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An analysis of possibilities for the establishment of a multipurpose and multidimensional cadastre in Poland

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ABSTRACT

An efficiently operating cadastral system may provide the basis for all processes for the purposes of rational and effective property management. The cadastre existing in Poland originates from the 13th century's tradition of land management. However, the work on the construction of an IT cadastral system was only initiated with the issuance of Regulation on the Land and Property Register in 1996. The implementation of its provisions resulted in errors visible in the cadastral documentation up to the present day. Currently, the Land and Property Register *i.e.* a public register serves the function of the cadastre in Poland. Regulation of 1996 initiated the stage of transition of (both descriptive and graphic) documents from analogue forms to digital data carriers. Most often, this was done by means of scanning or digitisation of the existing resources. As demonstrated by earlier studies, the process often failed to include the updating of maps and the verification of the compliance of the descriptive part of the Register Documentation with its graphic part. Moreover, significant inconsistencies were observed between the data originating from the Land and Property Register and the Land and Mortgage Register i.e. a register of rights to properties. Low accuracy of the cadastral data, and the incompleteness of sets of spatial data about cadastral objects create a significant barrier to the construction of a modern cadastral system in Poland. This study constitutes the analysis for the construction of a multidimensional cadastre in Poland, and to identify the groups of problems associated with its implementation. Based on detailed analyses of regulation and conducted case studies, a possibility was indicated for a gradual evolution of cadastral data from the 2D dimension to 3D. The study considered technical and legal conditions of designing cadastral systems worldwide. The proposed solution offers an opportunity to accelerate the construction of a cadastral system which is an effective tool of property management policy in Poland.

1. Introduction

The issues relating to a multipurpose cadastre has been discussed worldwide since the early 1990's. The project of Kaufmann and Steudler (1998) is one of the most important and known scenarios of the development of cadastral systems in the world. As reported by Ting and Williamson (1999): "Throughout history, the relationship of humankind to land has been dynamic. This dynamism has had a direct impact on the creation of cadastral systems and the subsequent evolution of their function." Therefore, "A Cadastre may be established for fiscal purposes (valuation and equitable taxation), legal purposes (land transfers), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection."

In turn, Williamson (2001) notes that: "Cadastral systems are the foundation and an integral component of parcel-based land information systems (LIS) that contain a record of interests in land. These systems are a central component of the land administration and land management systems in a state or jurisdiction". According to (Ting and Williamson, 1999) - This statement shows how far the application of cadastral systems has evolved. Moreover, the trend towards developing multipurpose cadastres to address planning for sustainable development issues as well as fiscal and economic imperatives is evident in a range of Western nations such as: Australia (Williamson, 1996), Canada (MacLauchlan and McLaughlin, 1998), Denmark (Enemark, 1994), Germany, Austria and Switzerland (Hawerk, 1995), New Zealand (Robertson, 1996) and the USA (NRC, 1983).

The issue of a multipurpose cadastre has also been addressed in numerous, more recent international publications. Most frequently, it concerns a broader context in the field of mutual experiences of designing land administration systems. This has been addressed *inter alia* by Bennett et al. (2007), Khalaj and Lashkari (2010), Riecken and Seifert (2012), and Parsova et al. (2012). Therefore, the issue is still topical and valid.

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The recent trends in cadastre development indicate the need to construct multidimensional systems. This has been addressed *inter alia* by Oosterom et al. (2011), Rahman et al. (2012) and Döner et al. (2010). Since 2001, a clear trend towards the construction of a 3D cadastre has been observed worldwide. This involves the development of new construction technologies, and the emergence of complex architectural structures (particularly in towns and cities). This has been addressed *inter alia* by Yu et al. (2012), Ying et al. (2012), Zhang et al. (2016), and Stoter et al. (2017). In Poland, the issues have been addressed in their papers by the following authors: Karabin (2012), Góźdź and Pachelski (2014), Siejka et al. (2014), Dawidowicz et al. (2014), Bydłosz (2015), Mika et al. (2016), Bydłosz (2016), Mika, (2017c), and Dawidowicz and Źróbek (2018).

