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Identification of the spatial causes of urban sprawl with the use of land information systems and GIS tools

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Abstract. Urbanization is one of the processes that determine the development of a country or a region, but it has both advantages and side effects. Some of its aspects may lead to unsustainable growth and dispersion of built–up area. The main causes of this process are increases in costs of transportation, infrastructure and nature conservation. There is a threat of uncontrolled spread of development as a result of urbanization processes, particularly in suburban municipalities. It has been requested by many researches that authorities put more interest in avoiding dispersed suburbanization, but they still are looking for better solutions, tools and procedures to solve this problem.
The aim of this article is to demonstrate the important role of spatial information from land information systems in identifying and predicting the causes of the development of dispersed built–up areas. Thanks to GIS instruments local authorities are more likely to preserve spatial order and avoid the side effects of "sprawling".

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Contents:

1. Introduction

1.1. The concept of suburbanization and its symptoms

The development of areas on the outskirts of a city is conditioned by the interdependencies that occur between the city – as a central hub – and its surroundings – the municipalities located in the closest neighbourhood. Interactions between economic functions of the city and rural areas as well as between the elements of space in the form of a settlement network or infrastructure may be observed in this area (Bański, 2006).

The concept of suburbanization etymologically derives from "suburbium" meaning peripheral area in relation to the developed land in the city or housing area adjacent to the administrative boundaries of the city (in "urban fringe" zone rather than "rural-urban fringe") (Lisowski, Grochowski, 2007).

There are two models of suburbanization (Fig. 1).

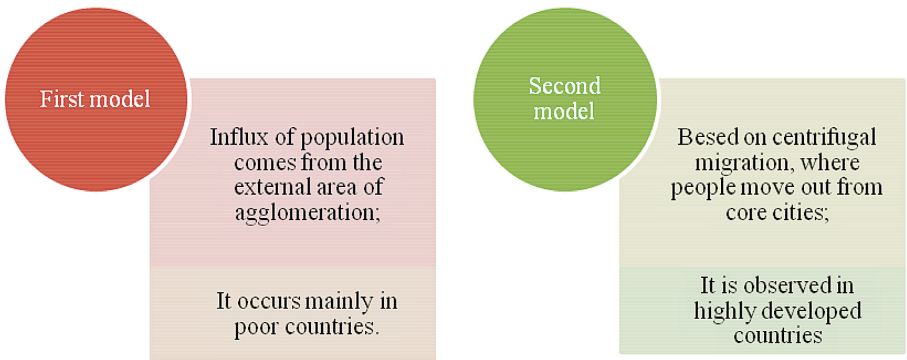

Fig. 1. Models of suburbanization

Source: Own study

In first model the influx of population comes from the external area of the agglomeration and the suburbs are rather underfunded districts of the poor. The second model is based on centrifugal migration, where people move out from core cities to live in smaller towns. They want to own their houses and reside in a natural setting. This often leads to the formation of entire monotonous areas of detached houses, without real contact with nature (it is too dense), or a sense of urbanity.

According to the second model, we may identify the following factors of suburbanization processes:

- ⇨ Freely met housing needs, with the dominant preference for "home with a garden";
- ⇨ The lack of coordination of spatial policy within major cities and metropolitan areas;
- ⇨ The pursuit of developers and investors to develop land which is more easily accessible (quality and price) (Lorens, 2005).

1.2. Urban sprawl – development of built-up and urbanized areas

Human activities contribute to the development of strongly anthropogenised areas. Urban sprawl accompanied by the development of residential, service and industrial functions as well as technical infrastructure leads to changes in the land use structure. There is a continuous increase in the area of land use patterns characteristic of urban territories (Senetra et al., 2014).

Suburbanization may take the form of dispersed suburbanization defined as urban – sprawl. It is a process of "sprawling" the city through the dispersion of built–up areas or urbanized space (Green, 1957). It is also called ex-urbanization.

We may notice here the degree of continuity in development – from a more dense to a more distributed development, because the "sprawl" of the city is a matter of degree, not an absolute form (Chin, 2002). The main features of this process, according to which the area of urban sprawl may be identified in space (Galster et al., 2001; Thompson, 2013), are:

— significant distance between different forms of land use,
— ow development density, particularly per hectare,
— lack of continuity and uniformity of land use,
— unilateral land use, rigorously separated uses (e.g. long distances between housing and retail),
— low centrality of spatial organization,
— local concentration of land use,
— "leapfrogging" past existing areas of build-up, leaving undeveloped gaps,
— dependency on the automobile.

Most of all, sprawl is characterized by development on previously agricultural or natural "greenfield" sites. The diagram of *urban – sprawl* creation is presented in Fig. 2.

