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USE OF GEOGRAPHIC INFORMATION SYSTEMS IN CRISIS MANAGEMENT

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Abstract:
The article identifies the possibilities and areas of application of geographic information systems in the implementation of crisis management tasks in public administration and it analyzes examples of their use in crisis management. It has been shown that in crisis situations these systems help to take a reasoned decision that is close to the optimum, in contrast to the common practice of intuitive decision- making in emergency situations.

Keywords:

geographic information systems, GIS, crisis management

INTRODUCTION

Geographic information systems (GIS) are currently being used in many areas of life. These are systems for acquiring, collecting, verifying, integrating, analyzing, transferring and sharing spatial data. In a broad sense, they cover methods, technical measures, including hardware and software, spatial databases, organization, financial resources as well as people interested in its functioning. In view of the significance of the matter, its most important applications relate to tasks associated with ensuring public security.

Ensuring internal and external security is the main and essential task of a modern state. The integral part of national security is crisis management, which consists in counteracting threats, preparing for their occurrence in advance as well as maintaining or restoring stability. The essence of crisis management is the formulation of objectives, planning, acquisition and organization of resources (human and material), command and control.

GIS software is dynamically growing and the possibilities of managing and making spatial data available via the Internet are increasing. Current geographic information systems allow for the integration of geodesic, architectural, conservatory and archival documentation and the collection and visualization of large amounts of data as well.

GIS functionality as well as spatial data acquisition methods such as electronic tachymeters, digital photogrammetry, remote sensing, satellite remote sensing, laser scanning, 3D scanners, INSAR, GNSS, GPS field measurements can be applicable in crisis management. The use of unmanned aerial vehicles for GIS purposes is a promising perspective. In crisis management GIS can, among others, provide secure access to up-to-date information necessary to make informed decisions.

The purpose of the study is to identify and assess the applicability of GIS technology in the implementation of crisis management tasks at the various levels of the crisis management system, including while making decisions under uncertainty and/or threat conditions.

1. DEMAND FOR SPATIAL INFORMATION IN CRISIS SITUATIONS

Crisis management has not yet had a comprehensive theoretical base that would fully explain this matter. Most of the works focus mainly on the development of systems responsible for threat notification and communication between management centers [6].

According to Art. 2 of the Act on Crisis Management, “crisis management” is the activity of public administrative bodies, being part of national security management, which consists in prevention of crisis situations, preparation for taking control over them by means of planned actions, responding to crises, mitigating the aftermath and recovery of resources and critical infrastructure [9]. Crisis management is aimed at ensuring public security and order, protecting the life and health of the public as well as property, the environment and cultural heritage in the event of a threat or during a crisis.

A crisis situation is understood as a situation that affects the level of people’s security, property of considerable size or the environment, causing significant limitations on activities of the competent public administrative authorities due to the inadequacy of forces and resources held [9]. Depending on the crisis source location, crisis situations can be divided into external (foreign/international) and internal (national). The international aspects of crisis management are becoming increasingly crucial.

According to the *National Security Strategy of the Republic of Poland*, the overriding strategic objective of Poland is to provide favorable and safe conditions for the realization of national interests by eliminating external and internal threats, reducing risks, the proper assessment of challenges and the skillful use of emerging opportunities. One of the main strategic goals of the state in the field of defense is the engagement in international crisis response operations, first and foremost carried out by NATO and the EU, as well as by the UN or within the framework of ad hoc coalitions.

In the event of any external threat to the state, the Republic of Poland will take steps to overcome the crisis / conflict as quickly as possible in order to minimize its effects and, in particular, to prevent the crisis from escalating into a direct threat of war

against Poland or its allies. Depending on the crisis development, competent authorities will decide to start implementing certain projects included in the *National Crisis Management Plan* [5], and in the case of the increasing threat of an armed aggression - in the *Defense Response Plan of the Republic of Poland* [8].

