods

The administrative procedure regulating the mode of the modernization of the register of land and buildings is contained in Article 24a of the Geodetic and Cartographic Law (The Act of… 1989). The secondary legislation relating to the processes implemented as part of the modernization are contained in Chapter 2 of the Regulation on the register of land and buildings (Regulation of the Minister… 2001). These issues were also the subject of the analyses in numerous scientific studies (Cagdas, Stubkjaer 2015; Dawidowicz, Zrobek 2014; Lisec, Navratil 2014). One of the most important tasks to be performed by the surveyor during the modernization of the cadastre is to determine the course of parcel boundaries (Hanus *et al.* 2014). Pursuant to §35 and §36 of the Regulation on the register of land and buildings (Regulation of the Minister… 2001), the surveyor must use all available sources of data on the position of boundary points and indicating parcel boundaries (Balawejder, Noga 2016). First of all, individual technical reports included in the database of the District Geodetic and Cartographic Documentation Center (PZGiK) are analyzed. The surveyor decides whether the information contained is reliable. Unfortunately, the legislature does not specify precisely what is meant by the term "reliability" of cadastral data. Certainly, however, the data is considered unreliable when they do not provide the accuracy required for boundary points. Pursuant to §61 section 1 of the Regulation on the register of land and buildings, the position of boundary points should be determined basing on detailed surveys with mean errors not exceeding 0.30 m relative to the 1$^{st}$ order geodetic control. Boundary points are assigned an attribute defined in the cadastral database as the mean error of the boundary point position (referred to as BPP). Depending on the accuracy of determining the boundary point, the BPP attribute can take the values from the closed interval of 1–6. This means that reliable boundary points are those for which BPP = 1 (accuracy of 0.00–0.10 m) and BPP = 2 (accuracy of 0.11–0.30 m). Figure 2 presents a numerical comparison of the analyzed individual technical reports, of which the reports qualified for use during the modernization were marked in red.

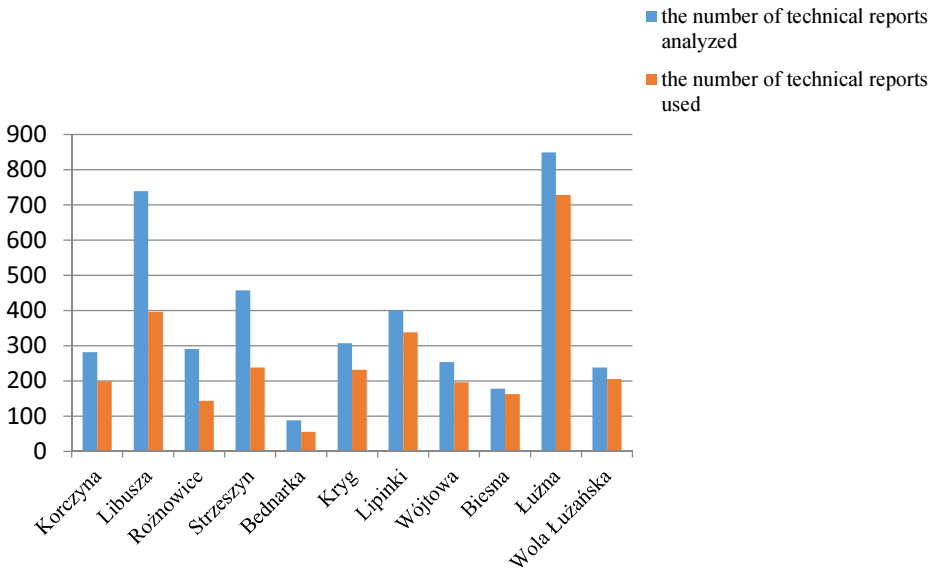


Fig. 2. The number of technical reports used in individual cadastral districts (source: own study)

As it is demonstrated in Figure 2, some part of the technical reports had to be rejected as they were not the source of reliable data to determine the course of the boundaries of cadastral parcels. The reasons for them being rejected are illustrated in Figure 3.