It should be stressed that Polish cadastre has a long-lasting tradition, as it originates from the 13th century's tradition of land management. However, the work on the construction of a cadastral system was only commenced with the issuance of Regulation on the Land and Property Register in 1996 (Regulation, 1996). At present, the Regulation is no longer valid but the adverse effects of its provisions can be noticed in cadastral documentation to this day (Hanus et al., 2014; Przewięźlikowska and Buśko, 2014; Mika, 2016, 2017a). The Regulation initiated the stage of transition of (descriptive and graphic) documents from analogue forms to digital data carriers. Mass production has begun of digital maps created through the direct processing from the paper version into a computer image by means of scanning or digitisation. Unfortunately, this primarily resulted in the duplication of errors occurring in the Land and Property Register. The processing frequently took place without updating the maps and without verifying the compliance between the descriptive part of the Registry Documentation and its graphic part. Moreover, the actual status of cadastral objects (parcels, buildings, and premises) on the ground was not unified with the legal status disclosed in a separate register known as the Land and Mortgage Register. Here, it should be noted that Polish cadastre may be incomprehensible abroad as the cadastral information on the objects and subjects is collected in two separate databases. The basic database, legally known as the cadastre, is the Land and Property Register. Having considered the global solutions, in particular principles proposed by Kaufmann and Steudler (1998), this database fails to achieve the basic objectives of a multipurpose cadastre as it does not collect legal information on cadastral objects and subjects. It is maintained by County Offices. On the other hand, legal information is contained in a separate database maintained by Land and Property Register Divisions of District Courts.

Fig. 1 shows the succeeding steps of the transformation of the cadastre in Poland over the last 50 years, which indicates the willingness to strive for changes leading to a multipurpose and multidimensional cadastre. These reforms result from the revision of regulations due to political transformations after 1989. A significant incentive to the commencement of the construction of a multipurpose cadastre (and, ultimately, a multidimensional cadastre) was Poland's accession to the European Union in 2004. It was connected with the need to unify regulations, and to introduce European standards. Since 2004, intensified work of the Head Office of Land Surveying and Cartography (GUGiK), aimed at the modernisation of the existing cadastral system, have been observed. An important project in this regard is the commencement of work on the construction of the Integrated System of Real Estate Information. At the moment, the system is not yet fully operational, but in the future it may serve as a multipurpose, or even a multidimensional cadastre. It contains a very extensive concept of the integration of many real estate databases, the practical implementation of which has appeared to be difficult and, as it seems, requires many more reforms. For this reason, it is reasonable to search for alternative solutions. One of them may be the original author's concept of a reduction in the number of databases, shown in Figs. 8 and 9 and discussed further on.

For comparison, a country with a similar recent history i.e. the Czech Republic has succeeded in developing a full-fledged cadastral system which integrates the register of legal and factual data on properties. As reported by Pesl and Slaboch (2002): "After the fall of the communist regime in 1989 a new governmental programme of restitution, privatisation and general economic reconstruction started. The current cadastre could not meet new demands and it was decided to come back to the time-tested principles of previous land register and land cadastre. The result is a "legal cadastre" integrating the land register (legal tool) and the land cadastre (technical tool) into the only instrument administered solely by survey authorities. This solution was accepted as the easiest one under the existing circumstances. In the years 1991 and 1992, new basic cadastral legislation was prepared and came into effect at the beginning of 1993. Thus, 1 st January 1993 is a milestone in the long history of the land cadastre in the Czech Republic and the beginning of the cadastral reform."

Meanwhile, in accordance with the regulations in force, the cadastre function in Poland is still served by a single database, namely the Land and Property Register. In addition, as shown by results of both this and previous studies (Maślanka, 2016; Mika and Leń, 2016) this particular database fails to meet cadastre users' expectations about the quality and completeness of the data collected in it. Modernisation works have been going on for years (Siejka et al., 2015; Mika, 2016) but, unfortunately, they do not bring the results desired from the perspective of interests of all user groups. A major obstacle to the modernisation of the Land and

