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BRIEF REPORT

Geographic Information System Technology: Review of the Challenges for Its Establishment as a Major Asset for Disaster and Emergency Management in Poland

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ABSTRACT

Technical and technological progress in the 21st century, especially emerging geographic information system (GIS) technology, offers new and unprecedented opportunities to counteract the impact of crisis situations and emergencies. Computerization and development of GIS enabled the digital visualization of space for interactive analysis of multiple data in the form of models or simulations. Additionally, computerization, which gives rise to a new quality of database management, requires continuous modernization of computer hardware and software. This study examines selected examples of the implications and impact of the GIS commonly used in Poland.

Key Words: disaster management, disaster preparedness, GIS

The currently socially acceptable functioning of the state in a globalized environment requires the ability to collect, process, analyze, and make available complex information. It is necessary to have information, not only about the physical properties of a phenomenon, but also about its implications in time and space. Data about a spatial object understood as an "abstract representation of an object, a physical phenomenon or an event related to a specific place or geographical area" are not enough. It is necessary to establish, in particular, an infrastructure for spatial information that meets public expectations. This translates into metadata-described spatial data sets and services, technical means, processes, and procedures that are used and made available by the leading authorities, other administrations, and third parties who contribute to the infrastructure for spatial information. These processes also include dynamic socio-economic changes. The mere possession of geoinformation is not enough to function properly in crisis management, so it should be used intelligently. This translates into the proper interoperability of spatial data sets and services, assumed by the legislator in Poland. Crises are often complex, geographical scale problems that require professionals to work in teams while dealing with a large amount of geographic information for decision-making.[1] Geographic information systems (GIS) must serve "the possibility of combining spatial data sets and services without repeated manual intervention, in such a way that the result is consistent and the added value of spatial data sets and services is increased."[2] In Polish conditions, the creation of precisely compatible infrastructure poses time-consuming problems of an objective and subjective nature.

GEOGRAPHIC INFORMATION SYSTEM

GIS is a complex system of databases containing information about coordinates locating spatial objects, which allows for various procedures to be carried out.[3] In addition, GIS is a tool for geographic research on micro, meso-, and macro-scales, which leads to visualization, but also to solving problems in spatial planning, management, and modeling. It should be added that the ways and methods of processing data about geographical objects, as well as the purposes of the systems, can vary considerably. Their results are linked to input data quality and input procedures, verification, algorithm design, interpolation, database management and processing, as well as numerous output procedures, graphic, cartographic, and textual presentation. The created model of the geographical environment in the database is a starting point for the analysis of objects after determining their characteristics, location, class, quantitative and qualitative characteristics, and relationships between them.[4] It is important to develop standards and standardized methods of data encoding and transmission. Request for Comments (RFC) documents containing protocols, concepts, methods, and Internet programs play a role in this process.[5]

The uses of GIS are varied, eg, in services to determine the location of investments, in the context of analyses

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in preparation for disaster risk reduction (DRR); the size of the expected revenues in terms of the extent of existing and potential outlets, but at the same time the risk of losses due to the presence of business and population in an area at risk of flooding, landslides, storms and strong winds, whirlwinds, as well as a cascade phenomena and the impact of their presence on long-term environmental degradation. This depends on the type of corporation or small to mid-size enterprise (SME); GIS also serves to create evacuation routes and protective buildings. The process should be carried out in close consultation with local agents to negotiate optimal routes and educate users of these evacuation routes.[6] This also applies to education and the use of public and critical infrastructure.

The Integrated Administration and Control System (IACS) is an important administrative and information technology (IT) system, and an obligatory tool in achieving the objectives of the EU Common Agricultural Policy, covering the whole country.[7] Its main element is the Land Parcel Identification System (LIPS), which entitles farmers to the subsidies received by them. It is linked to the National Land and Building Register and is the basis for verification and control of data provided by the farmer in the application for payment. Often, however, districts keep records with the use of a separate system, which results in differences at unit boundaries. The solution lies not only on the IT side, but also on the legal side, and on the implementation of law.[8]

According to the definition of the Polish Spatial Information Society, a spatial information system (or GIS) is "a system for acquiring, collecting, verifying, integrating, analyzing, transferring, and sharing spatial data. In a broad sense, it includes methods, technical means, spatial database and organization, financial resources, and people interested in its functioning."[9] The aim of the system is primarily to support decision-making, which is crucial in the 4 phases of crisis management: prevention, preparation, response, and recovery.