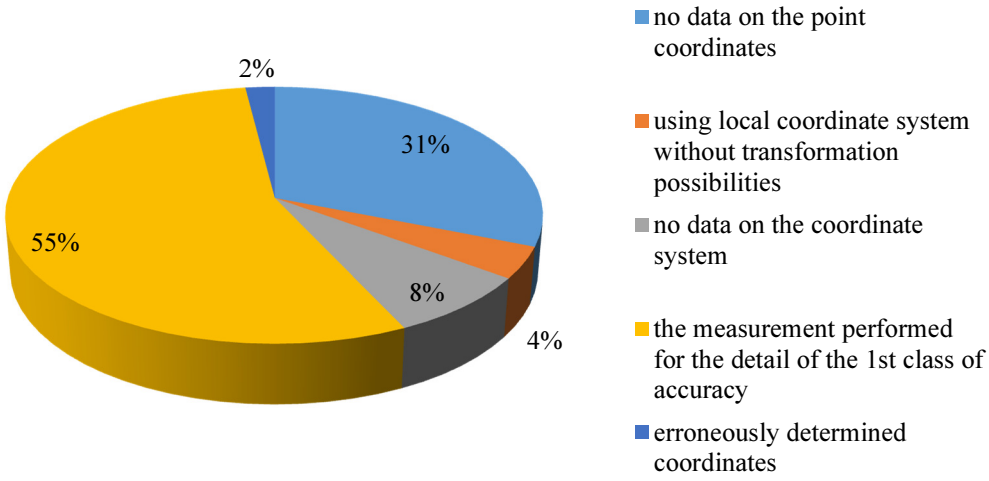


Fig. 3. The reasons for rejecting technical reports during the analysis of the source materials

If, for a given plot of land, there is no individual technical report, or the data contained therein is considered unreliable by the surveyor, then the data on the course of boundaries of such a parcel shall be determined subject to field measurements or photogrammetric surveys, preceded by the determination of the course of these boundaries – §37 section 1 of the Regulation on the register of land and buildings (Regulation of the Minister… 2001). According to several studies, when determining the boundaries using photogrammetric method, a sufficient resolution of the orthophotomap is 10 cm. However, a much better quality orthophoto material is achieved with the photogrammetric pass including high-resolution aerial photos with a pixel of the ground resolution not exceeding 7 cm (Kurczyński 2014).

Figure 4 illustrates a fragment of the orthophotomap for the same area at different resolutions. On the left there is the orthophotomap of 10 cm accuracy from the database of the Central Geodetic and Cartographic Documentation Center – CODGiK, on the right there is the orthophotomap of 7 cm accuracy, prepared on the basis of the passes dedicated to the modernization of the cadastre, carried out by the modernization contractor – the company MGGP S.A.


Fig. 4. Orthophotomap from the CODGIK database and Orthophotomap prepared by MGGP S.A.

The better quality of the orthophoto material visible on the right of Figure 4 was obtained through aerial photographs taken from a lower level (about 1500 m above the ground), with the number of images ensuring the obtained parameters of 84% of longitudinal coverage and 52% of transverse coverage. The passes were carried out in March, so the leaves of the trees did not obscure the picture of the area.

Digital photogrammetric measurement on the stereoscopic model involves creating vector layers of the digital map. Program operator draws linear objects, marking a characteristic point of the area, while drawing a line specific to a particular object (e.g., a boundary line of the cadastral parcel). The measurement of terrain details involves directing a measurement mark to intersect the surface. The point measured in this way receives the coordinates X, Y, Z. For linear objects, each turn point of the line is numbered and its coordinates X, Y, Z are determined. Therefore, the result of the photogrammetric measurement is a vector set of lines and 3D points. The orthophotomap developed in this way forms the basis for carrying out a comparative analysis of all kinds of data on the boundaries of cadastral parcels, classified as reliable basing on other sources. Having plotted these data and having assigned different colors according to their source, a boundary contour is created – Figure 5.

