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TECHNOLOGICAL CHALLENGES ASSOCIATED WITH LAND-USE POLICIES IN POLISH CITIES AND TOWNS

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ABSTRACT

Motives: Land-use policies are legal instruments that are available to local governments. Modern land-use policies require specialized software and spatial data. A survey was conducted in the cities and towns of two Polish regions, and the results were used to describe the challenges facing local authorities in relation to land-use planning.
Aims: The main aim of this study was to verify the use of spatial data formats and specialist software in the decision-making process in Polish cities and towns. The survey revealed differences in spatial data formats used by the analysed cities and towns. The research goal was achieved in the entire study group and in groups of differently sized cities.
Results: The challenges and implications for land-use policy and decision-making in cities and towns were discussed. The survey revealed differences in the way specialist software is used in land-use planning in the analysed towns and cities. The use of open-source software was examined, and the study demonstrated that georeferenced spatial data is generally lacking. The present findings can be used by the authorities to improve the process of formulating their land-use policies, and they suggest that municipal employees should regularly participate in training programs.

Keywords: land-use policy, GIS and CAD software, spatial data, cities and towns

INTRODUCTION

Land-use policy is one of the basic elements in the local development of cities and towns. Technology becomes an element that supports the implementation of land-use policy at these levels, both in preparing land-use management documents and monitoring land-use changes. It is also important to share data generated during work on land-use documents in cities and towns. These data are made available in various formats, which can be used second time in more accessible way depending on the approach used. Suitable data preparation requires both specialized software throughout the individual departments that deal with this process and the possibility of using adequate spatial data (Wang et al., 2019).

Geographical information systems support the design of land-use policies and the decision-making processes related to land-use planning areas (Deslatte et al., 2022; Feltynowski & Szajt, 2021; Masoudi et al., 2021). Computer-Aided Design (CAD) software can also be used (Habib et al., 2019). The quality of the

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findings used in land-use planning should be based on georeferenced materials that can also be processed by less experienced users (Simon et al., 2017).

Activities related to georeferencing source materials (land-use development plans) and, in particular, preparing them in a vector format may be a basis for incorporating the local community in decision-making. This could be done through the participation of residents in creating land-use policy at the preparation stage (Brown & Eckold, 2020; White, 2001; Załęczna, 2018). Public participation must be supported both by laws, which allow residents to create a land-use policy, and technology, which facilitates participation (Holsen, 2021).

Activities related to vectorizing spatial data in European Union (EU) countries result from the Directive Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), which indicates a clear road map that the member states should follow. One of the INSPIRE road map elements is a topic on land-use development (Jaroszewicz & Piotrowska, 2016). It is one of 34 topics covering the need to collect spatial information in the form of spatial data and share them with local actors. The spatial data sets listed in the INSPIRE Directive are an element of land-use plans and land-use policies created in the member states.

An additional advantage in implementing the INSPIRE Directive is the need to adjust the law of member states and incorporate the Directive into national legislation as an act (Cho & Crompvoets, 2019). These activities helped unify data at the national and the international levels, enabling cross-border research in this field.

The article aims to verify the use of specific spatial data formats and the software used to apply spatial data in decision-making in cities and towns. Based on data obtained in the survey, attention is drawn to the differences between cities and towns in using spatial data formats. This goal is verified in the whole study group and the groups of cities based on size. The other part of the study indicates the software used for land-use planning, considering the division into CAD and geographical information system (GIS) software. It also verified if local authorities use open-source software. Ultimately, the analysis conducted in the study should indicate how software and data formats are used and show the directions of such activities so that publicly emerging data are also available to final recipients – city and town residents.

Based on the results, it is possible to indicate challenges faced by local authorities. These challenges concern both the data format, which should be available as public information for residents, and the skills required to use specialized software in public administration units.

MATERIALS AND METHODS

Cities and towns in the research

The research's primary objects was the analysis of cities and towns, which are simultaneously seat of local government of communes. Cities and towns can be divided into three groups, based on the number of inhabitants living there, i.e., big cities (over 100,000 inhabitants), medium towns (from 20,000 to 100,000 inhabitants), and small towns (fewer than 20,000 inhabitants) (Majewska et al., 2020; Środa-Murawska et al., 2017).