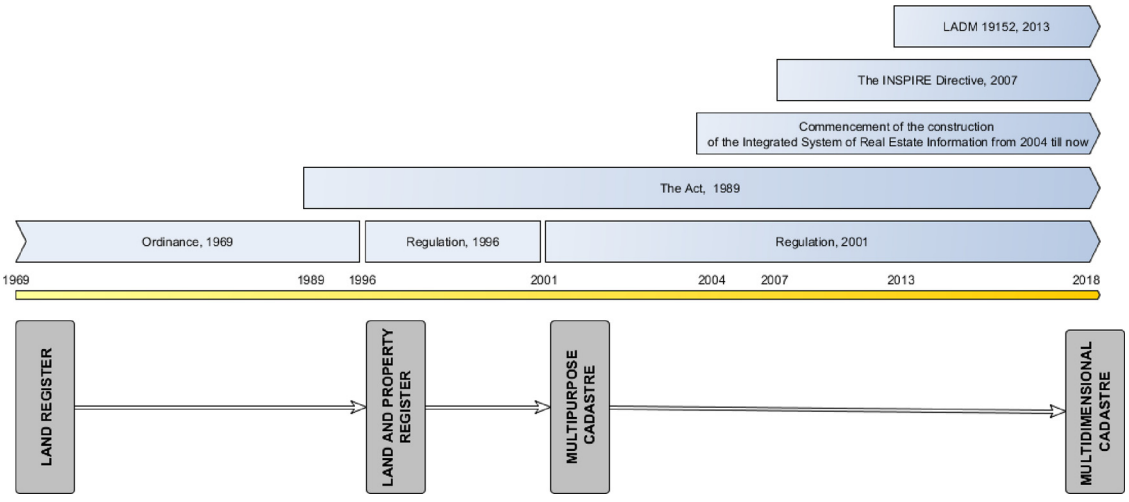

Fig. 1. Stages of the development of a multipurpose and multidimensional cadastre in Poland.

Property Register is the spatial diversity of land throughout the country, which results from historical events and the enforcement of inheritance law over many years. This issue has been addressed *inter alia* by Janus et al. (2016), Kwinta and Gniadek (2017) and Leń (2018).

This study constitutes the analysis of the construction of a multipurpose and multidimensional cadastre in Poland, and to identify the groups of problems associated with its implementation. The main problem is that the Land and Property Register does not contain complete cadastral information, and thus is not a reliable cadastral system. The selection of databases of which the 2D cadastre is comprised, and their development towards a 3D cadastre should be determined by the collection of complete information on cadastral subjects and objects (the so-called cadastral information). This information is dispersed across many databases, and their integration on a common platform is necessary to ensure European standards (Directive, 2007; LADM, 2013a,b).

The subject of this study is the cadastre in Poland. The aim of the study is to analyses legal and technical solutions applied in Polish cadastre as compared to global trends, to determine the prospects for its development, to search for new solutions as regards the construction of a full-fledged cadastre meeting global standards. The input data are provisions of Polish legislations and global standards, the literature on the subject (in both international and national aspects), and reliable land surveying and legal documents originating from the State institutions.

2. Materials

The research material for the purposes of these analyses was primarily the provisions of legislation (The Act, 1989, 2010; The Act, 1997), (Regulation, 1996, 2001; Regulation, 2012, 2015) in the field of cadastre, real estate management, and land surveying. An analysis of these provisions as compared to European standards (Directive, 2007) and (LADM, 2013a,b), and the verification of selected local components of cadastral databases enabled the determination of the current status of the system. They also allowed the obstacles to further stages of cadastral system development in Poland to be identified.

The study area (3166.88 km^2) covered several communes located in Southern Poland in Małopolskie Voivodeship, in Nowosądecki (**NS**), Gorlicki (**GR**) and Bocheński (**BC**) Districts - Fig. 2. The choice of the study area is not accidental. Małopolskie Voivodeship is a specific region in Poland as it is affected by the most visible defects in the spatial structure of land (farm scattering and fragmentation), which have a substantive legal consequences in the ownership structure (Janus et al., 2016; Mika, Leń, 2016). With the consent of authorities maintaining Land and Property Registers, a study on the quality of land surveying materials originating from various databases has been conducted. In Poland, the principle of unity of land surveying works for the entire country applies. Therefore, these materials, even though originating from various land surveying documentation centres, were characterised by identical technical requirements, and yet, an individual approach to the interpretation of regulations was observed, which was reflected in the methods for executing certified reports of land surveying works in the area under study. The inspection covered over 120 randomly selected land surveying and legal documents (official copies of, and extracts from the Land and Property Register and Land and Mortgage Registers). The study was carried out to determine the actual compliance (data validity), legal compliance (as regards the compliance between the actual data originating from the Land and Property Register and legal data for the same property, recorded in Land and Mortgage Registers), and technical compliance (as regards the topological and geometrical correctness of spatial data).