In principle, external crises are of political-military nature. On the other hand, internal crisis situations are essentially non-military in nature. Crisis situations can be divided into crises caused by natural factors and those caused by human activity. Examples of internal crisis situations are as follows:

- fires, forest fires;
- chemical contamination on land and sea, radiation contamination, gas explosions;
- epidemics of infectious diseases, epizooties, epiphytotics;
- construction / road / rail / air catastrophes;
- social protests (mass demonstrations, roadblocks, street riots, occupations of offices and businesses);
- acts of terrorism, cyberspace threats;
- weather anomalies (drought, heat, strong frost, heavy rainfall, hail, rain, hurricane, avalanche, snowstorm, flood, overflow, landslides);
- disruptions to electrical, fuel and gas systems (failures in electricity and fuel supply);
- extraction and disposal of unexploded ordnances, etc. [5].

Crisis management is a collection of actions taken during a crisis, its development, and the elimination of its effects. Crisis management can be divided into phases:

- crisis prevention (monitoring of the situation, warning of an imminent crisis, removal of crisis factors);
- preparation for taking control over crisis situations;
- response, control of development of the crisis situation (reduction of harmful effects of the crisis, restoration of normal conditions), management of the removal of crisis situation effects;
- reconstruction.

Each of these phases requires up-to-date and reliable information, including spatial information. The early identification of a crisis situation, risk analysis, forecasting the development of the crisis, and deciding on the most appropriate ways to tackle threats immediately play a key role in crisis management.

Acting in a crisis situation involves making decisions about events that may occur with a certain probability. In crisis management the formula below is used for the quantification of risks:

$$R = P \times S \tag{1}$$

where:

R – risk;

P – probability of risk occurrence;

S – losses, estimated potential damage after a catastrophe or a natural disaster.

2. AREAS OF APPLICATION OF GIS IN THE LIGHT OF THE ACT ON CRISIS MANAGEMENT

Among the crisis management tools mentioned in the Act [9], GIS are employed while creating, for example:

- threat maps that represent the geographical area covered by the risk of threat, taking into account different scenarios of events;
- risk maps, also known as risk matrices, risk models, risk characterization (formula 1); these are maps or descriptions of potential negative impacts of the threat on people, the environment, property and infrastructure;
- safety nets - a compilation of potential threats with a leading entity indicated for their removal as well as cooperating entities; spatial analyses can be performed on them.

Within the scope of civilian planning tasks, GIS primarily allows for:

- maintaining databases necessary for the crisis management process;
- preparing solutions in the event of destruction or disruption of critical infrastructure operation.

Moreover, in civilian planning GIS can be used for:

- continuous risk monitoring;
- ensuring rational management of forces and measures in crisis situations.

As far as critical infrastructure protection tasks are concerned, GIS is used primarily for collecting and processing information about threats to critical infrastructure.

At the level of the Government Center for Security, GIS can be applied to execute tasks such as:

- the analysis and assessment of the possibility of threat occurrence or their development in the country;
- gathering information about threats and analyzing collected materials;
- the development of conclusions and proposals for prevention and counteracting threats;
- monitoring potential threats;
- ensuring the information flow between national and foreign crisis management bodies and structures.

Ministers in charge of departments of government administration and heads of central offices who carry out crisis management tasks can use GIS, among others, for:

- the analysis and assessment of potential threats, including those concerning critical infrastructure;
- the organization of threat monitoring.

GIS offers similar applications at other levels of the crisis management system: crisis management teams, crisis management centers, provincial offices (Figure 1). For example, at the provincial governor's level GIS may be a useful tool in monitoring, planning, response and dealing with the aftermath of threats within the territory of a province.

In organizational units of provincial offices competent in crisis management issues, GIS may be employed, inter alia, for:

- data collection and processing as well as assessment of threats occurring in the region of a province;
- monitoring, analyzing and forecasting the development of threats in the territory of a province;
- providing necessary information on the current state of security for the provincial crisis management team, the crisis management team operating in the office of the minister competent for internal affairs and the crisis management center;
- collection and processing of information about critical infrastructure localized in the province.

In provincial crisis management teams – to assess existing and potential threats that may affect public safety, and forecasting on these threats.

In the provincial crisis management centers – to supervise the functioning of the detection and alarm system and the public early warning system.