The research was conducted in the Łódź voivodeship (hereinafter Lodzkie) and the Mazovian voivodeship (Mazovia). Lodzkie was selected purposefully for this study, while Mazovia was drawn from the remaining 15 regions in Poland. As a consequence of the selection, it was possible to identify 135 cities that were municipalities capitals in 2020 (Table 1).

Table 1. Number of cities and towns in selected regions in 2020

	Lodzkie	Mazovia
Total number of cities and towns	46	89
Big cities	1	3
Medium towns	14	22
Small towns	31	64

Source: own work.

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Research and data analysis tools

The study used a questionnaire, which was implemented by a professional research agency using a computer-assisted telephone technique (CATI). In each territorial unit, only one person answered the questions. The research tool has two metric questions to identify the surveyed representatives of local government. In the paper two questions from questionnaire together with metric questions are analyzed. The most important questions were those regarding:

a. the preferred data formats relating to land-use policy;
b. the software used, which supports the decision-making process in cities and towns.

For the questions related to the technology used in land-use policies, appropriately prepared multiple choice questions were used (Table 2). In both questions, there was the possibility to mark several answers, which allowed respondents to present the current conditions in the department responsible for land-use policy.

The main results were based on determining the significance of the results, which were measured by the Wilcoxon statistics (Siegel, 1956). This test made it possible to ascertain the significance of individual responses by comparing individual pairs and, consequently, summing up the results for individual responses. Thus, it was possible to identify the data and software that play an important role in the land-use policy of individual types of cities and towns. Wilcoxon statistics are a nonparametric alternative to Student's t-statistics.

The Wilcoxon matched-pairs test shows which pair of answers is more significant. It allows us to sum up the number of occurrences of the alternative hypothesis of the Wilcoxon test. The alternative hypothesis says there is a significant difference between the two variables (Wilcoxon, 1945). In the article cases of preferred data format (D), the value of the most significant answer is six, and for the software related to the land-use policy (S), the value of the most significant answer is three. The lower number shows the lower significance of variable.

The questionnaire data were analyzed using Statistica software version 13.3. This software allowed basic statistical analyses concerning the entire population and individual types of cities and towns.

RESULTS

Basic results

The primary results relate to assessing the percentage of cities and towns in the study. Slightly more than eighty-three percent of the population replied to the questions; 80.4% in Lodzkie, and 85.4% in Mazovia.

Based on the size of the analyzed cities and towns, the highest level of participation came from medium-sized towns, with a response rate of 97.2%. Small towns were characterized by 78.9% participation, while for cities, it was 75% (Table 3).

Table 2. Answers used in questions about the technology used in land-use policies

Preferred spatial data format		The software related to land-use policy	
Response code	Answers	Response code	Answers
D1	vector GIS data with georeferencing	S1	GIS software
D2	vector GIS data without georeferencing	S2	CAD software
D3	vector CAD data with georeferencing	S3	GIS and CAD software is not used
D4	vector CAD data without georeferencing	S4	others
D5	raster with georeferencing		
D6	raster without georeferencing		
D7	analog data		

Source: own work.

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Table 3. Cities and towns participating in the research

		Lodzkie	Mazovia	Total
Small towns	Number in research	22.0	53.0	75.0
	Percent of group	71.0	82.8	78.9
Medium towns	Number in research	14.0	21.0	35.0
	Percent of group	100.0	95.5	97.2
Big cities	Number in research	1.0	2.0	3.0
	Percent of group	100.0	66.7	75.0
Total	Number in research	37.0	76.0	113.0
	Percent of group	80.4	85.4	83.7

Source: own work.

Referring to the data analysis, in Lodzkie, the entire population of medium-sized towns and cities took part in the research, while for small towns, it was 71%. In Mazovia, the highest percentage of participation was found in medium-sized towns (95.5%). Meanwhile, 82.8% of small towns and 66.7% of cities participated.

Data format preferred in land-use policies

The analysis of the responses shows that more than half of the cities and towns in the study prefer data in the GIS georeferenced format (52.21%). A similarly significant rate of responses from cities and towns indicates the usefulness of georeferenced raster data (42.48%). Unfortunately, among the data used in land-use planning, the relatively high usefulness of analog data (33.63%) is still indicated. Other types of data are used to a lower extent. This is especially true of data without georeferencing and all data in the CAD format (Fig. 1).