3. Methods

In the study, the following research methods were applied:

- a descriptive analysis (analysis of the literature on the subject for the purposes of the presentation of the concept of a multipurpose cadastre in the world, the presentation of Polish solutions in the field under study with particular emphasis on legal solutions), particularly visible in sections INTRODUCTION and RESULTS.
- a comparative analysis (verification of the degree of compliance of land surveying and legal documentation based on a case study), particularly visible in sections INTRODUCTION and RESULTS.
- a systemic analysis (aimed at the development of an original author's proposal in the form of a schematic diagram of a multipurpose cadastre in graphic notation of systemic analysis according to (Robertson and Robertson, 1999), applied in section DISCUSSION.

4. Results

4.1. An analysis of regulations with regard to the construction of a multipurpose and multidimensional cadastre

Based on a thorough analysis of most important regulations in the

Fig. 2. The location of the research area (yellow) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Table 1
The characteristics of the development stages of the cadastre in Poland over the last 50 years.

Comparative criterion	Transformation stages			
	Land register	Land and property register	Multipurpose cadastre	Multidimensional cadastre
Legal acts	Ordinance (1969)	Regulation (1996)	Regulation (2001)	The INSPIRE Directive, ISO 19152
Data register	Land register	Land and Property Register	Land and Property Register, Land and Mortgage Register, Real Estate Prices and Values Register, Local Area Development Plan or Land Use Plan for the Commune, Orthophotomap.	Land and Property Register, Land and Mortgage Register, Real Estate Prices and Values Register, Local Area Development Plan, Orthophotomap, Land Surveying Register of Utilities Networks, Database of Topographic Objects, Other.
Data format	Analogue maps and registers	Analog and digital maps and registers	2D - digital maps and registers	3D - digital maps and registers
Purpose	Fiscal	Fiscal, statistical	Fiscal, legal, economic, planning, statistical	Fiscal, legal, economic, spatial planning, statistical, other
Object	Parcel Building	Parcel Building Premises	Parcel Building Premises	Land property Building Premises
Subject	Owner, Co-owner, Holder, Perpetual lessee, Possessor	Owner, Co-owner, Holder, Perpetual lessee, Possessor	Owner, Co-owner, Holder, Perpetual lessee, Possessor	Owner, Co-owner,
Type of registered rights	Ownership, Holding, Perpetual usufruct, Limited property rights, Obligations	Ownership, Holding, Perpetual usufruct, Limited property rights	Ownership, Holding, Perpetual usufruct,	Ownership, Holding,
Attributes	Descriptive and graphic (analogue format)	Descriptive and graphic (analogue and digital format)	Descriptive and graphic (only digital format)	Descriptive and graphic (only digital format)

field of cadastre and land surveying adopted after World War 2, a trend towards the construction of the multipurpose and multidimensional systems in Poland can be observed. Table 1 presents the characteristics of the development stages of the cadastre system in Poland over the last 50 years. The table is a supplement to the information provided in Fig. 1 showing schematically particular steps from the Land Register to a multidimensional cadastre.

4.2. A case study of technical documentation originating from land surveying databases with regard to the topological and geometric compliance

An analysis of land surveying documentation i.e. randomly selected sections of numerical maps presenting approx. 30% of the land cover of the area under study detected single topological and geometrical errors, the representative examples of which are shown in Figs. 3 and 4. These errors are possible to be eliminated in the near future, and have been forwarded in the form of a report to local institutions. They can be detected and removed automatically by appropriate software.