This process involves transforming the use land from rural to urban as well as forming single residential buildings instead of farmsteads. Firstly, linear development concentrates along easily accessible public roads – main roads and freeways. Secondly, new roads are built in order to lead to leapfrogging areas, in most cases local communication in peripheral areas is based on internal roads (Wolny, 2013).

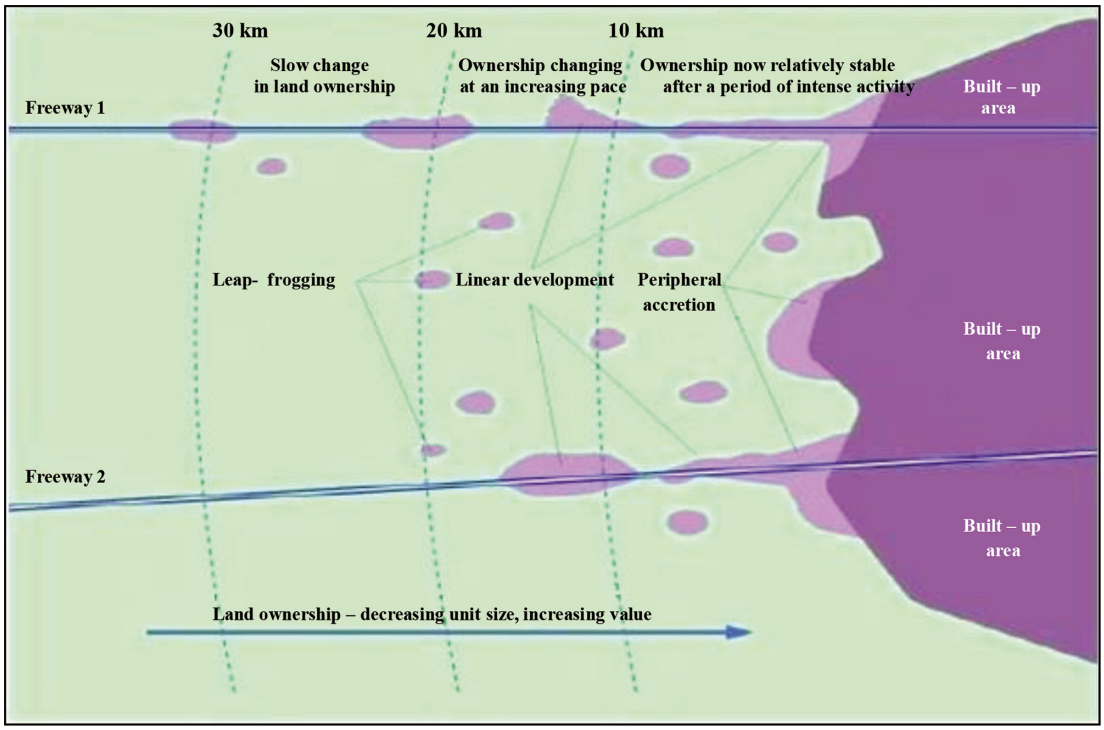

Fig. 2. Urban – sprawl schema

Source: Own study on the basis of Lisowski, Grochowski, 2008 and www.geocases.co.uk

Suburban areas are exposed to a particularly strong investment pressure due to the growth of cities and their expansion beyond urban limits. Such municipalities face the challenge of imposing spatial order on areas experiencing intensive development. On the other hand, lying in the proximity of a city is an important growth stimulant for suburban communes (Wolny et al., 2014).

2. Research materials and methods

In order to identify the spatial causes of urban sprawl there has been made a study of literature on the subject. The study included defining the processes of suburbanization in different spheres and selecting the main features of urban sprawl. The outskirts of Olsztyn – a capital of the Warmia and Mazury province in Poland – has become an area of detailed studies (a case study made in the commune of Stawiguda).

Then to demonstrate the important role of spatial information in identifying and predicting the causes of 'sprawl' there has been made a characteristic of the local land information system. Capabilities of the local land information system are shown against the Land Administration System which will be built in Poland.

The use of land information systems in their current form might be not enough to identify and predict the spatial causes of urban sprawl. That is why GIS software is recommended to be used in order to identify areas of concentration of space transformation caused by suburbanization processes. Therefore, the detailed analyses made in the article include the application of quatric kernel estimation with the use of Saga GIS software, which enables researchers to demonstrate areas of concentration on the cartographic background. Figure 3 shows the main stages of the research and the used methods.