The analysis of the responses in cities indicates the use of georeferenced GIS data by all units (100%). GIS data without georeferencing (33.33%), raster data with georeferencing (33.33%), and analog data (33.33%) are also used. No other types of data were used to create land-use policies.

In medium-sized towns, the most frequently used data are georeferenced raster data (60%) and georeferenced GIS data (57.14%). The third group of data is georeferenced CAD data (22.86%). As in the case of cities, analog data are also used (17.14%). Non-georeferenced raster data is another element that supports land-use planning (14.29%). The remaining data are less important for the land-use policy in medium-sized towns.

Small towns mainly use GIS georeferenced data (48%), although analog data constitute a significant share of data for land-use policy (41.33%). Georeferenced raster data (36%) are also very useful. Some small towns also use raster data without georeferencing (10.67%). The least useful are CAD data and GIS data without georeferencing (Fig. 1).

The data presenting the level of data used in land-use policies were also assessed for their significance. The results indicate that no important data could be indicated in the group of cities, which resulted from the number of responses and the small number of cities in this group. According to the interpretation of the Wilcoxon significance test, it should be considered that in the case of the entire population, GIS georeferenced data, georeferenced raster data and analog data should be considered more important than other answers. The same is true of the significance of the data used in small towns.

Concerning the data used by medium-sized towns, georeferenced raster and GIS data, show the highest significance level. For this group of towns, the level of significance is slightly higher in the case of georeferenced CAD data (Table 4).

Table 4. Wilcoxon test for preferred data format in land-use policy

	D1	D2	D3	D4	D5	D6	D7
Total	5	0	0	0	4	0	4
Medium towns	5	0	1	0	5	0	0
Small towns	4	0	0	0	4	0	4

Source: own work.

The software related to land-use policy

The respondents could make multiple choice answers to indicate the type of software used in creating land-use policy and spatial decision-making. Of the entire population, 30.97% of cities and towns use GIS software, while only 16.81% use CAD software. Of those, 6.19% indicated that they use

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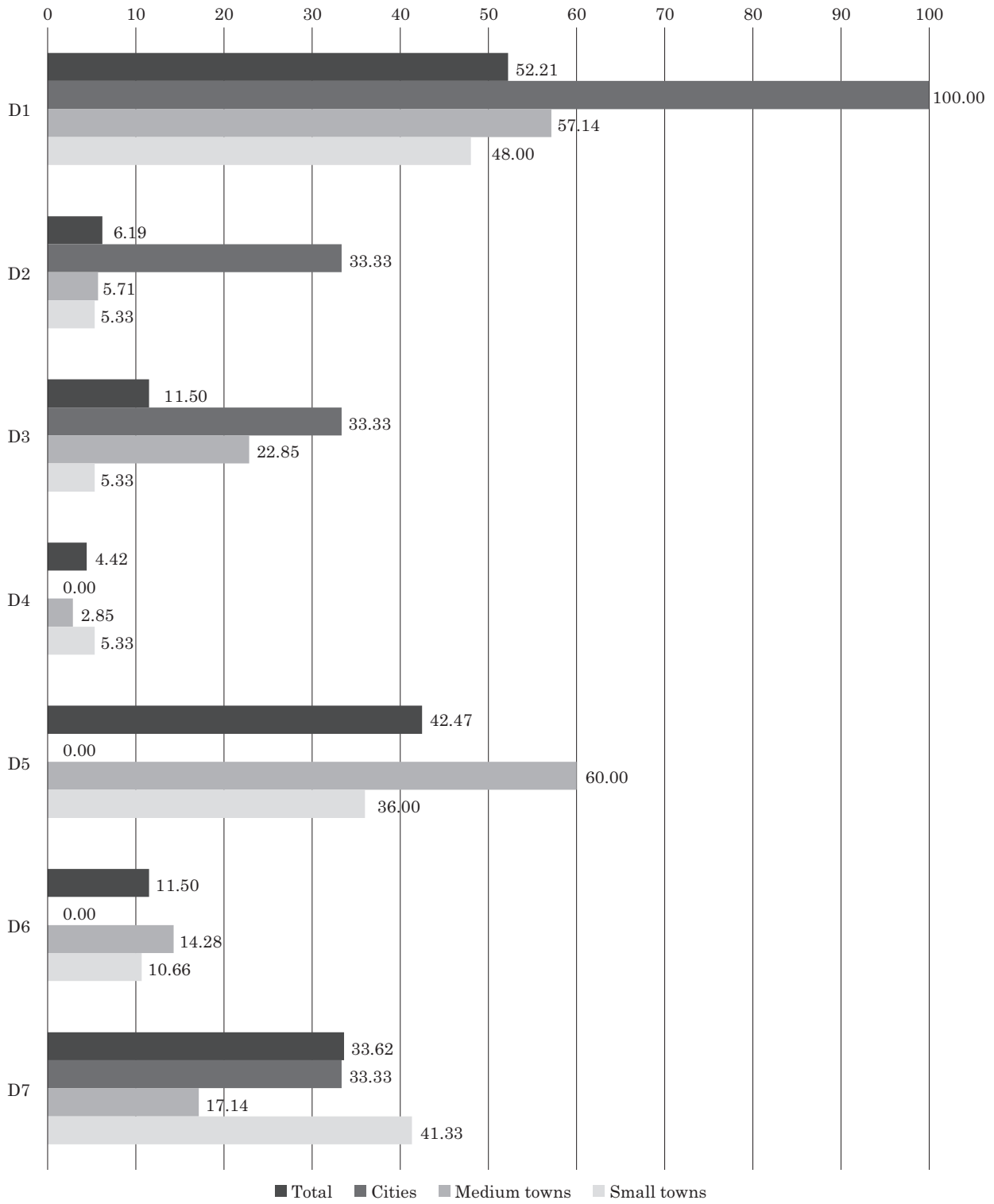