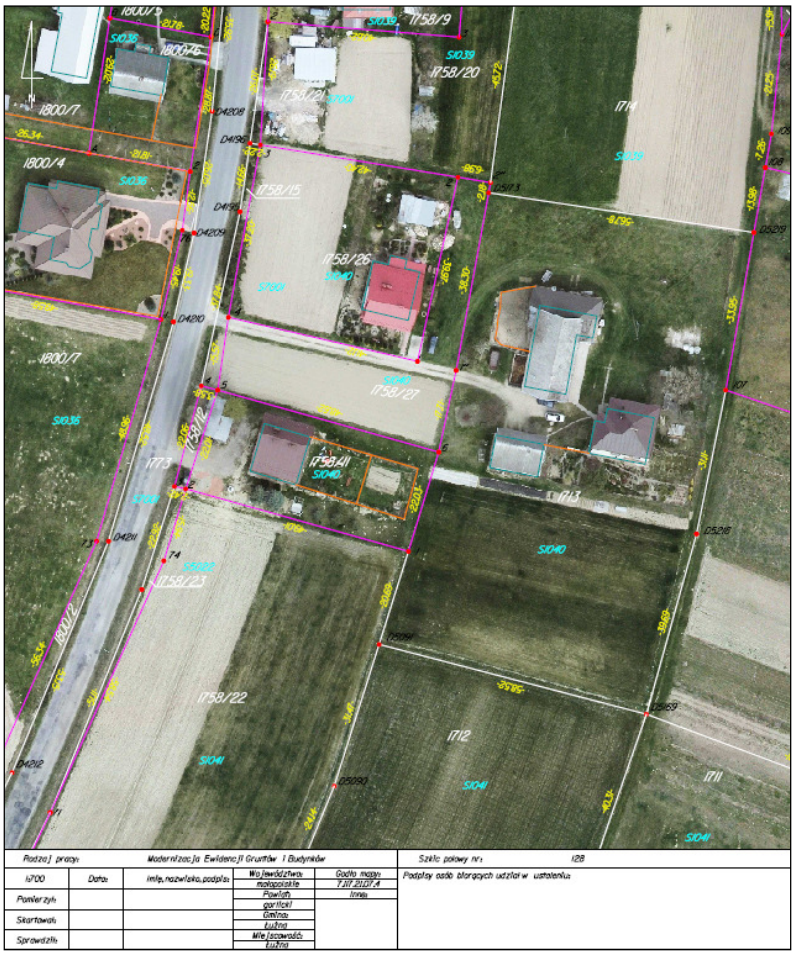


Fig. 5. Boundary contour from determining the boundaries in Łużna cadastral district

The boundary contour should visualize the source of the boundary lines, marking them with different colors. In Figure 5, pink color indicates the boundaries determined basing on the individual technical reports, white – the boundaries from the previously existing cadastral map, orange – the fences existing in the field, blue – contours of buildings. In addition, red color marks boundary points and yellow – linear measures regarding specific boundaries of the parcels.

In the case of measuring the boundaries of cadastral parcels, special attention should be paid to the boundaries of the parcels located in built-up areas. A strict control should be implemented regarding the boundaries determined during the photogrammetric measurements of their course that has been presented basing on the source materials from PZGiK database and the cadastral map. In agricultural land, boundary turn points should be determined on the lines running in the middle the clear boundary strips between plots of agricultural land.

The orthophotomaps prepared in this way in the form of boundary contours are the basis for determining the course of the boundaries of cadastral parcels. The procedure can be carried out indoors instead of in the field, for example in municipal buildings in each village. The presentation of the boundaries should be performed on the computer screen, demonstrating boundaries of cadastral parcels to their owners, perpetual users or spontaneous possessors on the orthophotomap. It is necessary to specify the exact dates and times for individual parcels, notifying the parties interested in the common boundary to arrive on the same day and at the same time. During the determination procedure, relevant documents must be prepared, such as protocols of determining the boundaries of the parcels and boundary contours. If the parties agree on the presented course of boundaries, then the contour and the protocol should be signed by all the parties to the proceedings and by the modernization contractor.

**Discussion**

For the analyzed object of the modernization, all the boundaries of the parcels were established using the photogrammetric method. About 80% of all the procedures of determining the boundaries were carried out without any comments from the owners. In about 10% of the cases, the parties requested to introduce changes to the proposed boundaries of the parcels, and the remaining 10% demanded that the determination of the course of the boundaries of the cadastral parcels should be carried out in the field. Fig. 6 illustrates a pie chart demonstrating the effects of the applied solutions while determining the courses of the boundaries of cadastral parcels using the photogrammetric method.