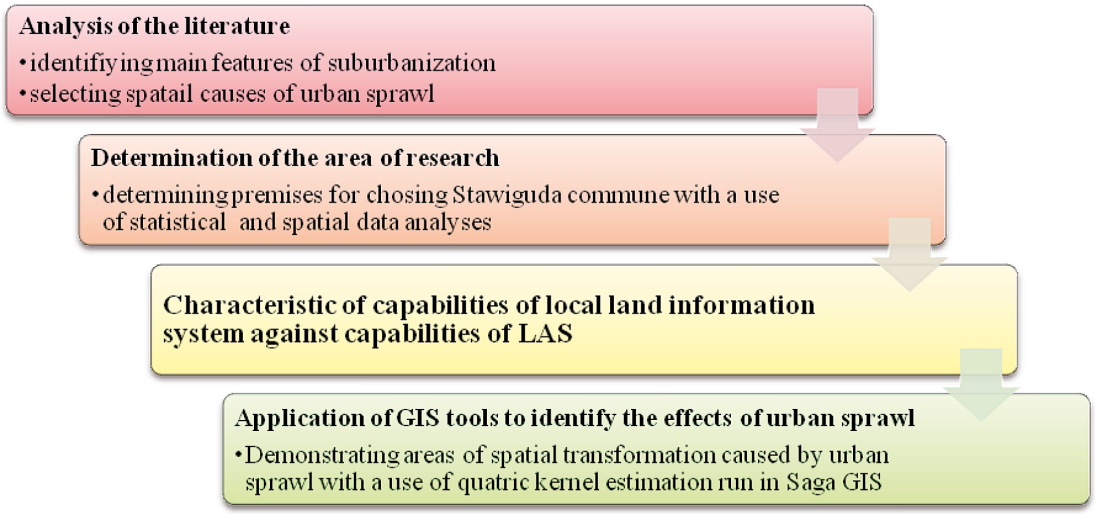

Fig. 3. Stages of research and used methods

Source: Own study

3. Results: Identification and diagnosis of urban sprawl and the use of land information systems and GIS tools

3.1. Local land information system – an example of a system made in the commune of Stawiguda on the outskirts of Olsztyn

There is a great need for local authorities to use land information systems for their purposes. It is also a source of information for local citizens and investors who are interested in developing land.

The use of geoinformation in municipal councils should be evident in its use by the local community which would encounter new technologies while contacting public administration. It will allow for accelerating the process of implementing geoinformation in everyday life (Feltynowski, 2013).

Particularly communes in suburban areas should have their own systems with reliable, continuously updated spatial information. That is why a system created in one of the communes on the outskirts of Olsztyn – the capital of the Warmia and Mazury province in Poland – has been subjected to analyses. The commune of Stawiguda is situated in the south outskirts of Olsztyn (Fig. 4).

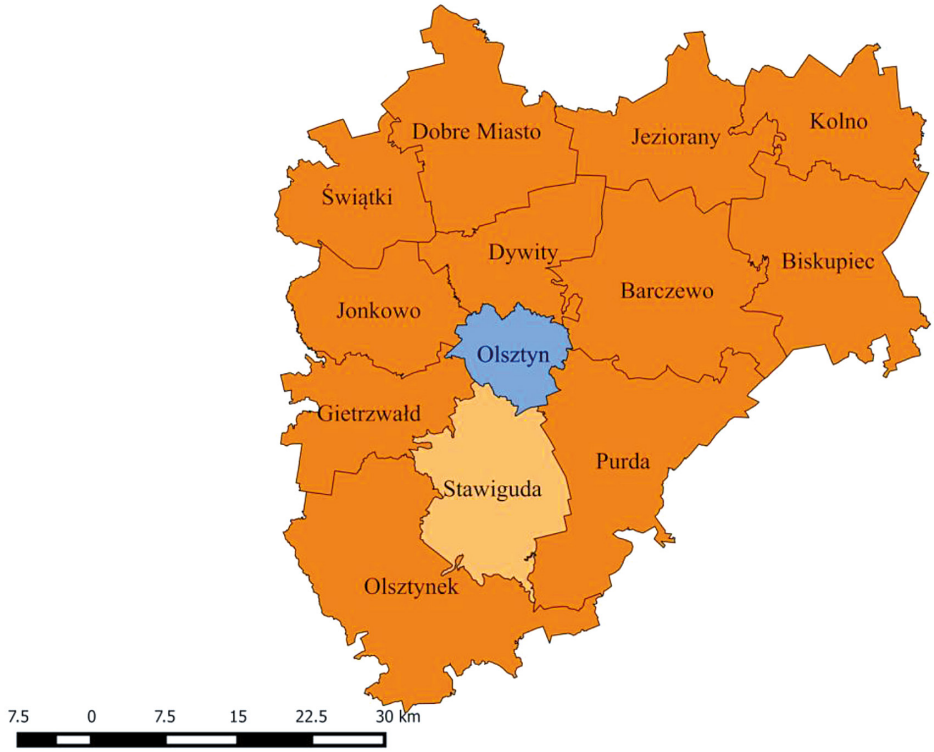

Fig. 4. Location of Stawiguda in the District of Olsztyn

Source: own study, based on data from CODGiK (http://www.codgik.gov.pl/).