Fig. 1. Preferred spatial data format in cities and towns
Source: own work based on research.

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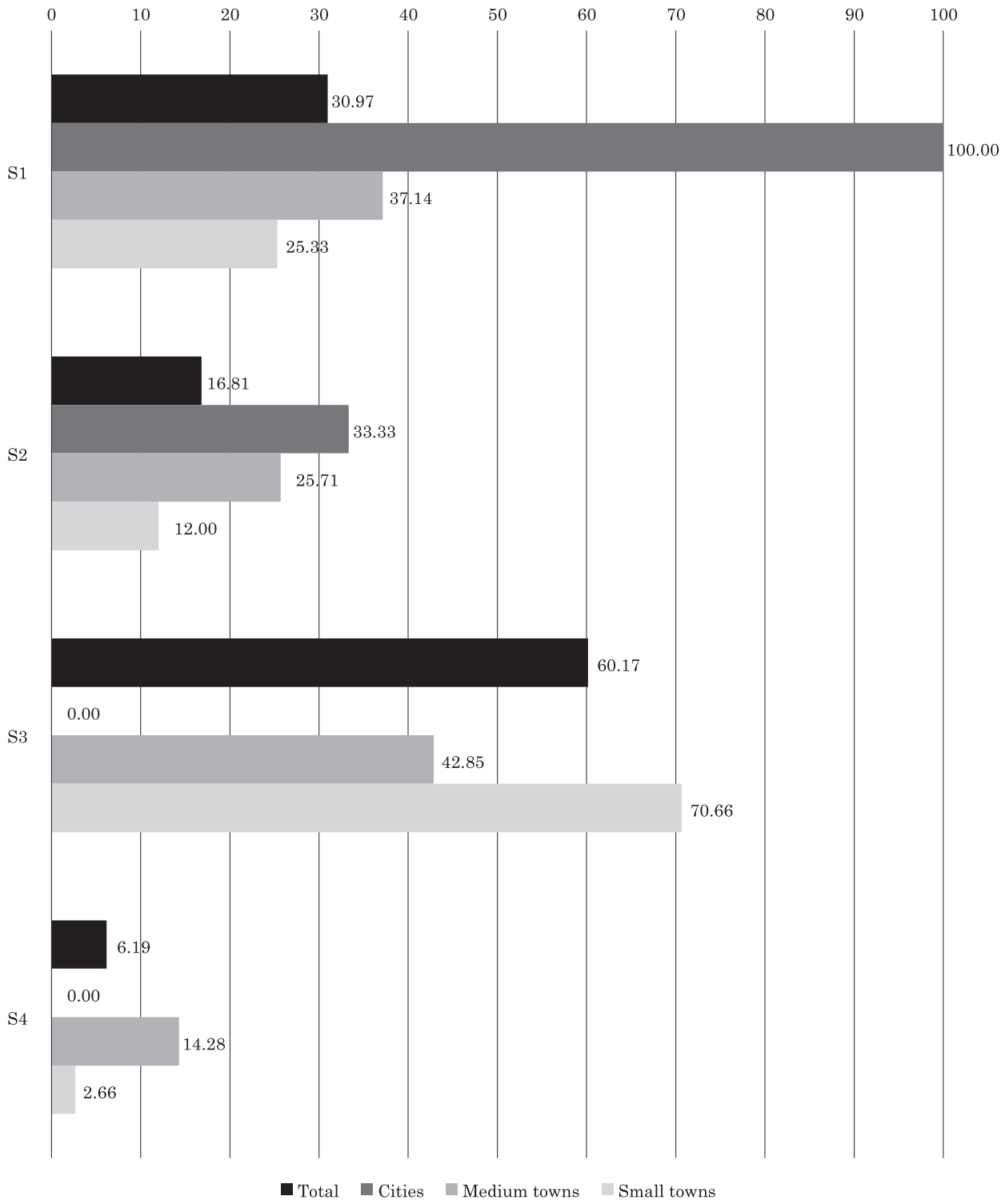