At this point, it should be stressed that GIS cannot be simplified to a software and hardware-based information system alone. Nevertheless, its essence is spatial data, or more precisely, the way it is organized, that is, the use of such data for advanced, time-consuming analysis. Unfortunately, in current Polish operational conditions, the exchange of information, despite ready-made technological solutions, is not very effective, and it is worth pointing out what stands in the way.

Time and place are major characteristics for every crisis situation, which means that services, inspections, and guards must use spatial information. The entire public administration (national government and local government) functions in a similar way, covering practically every area of our lives with its expertise. As a result, many spatial information systems are used in Poland, which are often limited to the specialized needs of the user. Public administration, in modeling, usually uses low-budget solutions, such as QGIS (Free and Open Geographic Information System), which creates cartographic or static models, and rarely dynamic models for the general public use.[10] GIS are most often used in an advanced way by services, inspectorates, guards, and authorities of Polish metropolitan areas. The latter use it mainly to expedite the identification of threats, their modeling, and prediction of the consequences for the more than 1 million people they manage.

CAPACITY IN CRISIS RESPONSE OPERATIONS

The most frequently used GIS products are multi-layered spatial visualizations such as national geoportal, local government spatial information systems, command support systems, hazard maps, etc. They are based on digital data, tabular data, paper maps, aerial photographs, and satellite data. The spatial range of most of them is limited to the administrative division of Poland, especially the local government division. In terms of content, they cover an area dedicated to a specific institution and, therefore, are limited most often to strictly specialized areas.

The most advanced, from a data volume perspective, spatial information system in Poland is the National Geoportal, which dates back to 2005. The Main Office of Geodesy and Cartography created the "Geoportal," which makes the widest possible range of geospatial data available to the general public, including selected government and local government departments, as well as ordinary citizens, and other legal entities.[11] The project was not so much intended to increase the innovativeness and competitiveness of enterprises on the market, but above all to accelerate the modernization of public administration work, and to build an informational society. The creation of nodes of the National Spatial Information Infrastructure made it possible to provide access to databases of cadastral surveys that defines and quantitatively sets boundaries for legal purposes, general geographic, raster, etc.

Continuation of the project in 2009 made it possible to expand the spatial information infrastructure with "Geoportal 2" for agriculture, forestry, construction, as well as specialized public administration and private entities. The databases were expanded to include the archive of the National Surveying and Cartographic Resource, while the National Spatial Information Infrastructure and registers of the Surveying and Cartographic Service were modernized to ensure interoperability within the framework of the implementation of the INSPIRE services set out by the European Commission.[12] As a result, it has been possible to combine spatial data sets of public authorities into a "compatible or inclusive whole" with access at the national and European level.

Another example of the use of GIS on a mass scale is local government spatial information systems. They are one of the more advanced products, using many maps with increased accuracy, multi-domain layers, with a significant time span, covering

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urban metropolitan areas, and more precisely metropolitan associations. This is mainly due to the fact that the leading cities in such associations want to make it easier for investors, tourists, and residents to move around the urban space.

It is worth describing in more detail the GIS solutions applied by selected cities in Poland, especially in view of the important role played by local government in each of the 4 phases of crisis management.[13]

In the capital of Poland, Warsaw, there is an extensive spatial data service with an air quality index, places of local activity, tourism, flood hazard, and groundwater intakes.[14]