According to the data from the Central Statistical Office, Stawiguda is a commune with the area of 22287 km^2. The development of this commune depends on the relation with the core city of Olsztyn. Statistical data such as number of population, population density and net migration prove the suburban character of Stawiguda. Table 1 shows values of the features mentioned above between 2006, 2010 and 2013. From 2006 to 2013 we may observe almost 50% growth of population and population density. These features depend mostly on high values of net migration.

Table 1. Selected statistics characterizing the demographic development

Specification	Values in a period		
	2006	2010	2013
Population	5141 people	6638 people	7696 people
Population density	23 people/km^2	29 people/km^2	35 people/km^2
Net migration	115 people	471 people	258 people

Source: own study based on the data of the Central Statistical Office (www.stat.gov.pl)

Such a developing commune needs instruments to both stimulate and control this development. That is why the municipality of Stawiguda has created a land information system, which is a system designed for various local actors. This system includes different layers and presents information such as:

— boundaries of plots,
— names of districts (villages),
— orthophotomap,
— land use plans,
— visual map,
— topographic map.

Moreover, there are options such as searching for a specific parcel, land use plan with different functions of the land or measuring distance or area. Fig. 5 presents the capabilities of the local system.

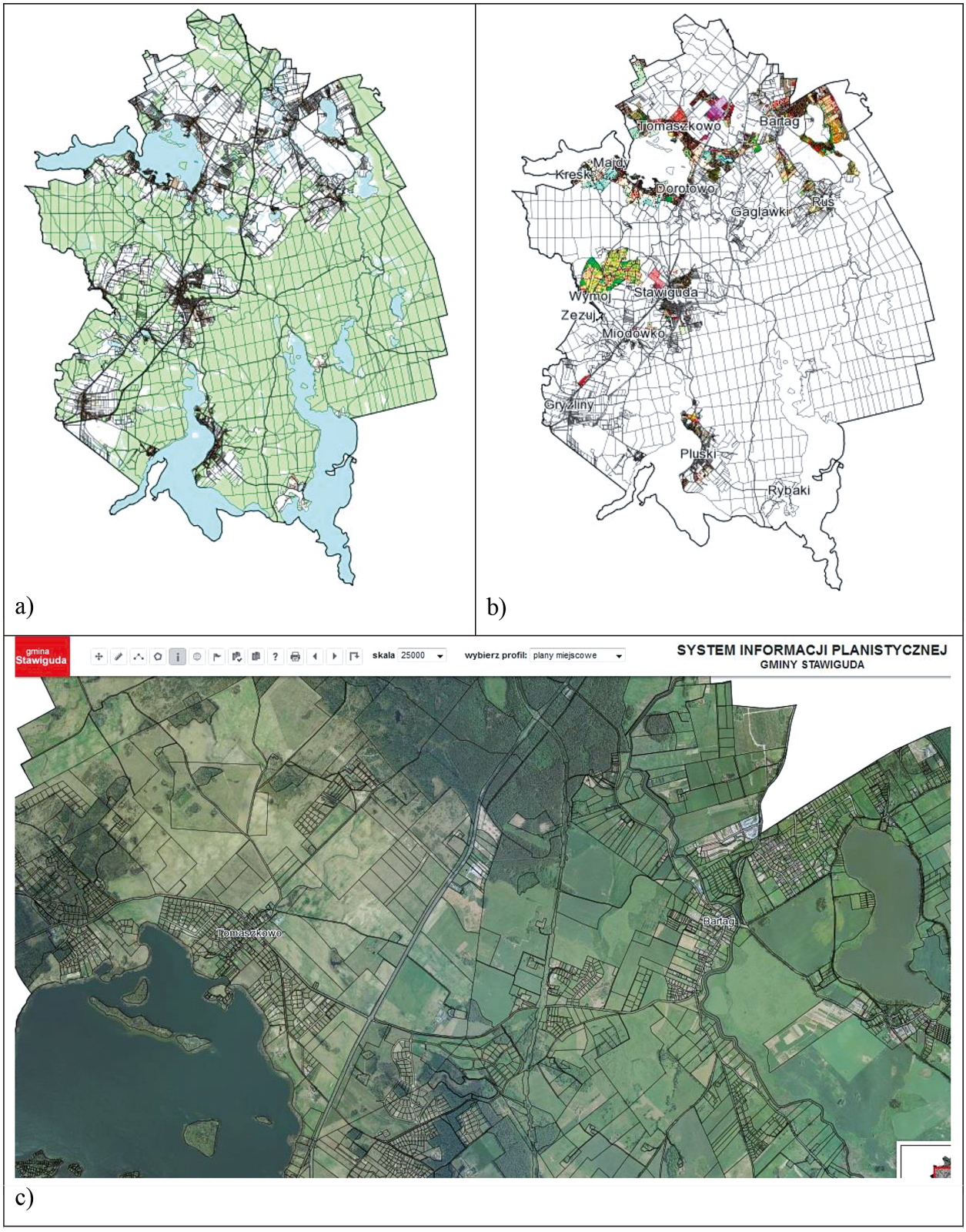

Fig. 5. The use of spatial information system in Stawiguda commune

Explanation: a – Visual map of Stawiguda commune, b – Land use plans in Stawiguda commune, c – Part of the orthophotomap with boundaries of plots in the north part of Stawiguda commune