Fig. 2. The software used in cities and towns
Source: own work based on research.

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EWMapa software, which combines the advantages of both CAD and GIS systems. In this part of the survey, the respondents also included responses indicating that activities related to land-use policy, both GIS and CAD software, are outsourced to external entities. Importantly, 60.18% of cities and towns do not use GIS or CAD software in their land-use planning activities. Only 39.82% of cities and towns use software to support the creation of a land-use policy.

All cities indicated that they use GIS software, while only 33.33% use CAD software. The situation is different for the other two groups of towns. In medium-sized towns, GIS software is used by 37.14% of responding units, while CAD software is used by 25.71%. Of these towns, 42.86% of local governments do not use any specialized software. In 14.29% of medium towns, other software is also used to support land-use planning and decision-making. In small towns, the percentage of units using specialized types of software is even lower. Only 25.33% of units use GIS software, and 12% use CAD. Regarding the use of other software to support the creation of land-use policies, only 2.67% of small towns reported such possibilities. Unfortunately, in this group of towns, 70.67% of units indicated that they do not use any software (Fig. 2). It should also be emphasized that only 57.14% of medium towns and 29.33% of small towns use any software.

The assessment of significance using the Wilcoxon test reveals similar conclusions to the preferred data format, where due to the small number of cities, it was not possible to indicate significant answers in the context of pairwise comparisons. Across the entire group, the responses about not using software in land-use policy were significantly more important than the others. The use of GIS and CAD software had a lower level of significance. For medium-sized towns, only the indication about not using software was slightly significant. In the case of small towns, the test showed a high significance of the lack of software use and a slightly lower significance for the use of GIS software (Table 5).

Evaluating software type of license used by the end-user states reveals that with CAD software, all cities and towns used commercial licenses. The situation was different for GIS software. According to the results, 68.57% of cities and towns use open source software, 14.29% use only commercial GIS software, and 17.14% use both types.

Table 5. Wilcoxon test for the software used in cities and towns

	S1	S2	S3	S4
Total	2	1	3	0
Medium towns	0	0	1	0
Small towns	2	0	3	0

Source: own work.

DISCUSSION AND CONCLUSIONS

The need to use GIS and CAD software

GIS software prevails over CAD software in Polish cities and towns. The actions of local government authorities, in particular, in small and medium-sized towns, should be based on improving the skills of employees who deal with land-use planning issues in the commune. This need is noticed in Polish cities and towns, but the problem is also presented in the international literature (Baldwin et al., 2014; Obermeyer et al., 2016). Although knowledge about using GIS and CAD software seems necessary nowadays, research shows a knowledge gap. It should also be noted that this study indicates that local authorities outsource services to external entities, which is reflected in previous research (Rocha et al., 2003).

The conclusions drawn based on the research show that steps should be taken to address the problem, which is caused by a gap in the use software in public administration at the local level. Research clearly shows that city and town size matters for the level of GIS and CAD use. Such software should be employed in rural areas, which are often below the level of development of small towns in this context (Feltynowski, 2012; 2018).