4.3. A case study of technical documentation originating from land surveying and legal databases with regard to the compliance between the descriptive data on cadastral objects and subjects

The case study was conducted based on a comparative analysis of land surveying and legal documentation in the form or official copies of and extracts from the Land and Property Register and Land and Mortgage Registers for 120 randomly selected properties. The scale of inconsistencies as regards the descriptive data on objects and subjects registered in the Land and Property Register and in Land and Mortgage Registers confirmed the results of a previous study conducted on another object (Mika, 2017a). Of the 120 examined cases within the study area, a total of 84 errors were found, including those concerning the names of owners (11 cases), the surface area of parcels (14 cases), the surface area of premises (18 cases), building numbers (2 cases), parcel numbers (17 cases), usable land classes (14 cases), and owner's addresses (8 cases). These errors should be verified throughout the country, and removed before incorporating these data into the multipurpose cadastre databases. The problem is that they need to be detected and removed manually. This solution requires time and financial expenditures, which can significantly delay the development of the cadastre in Poland.

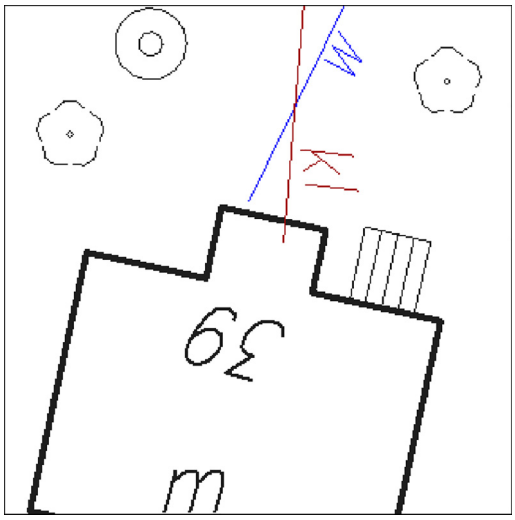

Fig. 3. An example of topological errors.
Source - own materials.

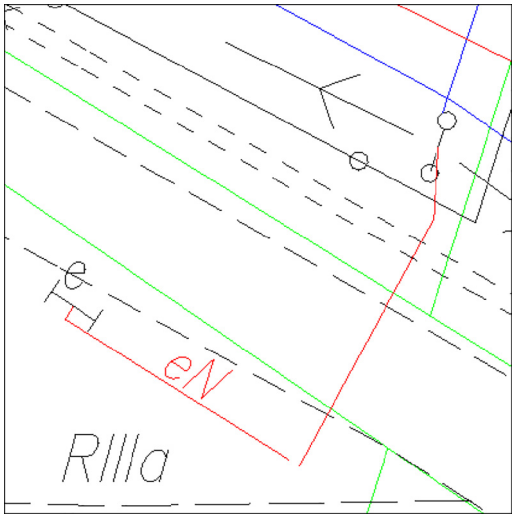

Fig. 4. An example of topological errors.
Source - own materials.

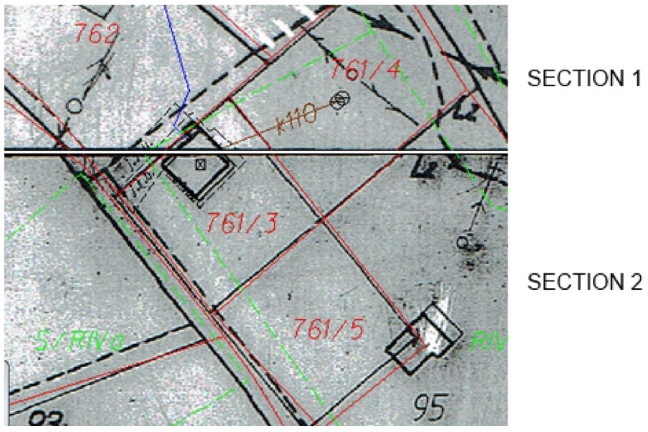

Fig. 6. The differences between information contained in several databases with Gorlice District as an example.
Source - own materials.

4.4. A case study of technical documentation originating from land surveying databases with regard to the readability, quality and compliance of graphic data

A further case study of land surveying documentation revealed significant errors as regards the readability of graphic materials. The test sample covered approx. 30% of the surface of the area of each of the districts under study. Fig. 5 shows an example of an incorrectly selected scale of a map burdened with excessive content. The occurrence of such maps significantly complicates the surveyor's work, and is a major obstacle to the modernisation of the Land and Property Register.