Source: Own study after http://sip.stawiguda.pl

However, the system does not include all/complete information that helps identify different spatial aspects of suburbanization. More detailed research involving data transformation and visualization against a cartographic background is usually conducted in specialized programs such as: ARC GIS, QANTUM GIS or SAGA GIS.

With the aim to identify areas under development pressure caused by suburbanization processes research has been made in the commune of Stawiguda on the basis of / examining information collected in the period of five years for the needs of the dissertation "The study of changes in land development on the outskirts of Olsztyn caused by investment process with the use of geodetic – cartographic information".

3.2. Characteristics of the Polish Land Administration System

The existence of information systems supporting decision-making for optimal space management is necessary. Therefore, individual municipalities build their own local land information systems independent from particular public registers such as Cadastre, Land and Mortgage Registration, Land Use Plans, Registers of Real Estate Prices and Values, etc. Thanks to the projects of building strategic Land Administration Systems (LAS) developed by FIG (1995, 1996, 2014) and UNECE (1996, 2005a, 2005b),Williamson et al. (2010), the Polish government is redoubling its efforts to create a universal integrated land administration system in Poland. The government plans to create a national LAS called the Integrated Real Estate Information System (**Z**integrowany **S**ystem **I**nformacji o **N**ieruchomościach – **ZSIN**), which will be a multi-purpose register available for public authorities and individuals. The basis for the creation of a national LAS is the Regulation of the Council of Ministers of 17 January 2013 on the Integrated Real Estate Information System.

The ZSIN will functionally integrate the Real Estate Cadastre, Land and Mortgage Register (**N**owe **K**sięgi **W**ieczyste – **NKW**), Tax system, Register of Economic Entities (**Re**jestr **Go**spodarki **N**arodowej – **REGON**), Population Register (**P**owszechny **E**lektroniczny **S**ystem **E**widencji **L**udności – **PESEL**), official register of the territorial division of the country (Krajowy Rejestr Urzędowego Podziału **Teryt**orialnego Kraju **TERYT**), national register of producers and agricultural farms and the register of applications for subsidies (**KSEP**) as well as other public records through the functional specification of **Integrating Electronic Platform (IPE)** which will make it possible to view and transfer data between a number of public registers. A/The diagram of IPE and ZSIN system operations is presented in Figure 6.

ZSIN will be based on the following functional assumptions (Dawidowicz et al. 2014; Buśko et al. 2014):

1) the exchange of data between the real estate cadastre and other public records will be in electronic form,
2) the tele-information system, used for the maintenance of the central repository, is to enable recording, updating and maintaining data files, and making them accessible in GML formats,
3) the applied software should allow for visualizing data and restoring the history of particular objects (Including specification of the object data status at the specified moment),
4) the software enabling automatic generation of notifications of changes to the cadastre, automatic generation of data update,
5) access to data will take place over the Internet,
6) procedures for data conversion and cadastral database updates will be implemented by a set of applications,
7) data integration will be carried out by Integrating Electronic Platform (IPE),
8) data network will consist of LAN and WAN,
9) for the transformation of the source database of real estate cadastre in modern cadastral database there should be installed an application that will integrate the descriptive part and mapping,
10) the applied tele-information system should allow for performing analyses of data files which should concern in particular:
    - preparing monthly reports with information on the number of buildings,
    - performing statistical analyses concerning utilisation of data stored in registers, which are included into the IREIS system,
    - performing analyses of coherence and quality of data files concerning the land and buildings registers,