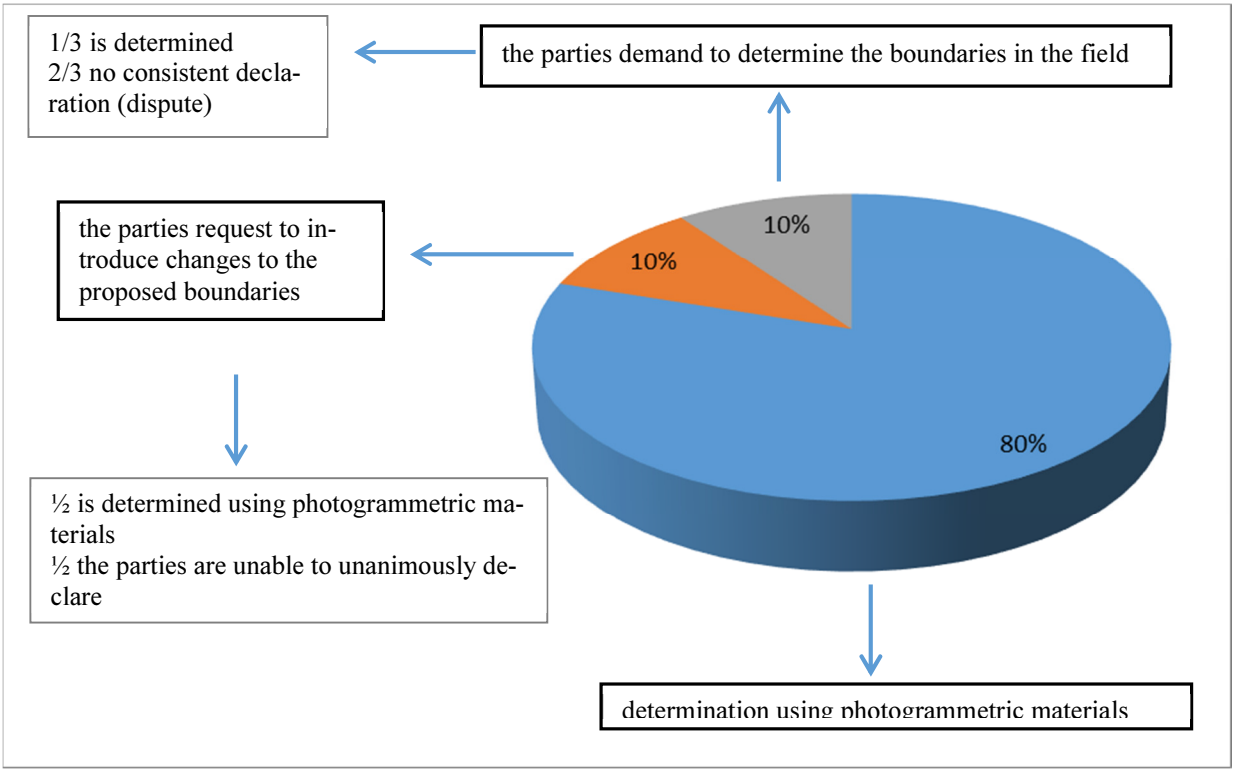


Fig. 6. The solutions (procedures) applied while determining the courses of the boundaries using the photogrammetric method

The beneficiaries of the modernization of the cadastre can be divided into three groups: districts, municipalities and cadastral entities (owners). In the District Geodetic and Cartographic Documentation Center the missing cadastral data is completed, and the quality of the previously existing record data is improved (Przewiezlikowska, Busko 2014). Before the modernization of the register of land and buildings, in each of the districts, only about 10% of the boundary points were determined with the required accuracy of 0.30 m – (§61.1. of the Regulation 2001). After the modernization, more than 90% of the boundary points meet the required accuracy – they are characterized by the attribute of the

error of the boundary point position BPP 1 (the accuracy of 0.00 m–0.10 m) or BPP 2 (the accuracy of 0.11 m–0.30 m). Table 1 demonstrates the improved data quality as exemplified by the three districts. The Table contains a comparison of the number of boundary points and their position error BPP before and after the modernization.

Table 1. The number of boundary points in Łużna cadastral unit – the state before and after the modernization

| District | State before the modernization Number of boundary points | | State after the modernization | | | |
|---|---|---|---|---|---|---|
| | | | Number of boundary points | | | |
| | estimated | determined with the required accuracy | total | BPP 1 | BPP 2 | determined with the required accuracy |
| Łużna | 17000 | 1300 | 17861 | 9785 | 1190 | 10975 |
| Biesna | 5000 | 400 | 5722 | 3333 | 253 | 3586 |
| Wola Łużańska | 5200 | 450 | 5644 | 3004 | 308 | 3312 |

The overall characteristics of the quality of boundary points after the modernization of the cadastre in the discussed object is illustrated in Figure 7.