In Kraków, Poland's leading investment and tourist city, GIS has been enhanced to include 3D imaging of the city's buildings (2D outlines of the buildings were juxtaposed with high-altitude flight data from LIDAR laser scanning) and 3D imaging of noise maps. Additionally, GIS has been enhanced with a map composition of "Urban Space and Planning" dedicated to industry (investment) users, including architectural permits and decisions, real estate price registers, urban development plans, etc. Additionally, safety maps, greenery management, liquidation of low emission sources, transport corridors, degraded areas, and investment offers have been included. One can clearly see how the local government of Kraków is reacting to the nuisances related to investments, tourism, and smog, which are so characteristic of the city. Maps of landslides and areas at risk of mass traffic at a scale of 1:10,000 for the City of Kraków have been created (Districts I-XVIII).[15]

In Wrocław, apart from the traditional layers, GIS has been enhanced by a map of solar potential, a map of traffic bottlenecks, and, similarly to Kraków, 3D modeling of the city buildings has been applied. In the context of flood hazards, a height map is used.[16]

In Gdańsk, GIS, as in the previous cases, consists of classic layers important for the proper functioning of residents, tourists, and investors. The "Map of Order," which increases the effectiveness of maintaining cleanliness and order in the city area, is unique in Poland. The map allows for efficient identification of the landowner or those responsible for any irregularities, and for the reporting to the relevant city services.[17]

In Lublin and Poznań, due to the lower intensity of tourist and investment traffic compared with the above-mentioned cities, GIS is characterized by classical layers, without individual solutions. However, it is worth noting that the number of tabs, in particular thematic layers characteristic of the city's specificity, has been enhanced. In Lublin, detailed map services, such as nature, city investments, spatial planning, transport and export have been created, and the layers are only just emerging. This procedure has resulted in greater transparency of the spatial information system.[18]

A review of local government spatial information systems demonstrates their significant importance for the preparedness of local governments for possible disasters. Numerous researchers have provided insight as to the value of GIS by integrating it into vulnerability analysis thereby improving models that can aid communities in hazard mitigation and resilience enhancement efforts.[19]

In practically each of the 4 phases of disaster management, GIS provides necessary information. In prevention (first phase), it warns against risks, which eliminates and reduces the untoward consequences (ie, reducing the probability of a disaster). During preparation (second phase), it facilitates the development of emergency response plans (records strengths and resources). In response or third phase, it supports rescue operations and determines the variables of secondary damage and losses. During reconstruction (fourth phase), particularly in the long term, GIS optimizes the restoration of the predisaster condition and enables the creation of conditions that operationally and infrastructure wise that are less sensitive to the next disaster.

OPERATIONS UNDERTAKEN AT THE NATIONAL LEVEL

The IT System for the Country's Protection Against Extreme Hazards (*pol. – ISOK*) was launched in 2013 and financed by the European Regional Development Fund under the Innovative Economy program. The result is Hydro-portal publishing hazard and flood risk maps, featuring the possibility to download a pdf file for major Polish rivers (with the probability of occurrence: 0.2%, 1%, 10%, including water depth). The risk maps take into account the negative consequences for the population and the value of potential losses. ISOK currently consists of 2 IT centers dedicated to Polish waters and the Institute of Meteorology and Water Management in Warsaw – Public Information Bulletin (*pol. IMGW-BIP*). ISOK is also supposed to facilitate the work of various public institutions, including crisis management services, governmental and local governmental administration at all levels through internal access to the system.[20] The integrated data system has been designed to facilitate water management. A dynamic risk forecast is also expected.

The GIS used to create a national drought map using 3 types:

- Landslides are among the most dangerous and common geothreats in Poland. Every year, they pose a threat to people and bring about losses in road and railway infrastructure, crops, stands, and general degradation of areas subject to mass land movements. Threatened areas are river valleys and the Carpathian region, where more than 90% of all landslides in Poland are concentrated. In 2006, the Landslide