A comparative analysis of the co-existing land surveying maps (the cadastral map and the principal map). The next figure (Fig. 6) shows the result of the overlay the numerical data from the register database (green colour) on the raster of the principal map (black colour) and the result of inventory measurement (red colour). It reveals significant differences in contents of the maps.

In turn, Fig. 7 shows a partial result of an inventory of field details, carried out by means of a field interview in Gorlice District. The objects located on the valid principal map that have not been found in the field are marked in red in Fig. 7.

5. Discussion

It follows from the conducted analyses that at the stage of the development of the concept of a multipurpose cadastre, it is important to properly select databases that provide data in the 2D dimension, and only then to gradually introduce 3D elements in order to create a multidimensional cadastre. Due to the inconsistencies observed in the range of both (spatial) descriptive and graphic data, it seems reasonable to consider the integration of the lowest possible number of databases for the purposes of the multipurpose cadastre. In order for a cadastre to meet its fiscal, legal, planning and other objectives, it should collect, process, and share to users the up-to-date and complete cadastral

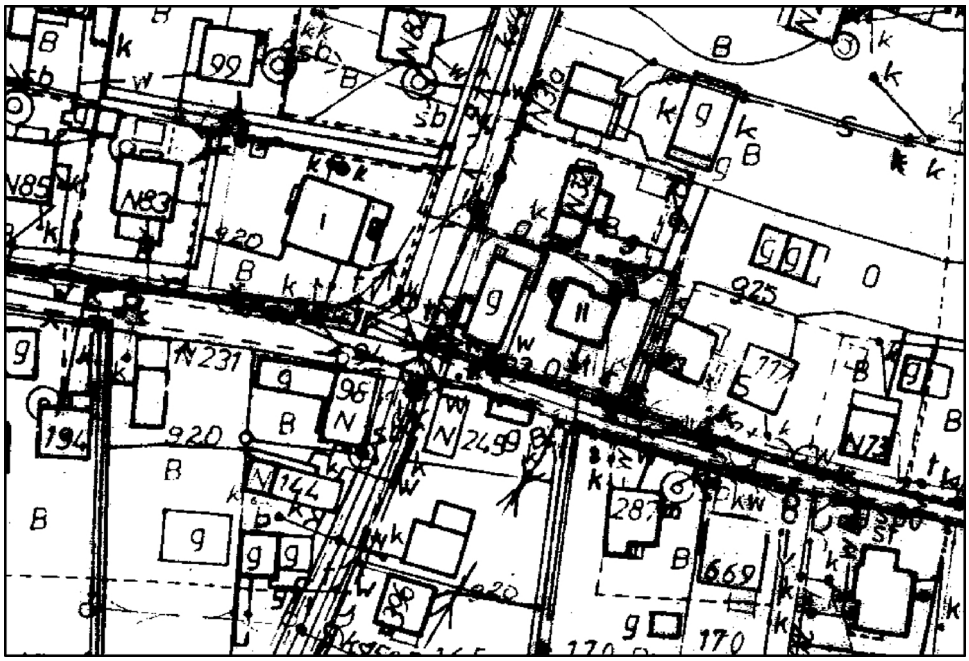

Fig. 5. A section of the principal map of the Barcice area.
Source - own materials.

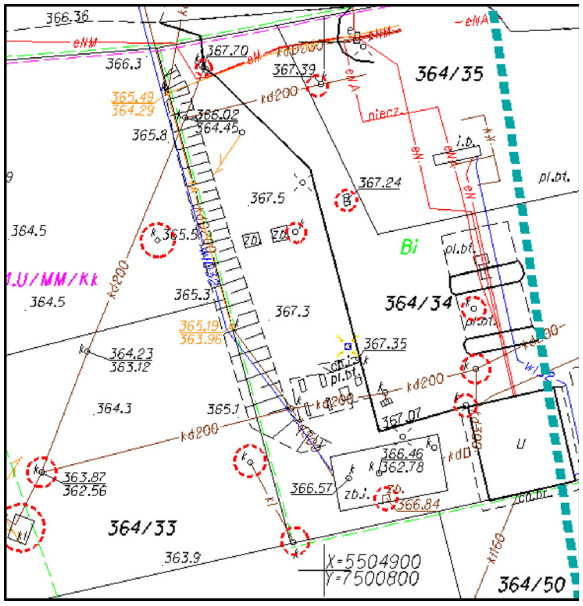

Fig. 7. A section of inventory documentation.
Source - own materials.