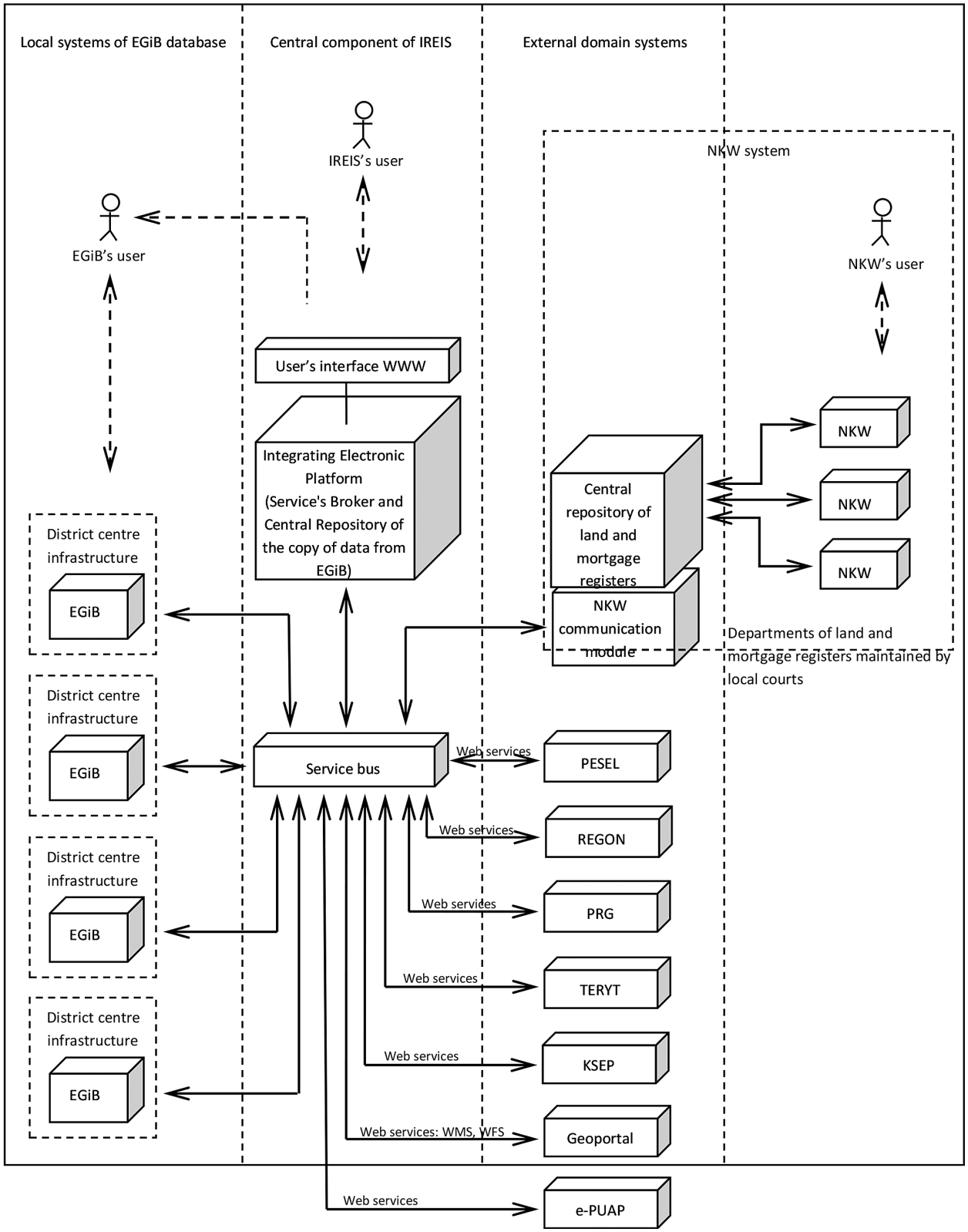

Fig. 6. Architecture of Polish Land Administration System (ZSIN)

Source: Regulation of the Council of Ministers of 17 January 2013 on the Integrated Real Estate Information System

and performing spatial analyses (Fig. 7).