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Counteracting System database (*pol. System Osłony Przeciwosuwiskowej- SOPO*) system was established to identify and document the affected areas in detail.[21] Monitoring is carried out on several dozen particularly dangerous and active landslides. The main work of the Geosafety Centre (PGI-PIB) is carried out in Śląskie, Małopolskie, and Podkarpackie voivodeships. The SOPO database is available by means of an Internet application, and also to local governments. Surface monitoring is possible thanks to laser scanning, surveying, Global Navigation Satellite Systems (GNSS) for position determination, and interferometric methods using satellite radar imaging (InSAR; SAR Interferometry).[22] Depth monitoring is also carried out. The data are used to develop landslide susceptibility maps as well as landslide hazard and risk maps and actions to reduce landslide risk. The data available include geothreats and underground waters of the Geoportal (PIG-BIP).[23] The same institution has produced 15 Geological-engineering Atlases of urban agglomeration areas (Bydgoszcz, Katowice, Koszalin, Kraków, Łódź, Piaseczyński County, Płock County, Poznań, Rybnik, Tricity, Wałbrzych, Warsaw, Wrocław) and cliff areas, and 2 more are under preparation, for the cities of Szczecin and Lublin-Świdnik. The completion of the atlas is scheduled for 2021).

- The Forest Data Bank contains, among others, data on forest fire danger in Poland, with archiving of historical data. Maps of forest fire danger in the country are created by the Forest Research Institute on the basis of analyses of relative air humidity and litter moisture, and by the organizational bodies of the State Forests in 60 forecast zones; the map is prepared daily (during the forest fire danger season, ie, from April 1 to September 30) by the Forest Fire Protection Laboratory of the Forest Research Institute. More and more often, the State Forest Inspectorates also use fire detection systems, the Smoke Detection system (hazard detection and population notification).[24]
- GIS is used for the analysis and classification of fire hazard regions in Poland.[25]

GIS plays an important role in response, prevention, and risk minimization. Crises are understood as natural disasters, military, social or religious conflicts, as well as information and political terrorism. In Poland, there is a structure of crisis response according to administrative authorities, and related management centers and central, nationwide crisis coordination teams. Next to this, there are teams with rescue coordination positions and rescue notification centers.[26]

In terms of services, with inspections and guards on 24-h disaster preparedness, the geographical information system has become the foundation of the Command Support System (*pol. System Wspomagania Dowodzenia – SWD*). Since 2013, it has improved police operations in emergency situations, mainly in police interventions, and optimized the management of operations, human resources, and information. In addition, it has been possible to visualize police actions thanks to the Universal Maps Module, use of mobile terminals, automate reporting and statistics, and exchange of information with the Emergency Call Centre and the State Fire Service (PSP). In 2014, it was decided that, ultimately, emergency calls to 997 would be transmitted to the Police Command Support System by the operators of the Emergency Notification Centre. Currently, the Polish Police is facing the task of system modernization, mainly in terms of responding to calls, managing personal data, and advanced cooperation with external entities.[27]

The situation is analogous to that of the Emergency Notification Centre (a unified 112 system handling notifications throughout Poland). Operators use GIS mainly to automatically obtain information about the location of the caller and obtain their data, and to electronically transmit the call to the relevant services. Apart from the Police, the Command Support System is also used by the State Fire Service and the State Medical Rescue Service. In connection with GIS, it is possible to locate the place of the incident, track service vehicles, analyze data on the surroundings, or determine the consequences of the incident in terms of the area of occurrence. GIS also supports the Mountain Volunteer Ambulance Service in operations with extensive media coverage. Thanks to the geoinformation system it is possible to increase the effectiveness of rescue and search actions in difficult weather conditions, which increases the public feeling of safety in the mountains. It is used mainly for statistics of missing persons' behavior, navigation, action planning, location of patrols in the field, remote tasks, or field updates. It is also worth emphasizing the importance of the "National Map of Security Threats" based on the infrastructure of the National Geoportal system, where information from the category of crimes, offenses, and threats can be reported for free. This initiative ideally fits in with the need for social activation or management of public security within the framework of institutional and social partnership to optimize the resources of equipment and personnel of services.[28-30]

LIMITATIONS

In implementing new technologies, especially those that immediately involve the entire population, there will be concerns raised as to its limitations.