information on cadastral objects and subjects. A discussion on the minimum criterion for databases for the purposes of the cadastre, based on legal and technical provisions as well as international requirements, indicated that the best solution appears to be the integration of the following databases:

- In the 2D system - the use of the following land surveying, legal and planning databases is suggested: the Land and Property Register maintained by County Offices, the Land and Mortgage Register maintained by District Courts, Local Area Development Plans prepared for communes or Land Use Plans for communes, and the Real Estate Prices and Values Register in order to supplement the descriptive attributes concerning the values of cadastral objects (Fig. 8).
- In order to obtain 3D information on cadastral objects (land properties, buildings and premises), the use of parts of the following databases is suggested: the Land and Property Register and Land Surveying Register of Utilities Networks, reinforced with information from the Database of Topographic Objects, and synchronisations with descriptive and spatial attributes originating from Land and Mortgage Register, Local Area Development Plans, and the Real Estate Prices and Values Register databases (Fig. 9).

The thus defined cadastral system would contain descriptive and spatial information meeting the formal requirements for the obtaining of complete cadastral information. An orthophotomap may be an additional component of the system.

These considerations can be presented in the form of a schematic diagram of a multipurpose cadastre in graphic notation according to (Robertson and Robertson, 1999). Figs. 8 and 9 present the discussed issue of the integration of components of the existing databases in order to create a multipurpose and multidimensional cadastre containing a minimum number of databases necessary to obtain complete and reliable cadastral information.

6. Conclusion

Based on a thorough analysis of most important regulations in the field of cadastre and land surveying adopted after World War 2, a trend towards the construction of a multipurpose and multidimensional cadastre in Poland can be observed. However, low accuracy of the register data, and the incompleteness of sets of spatial data about cadastral objects create a significant barrier to the construction of a modern cadastral system in Poland. Significant inconsistencies were observed between the data originating from the Land and Property Register and the Land and Mortgage Register i.e. a register of rights to properties. It is therefore necessary to design a system meeting the data interoperability conditions along with verification of the harmonisation of information flow between the databases contained in it. The issue has been addressed *inter alia* by Steudler and Williamson (2005); Ledoux and Meijers (2011). In Poland, this issue was explored *inter alia* by Mika (2017b).

Meeting the above conditions would significantly improve the quality of cadastral data. However, it should be clearly noted that this quality is determined, to a large extent, by the quality of data collected in official spatial databases of which the cadastral system will be comprised in the future. The case study of land surveying documentation revealed significant errors as regards the readability of graphic materials. This is the quality that directly translates into substantive effects of all processes related to property management, since the quality of cadastral data is crucial for making any strategic, planning and design decisions on a local scale. As a consequence, it translates into the quality of data on a global basis (on both the national and