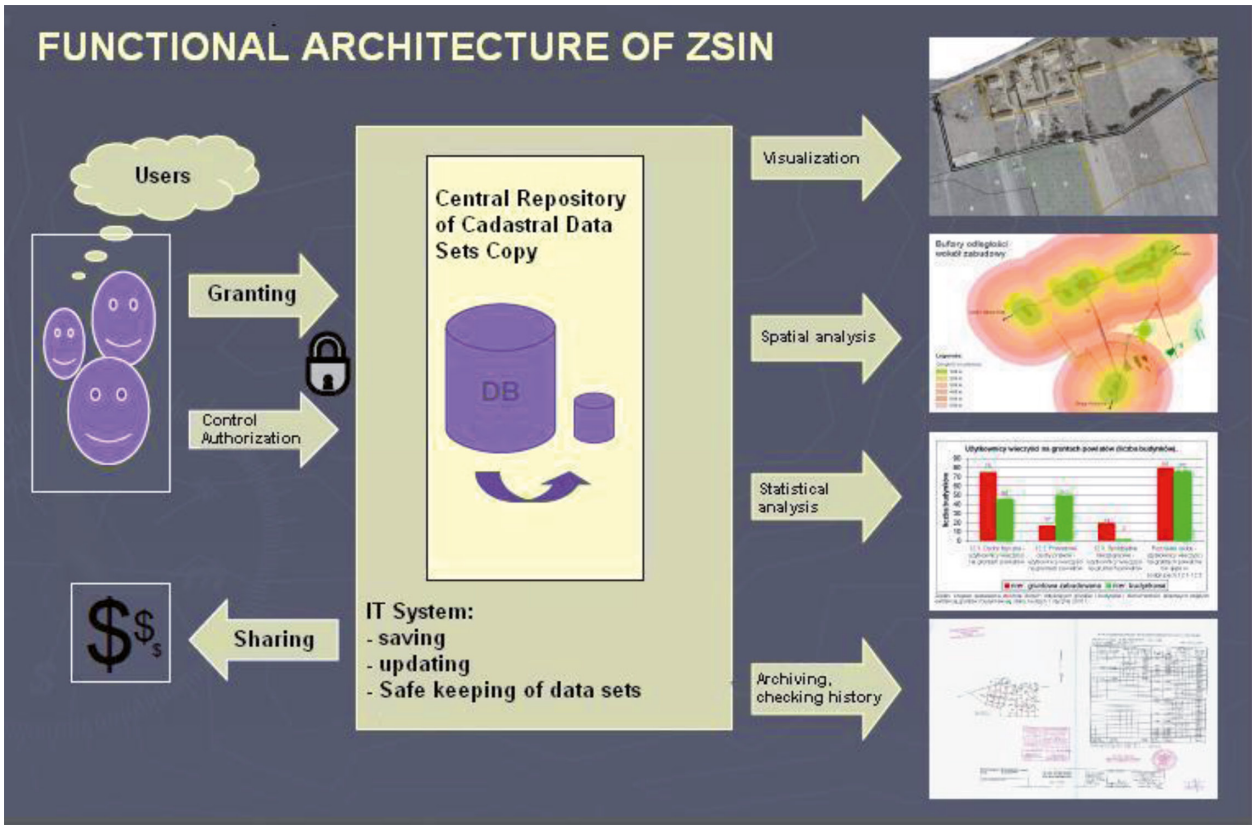

Fig. 7. Diagram of ZSIN functional architecture

Source: Dawidowicz, Źróbek, 2012

As can be seen from the above description and Fig. 7, the functionality of LAS in the future will fill the gap in the information systems and flexibly adapt to the needs of users in particular in the field of spatial analysis as described by the author, for example with using quatric kernel estimation.

4. The use of GIS software to identify developing areas on the outskirts of Olsztyn

The GIS software may be used in order to identify areas of concentration of space transformation caused by suburbanization processes. The research which was conducted on the outskirts of Olsztyn showed that cases of land use and spatial transformation made by investment pressure are related to the process of urban sprawl. GIS software like SAGA GIS and QUANTUM GIS (QGIS) were used in this research and the connection was identified with the use of quatric kernel estimation.

The investors take the initiative in transforming land by applying for development conditions for specific parcels and dividing large plots to ones more suitable for residential development. That is why data from decisions on location, as well as decisions on approving land divisions, were collected and transformed in geostatistical analyses.

In order to determine spatial relationships, data were collected about all the zoned land parcels which were the subject of decisions on location, as well as decisions on approving land divisions in the commune of Stawiguda. The collected primary data were transformed by assigning universal numbers to the parcels, and then imported to the Saga GIS program. There this data were visualized against a cartographic background, which included the location and the boundaries of land plots. The program was

run to perform quatric kernel estimation. Data were assigned to the centroids of the plots to which the cases applied. The analyses enabled us to determine regions with concentration (Fig. 8 and 9).