The multithreaded use of GIS and CAD software in land-use planning also supports activities that use aerial and satellite imagery (Hütter, 2018). All activities

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based on new technologies improve the living conditions of inhabitants by properly supporting land-use planning with software (Hoffman & Lemper, 2018; Pollard, 2000).

The need to use data in land-use planning policy

Apart from the ability to use software, data availability is essential. In Europe, the EU first took action in 2007. Despite the passage of time, the use of data in land-use policy is still a barrier. Although volumes of data within national spatial data infrastructures have been opened and made available (and not only to public administration) thanks to the principles of the INSPIRE Directive, it has not significantly affected the use of spatial data (Izdebski et al., 2021; Ronzhin et al., 2019).

In line with the characteristics of the software used in public administration, the most valuable data are the georeferenced vector and raster data. This area of research is indicated as developmental due to the diversity of the public sector in countries that implement INSPIRE (Masser & Crompvoets, 2016). The experience of the EU member states can also be used in other countries, depending on the needs related to the development of the use of spatial information in spatial planning.

Data quality in land-use planning plays a significant role in influencing the value of plans and other documents (Stelmach-Fita, 2017; 2021). Therefore, the people who create, actualize, and use data in land-use policy must know the specifics of the spatial information they use. It is not possible without a practical analysis of these data collections, which in small and medium-sized towns requires further development, especially in terms of the usefulness of spatial data. As with software, it also requires continuous training for commune employees.

Supporting the development of spatial databases will allow them to be better used in the future, both in land-use planning and other areas of local government activity. This type of approach will allow space to be created both in cities and rural areas (Theobald et al., 2005). The generated spatial data will also be the basis for evaluating the changes in cities and towns as land-use planning is an ongoing process.

The need to improve the quality of materials in the decision-making process

Combining the software implementation process and high-quality spatial data is an element that supports decision-making, both in the short and long term. Decisions made by local authorities in various areas increasingly depend on adequate access to spatial information. Activities of this type should also be supported by the participatory creation of land use (Bojórquez-Tapia et al., 2001; Brown & Eckold, 2020; Jelokhani-Niaraki, 2021).

As part of the land-use policy supported by GIS software, it is possible to proper decision-making in the city and town space. GIS has become a tool used to collect data used in decision-making in various fields (Eren & Katanalp, 2022; Everest et al., 2021; Ustaoglu et al., 2021). Data used in the fields of commune functioning allow their implementation in various policies created at the city level (Ferretti, 2021). Thanks to GIS and CAD data, it becomes possible to improve the quality of information on the functioning of the cities and towns, which is a challenge for land management and brownfield recovery (Ferretti, 2021; Omidipoor et al., 2019).

Regardless of where support is used for decision-making that has a spatial dimension, it remains a priority activity for city and town authorities. Thanks to the use of GIS technology, it is possible to prepare land-use planning documents more efficiently. Planning tools make it possible to balance approaches based on competition for specific land uses. At the same time, the use of software and spatial data in decision-making may be one of the factors that eliminate ideas that are least compatible with the preferences expressed by all local actors.

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Open source software

Due to the need to limit the expenditure of budget funds, city and town authorities should decide to use open-source software. This approach makes it possible to use existing technology and implement changes that result from the needs reported by users. Software innovations should improve the quality of services provided by local government authorities.

Cities and towns are important recipients of services provided by open-source software vendors (Bouras et al., 2014), and it should be emphasized that open-source programs make it possible to achieve results comparable to commercial software on the market. An essential element of open source software in public administration is that it affects how institutions operate in technological, organizational, economic, and social areas (Bouras et al., 2013; Shaikh, 2016). It also leads to the development of public institutions in line with global trends.

Research limitation

The limitation of research on using spatial data in spatial planning processes is primarily the costs of their conduct. Some data in this scope are available from a survey by Statistics Poland on the type of data used in spatial planning. There are no systemic studies related to the use of software for spatial planning purposes. Researchers should remember that the software allows for appropriate spatial data processing and supports the decision-making process in spatial planning.

What turns out to be important in this type of research is their extension to all regions in Poland and their implementation in local governments outside Poland, which will allow for a broader inference process in the European and intercontinental context.

In the case of internationalization of research, a limitation may be various legal systems that affect the organization of departments related to spatial planning and the scope of their activities undertaken.

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