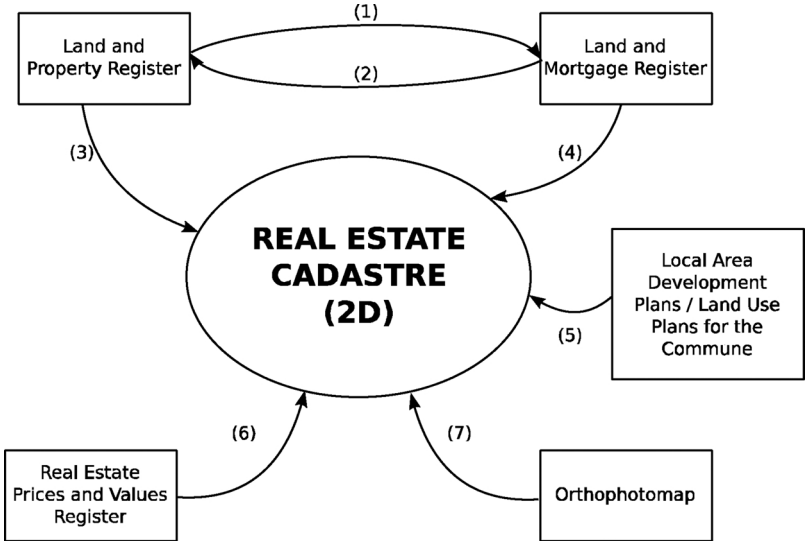

Fig. 8. A schematic diagram of a multipurpose cadastre in graphic notation of systemic analysis according to [Robertson and Robertson, 1999].
where:
(1) and (2) – a feedback loop between the mutual relationships of particular systems,
(3) – a flow of descriptive information on the actual status of a property, and a flow of spatial (graphic) information on a property,
(4) – a flow of information on the legal status of a property,
(5) – a flow of information on the functions and planning intentions,
(6) – a flow of information on the property value,
(7) – a flow of information on the spatial distribution of objects.

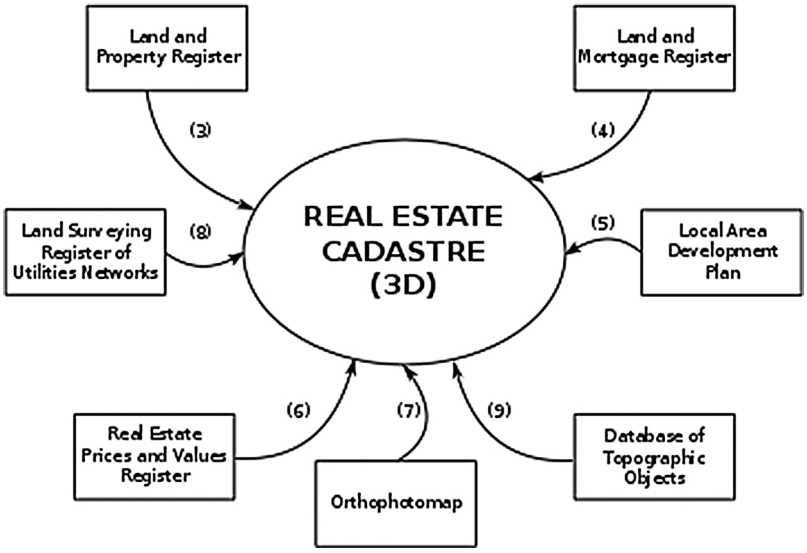

Fig. 9. A schematic diagram of a multidimensional cadastre in graphic notation of systemic analysis according to [Robertson and Robertson, 1999].
where:
(3) – a flow of descriptive information on the actual status of a property, and a flow of spatial (graphic) information on a property,
(4) – a flow of information on the legal status of a property,
(5) – a flow of information on the functions and planning intentions,
(6) – a flow of information on the property value,
(7) – a flow of information on the spatial distribution of objects,
(8) – a flow of information on the utilities networks,
(9) – a flow of information on the land cover and relief, and a flow of information on the location of field objects.

international scale).

Due to the inconsistencies observed in the range of both (spatial) descriptive and graphic data, it seems reasonable to consider the integration of the lowest possible number of databases for the purposes of the multipurpose cadastre. The original author's solution for the construction of a multipurpose cadastre, evolving over time towards a multidimensional cadastre, is an alternative to the national concept of the Integrated System of Real Estate Information.

It requires several conditions to be met:

1 Unification of objects and areas affected by the Land and Property Register and the Land and Mortgage Register
2 Verification of any non-compliance between data collected in selected databases.
3 The creation of a Local Area Development Plan module along with data from the Real Estate Prices and Values Register, as a supplement to data for the purpose of obtaining the property value attribute.
4 The inclusion of the Land Surveying Register of Utilities Networks as the basis of 3D information.
5 The use of the Database of Topographic Objects as the final module enabling the introduction of a multidimensional cadastre.

In the thus defined system, the legal status of objects will correspond to their actual status within the space. Subsequently, the issue of the extent of ownership right and other rights (including limited property rights and obligations) will have to be solved, so that it corresponds to the spatial boundary of objects.

It should be noted that this solution is a simplified version of the Integrated System of Real Estate Information project, as it contains a smaller selection of databases taken into account in the construction of a cadastre. From the perspective of the interests of users of the cadastre system, it is regarded as the core of real estate management.

This concept is technically feasible because appropriate tools, e.g. GIS or CAD software, are available. However, it requires the development of appropriate legal mechanisms by means of administrative changes.

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