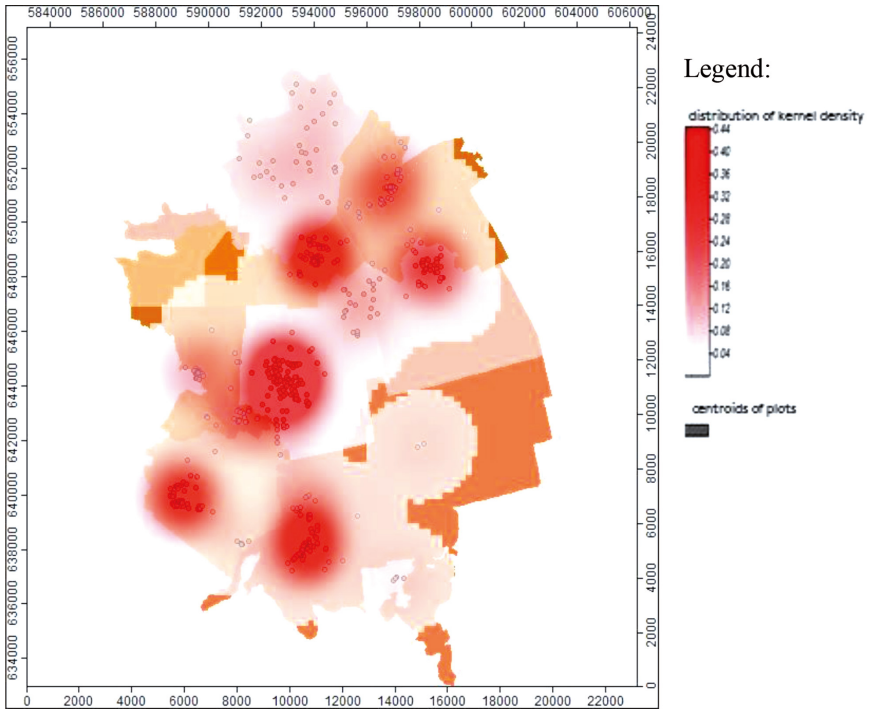

Fig. 8. Distribution of the density (Quatric Kernel) of decisions on location in the commune of Stawiguda in 2006–2010

Source: Own study after Wolny, 2013

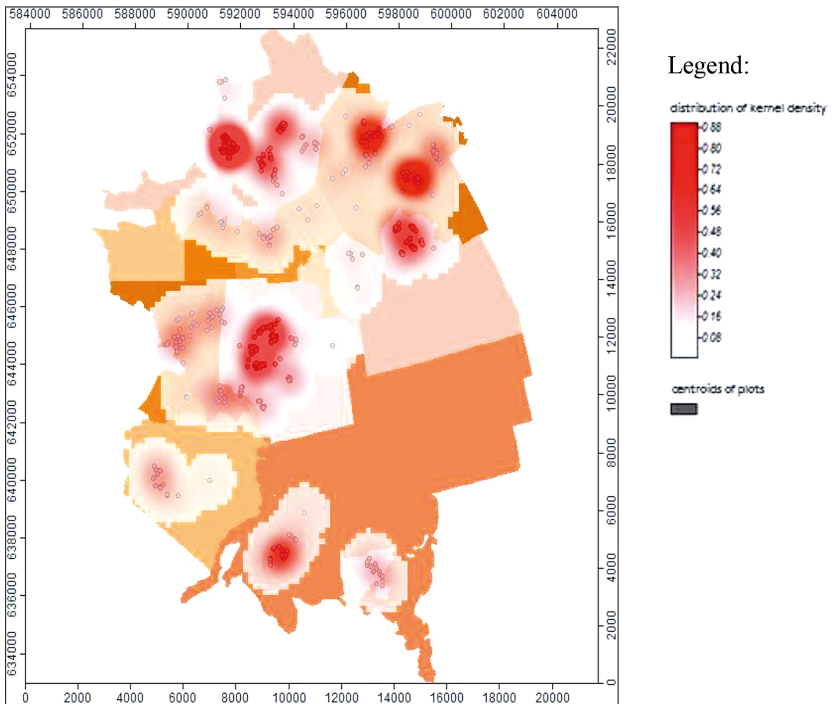

Fig. 9. Distribution of the density (Quatric Kernel) of divisions approved by decisions in the commune of Stawiguda in 2006–2010

Source: Own study after Wolny 2013

As we notice from Fig. 7 and 8, areas of concentration are situated in the north part of the commune of Stawiguda, neighbouring the city of Olsztyn as well as near the axis of the main roads leading to the city. Both land information system and more detailed analyses indicate intensive processes of space transformation – changes in land use and intensity of use. They are initiated by local governments primarily through the adoption of local plans, but also by investors applying for development conditions in specific locations and dividing plots. Areas with a more urban character developed through the initiative of investors are evidence of progressive suburbanization in a "sprawling" manner.

5. Conclusions

The presented analysis shows that suburban areas as exemplified by the area of the commune of Stawiguda are exposed to a particularly strong investment pressure due to the expansion of the core city beyond urban limits. Municipalities such as Stawiguda, presented in this article, have to face the challenge of imposing spatial order, particularly on the areas which experience rapid and intensive development. The location in the proximity of the city is still an important growth stimulant for most of the suburban municipalities.

Local authorities need new instruments to retain control on this dynamic development and to continuously monitor changes taking place on a wider scale. Areas with a more urban character developed through the initiatives of investors are challenges for land use planning as well as municipal and regional strategic development. That is why local authorities should use geoinformation. In order to avoid the side effects of urban sprawl, there should be a great need for integrating different sources of information and implementing different spatial and geostatistical analyses.

The municipality of Stawiguda has adopted good practices of transferring and integrating information. However, detailed analyses showed that not only land use plans result in changes in land use. In order to improve the tools, transferring information from local registers to the land information system is highly recommended.

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