Subjective variables limiting the universality of GIS may be found in Poland, which many other countries may identify with:

- The majority of officials still have a departmental mentality and are not willing to share detailed information with other institutions. This outdated, archaic thinking is now becoming one of the most important subjective barriers to the effectiveness of public administration; this approach contributes to reducing the diversity of research that can potentially reduce disaster risk.
- The systems are not sufficiently compatible with each other, so that the exchange of information between institutions cooperating on a specific event (disasters/crises) takes too long or is too vague and, therefore, is of little use. In terms of systems, there are

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no contraindications for advanced inter-departmental cooperation. Most institutions base their systems on multi-format, free and open (QGIS), or paid-for, for example, ESRI (ArcGIS) geoinformation programming. It uses spatial data sources in compatible formats. However, the map is based on "OpenStreetMaps" in scales provided by the publisher.

- Because of the complexity of the data structures captured or recorded in a GIS system, some data analysis is impossible to perform.
- In performing data analysis using a GIS system, there is a lot of generalization due to the massive amount of data being analyzed. The user stands to lose a lot of information due to the generalization of data.
- A GIS system stores extremely large amounts of data at any given time. This may create problems when it comes to analysis due to the complexity of the data and the risk of generalization. It also creates problems when it comes to interpretation.
- The analysis of selected urban spatial information systems in Poland (Warsaw, Kraków, Wrocław, Gdańsk, Lublin, and Poznań) confirms, primarily, a low degree of unification and intuitiveness of the application software and, most importantly, compatibility between the systems. Here, we can see the clear disadvantage of a lack of central supervision, which results from the constitutional division of administration into the government and local government. The former, certainly in this matter, has no possibility to impose obligatory solutions on the latter.
- An important element influencing the readiness to counteract the effects of disasters are staff shortages, and more precisely insufficient administrative human resources, which creates delays in updating databases.
- The data collection process using a GIS system is usually expensive in the long run because not all the data collected will be useful and yet all require storage and analysis. It requires specialists with advanced knowledge of spatial analysis tools, digital raster image processing, and creating and running multilayer models.
- There is a significant difference between the leading cities in Poland, such as Warsaw and Kraków, and the remaining cities in the quality of spatial information systems. It is highly probable that the less populated the area the worse the qualitative access to geoinformation.
- The staff turn-over in services, inspections, and guards, and the administration as a whole, generates costs in the form of additional training in the field of professional development (GIS operation).[31-33]

CONCLUSIONS AND POTENTIAL FUTURE OUTCOMES

GIS provides an opportunity to introduce more effective access to spatial information for beneficiaries who are currently acquiring information in offices, which involves eliminating travel costs and reducing the time spent on data acquisition.

Nowadays, "in the most general sense, security can be defined as the certainty of existence and survival, the state of possession, and the functioning and development of an entity. Security is not only the result of the absence of threats but is primarily the result of the creative work of the particular entity and is variable in time, ie, it has the nature of a social process". In the past, traditional maps were used to describe geographical space, to which data were manually applied. Computerization and development of GIS systems enabled the digital visualization of space for interactive analysis of multiple data in the form of models or simulations. On the other hand, computerization of the environment has become a source of new threats for the state, society, and individuals themselves, especially in the area of personal data protection. However, technical and technological progress seems nowadays to be indispensable, due to the multiple possibilities it provides, for example, in the area of geoinformation.

Even now, the spatial information system makes it possible to collect, store, process, and visualize spatial data, which gives a new dimension to public administration activities. For example, in crisis management, the readiness of services, inspections, and guards in case of disasters is now incomparable to previous years. Unfortunately, a spatial information system requires appropriate hardware, software, accumulated spatial databases, and appropriate procedures for processing and sharing information. This requires not only costly modernization, but also the maintenance of professional human resources.

GIS provides an opportunity to introduce more effective access to spatial information for beneficiaries who are currently acquiring information in offices, which involves eliminating travel costs and reducing the time spent on data acquisition.

From decade to decade, the advantages of GIS have increased the sense of security of Polish society, but on the other hand, they have generated new costs and concerns for public administration. Therefore, it is worth considering the introduction of nationwide standardization, which will reduce the abovementioned problems, and additionally address the modernization related to the implementation of new technologies.[20,34-36]

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