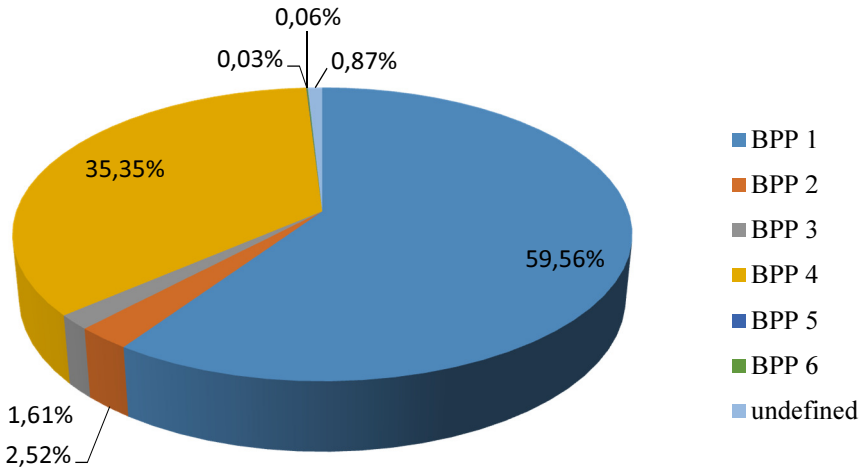


Fig. 7. Percentage share of the value of the BPP attribute of the boundary points in the districts after the modernization of the cadastre

**Conclusions**

The use of the photogrammetric technology to determine the course of the boundaries of cadastral parcels during the modernization of the cadastre results in a number of advantages:

- For larger areas, it reduces the time needed to carry out the modernization of the cadastre.
- It allows for a greater control of the implementation of the works related to the modernization, and therefore there are fewer errors.
- It allows to visualize a larger area, making contacts with the owners of the parcels easier.
- The prepared survey is uniform in terms of time, up-to-date and easy to verify in case of any comments made by the owners of the parcels, even after a longer period of time.
- A great material is created, documenting not only the course of the determined boundaries, but also the topographic details existing in the field (Van Gils *et al.* 2014).

The above-mentioned advantages can be gained subject to fulfilling the necessary conditions and rules relating to the use of the photogrammetric method:

- The captured images must be characterized by the adequate quality, which is associated with carrying out the passes at low level (about 1500 m above the ground) and a large number of pictures taken, which should ensure a value of more than 80% of longitudinal coverage and over 50% of transverse coverage.
- The photogrammetric passes should be conducted in the months of March–April and October–November, with no cloud cover and with moderate wind.
- The condition of a correct performance of the determination of the boundaries of cadastral parcels basing on orthophotos is that the operator should prepare the orthophotomap on the basis of the measurements carried out on the stereoscopic model, as described in this article.
- Before the commencement of the modernization of the cadastre using the photogrammetric technology, it is necessary to run informative meetings for the residents, with the participation of local government units, district and municipality representatives. During these meetings, even before the procedure of determining the boundaries of cadastral parcels, the owners should be familiarized with the specificity of this technology, its course and advantages.
- If there are boundary markers in the field, the date of the pass must be announced earlier, so that the owners can uncover the boundary markers, or even mark them with white paint.

In Poland, it has not been verified yet what the actual accuracy of determining boundary points is, after the modernization of the cadastre using the orthophotomap. It would be recommended to introduce such check measurements for randomly selected group of boundary points as obligatory for the verification of the results of the modernization of the cadastre. Therefore, as part of the check measurements, classical field surveys (tacheometric or satellite) should be carried out, regarding the position of the boundary points and comparing their results to the results obtained with the photogrammetric method.

**Acknowledgements**

This work has been done as a part of scientific research carried out in Department of Integrated Geodesy and Cartography 11.11.150.
I would like to thank the MGGP S.A. for providing data that enabled me performing scientific research.

**Disclosure statement**

I have not any competing financial, professional, or personal interests from other parties.

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