At the local level crisis management is the responsibility of the starost as the chairman of the district council, the district crisis management team, the district crisis management center, the commune head, the mayor, the city president, the municipal crisis management team, the municipal (city /town) crisis management center.

When it comes to crisis management, the starost's tasks, which can be supported by GIS, include the management of monitoring, planning, response and removal of effects of threats in the district.

District crisis management centers provide the information flow for the needs of crisis management and perform tasks in the district territory in favor of provincial crisis management centers.

The tasks of the commune head, the mayor, the city president as the authorities responsible for crisis management in the municipality, which may be supported by GIS, include, among others, the management of monitoring, planning, response and removal of effects of threats in the municipality.

GISs can also be applied in the implementation of crisis management tasks by units of the armed forces. Examples of such tasks include:

- participation in threat monitoring;
- performing tasks related to the assessment of effects of disturbances in the threat occurrence area;
- executing search-and-rescue tasks.

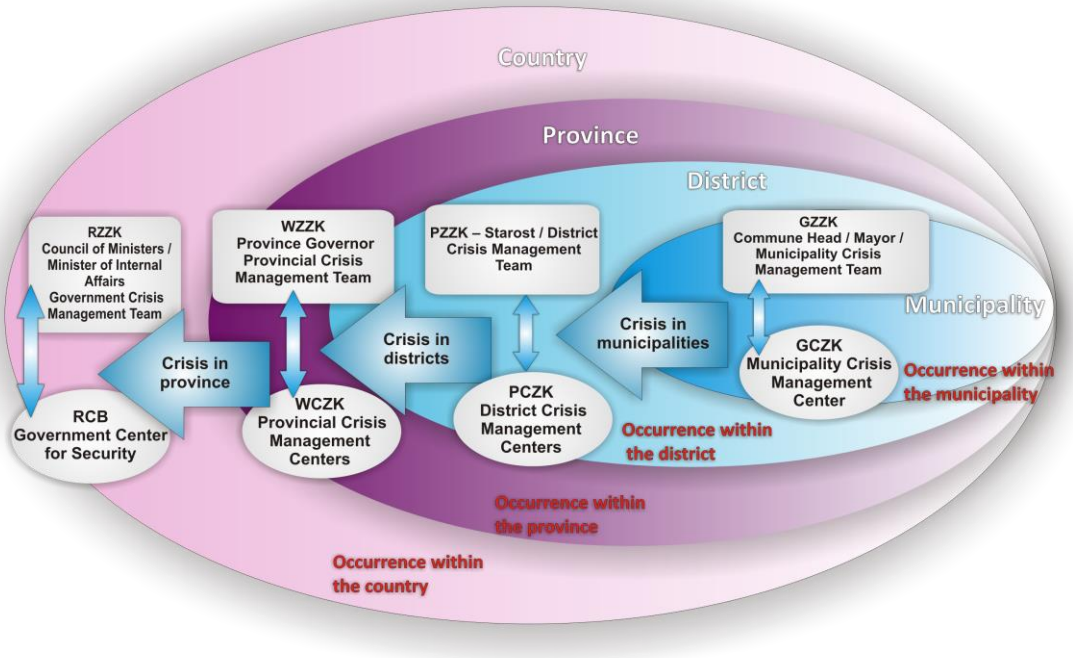

Fig. 1. The organizational model of notification and crisis response

Source: [7]

3. GIS TASKS IN CRISIS MANAGEMENT

GIS offers numerous possibilities for managing, forecasting and evaluating facts in crisis situations, it is also relevant to many decisions made in all management functions (planning, organizing, leading, controlling).

The GIS application in crisis management may involve the following tasks:

- management of information about actual and/or potential threats;
- inventory of objects and events, integration of data acquired from various sources;
- quick access to collected data, linking information layers;
- performing in-depth spatial analysis, modeling and simulations, creating thematic maps;
- identification of areas at risk of natural disasters;
- planning rescue operations;
- monitoring changes and determining the extent of damage;

- publishing maps and sharing information on the Internet.

These tasks form the basis for activities carried out by the security services.

Spatial data (thematic layers) that may be needed to accomplish these tasks include:

- potential threats together with their impact;
- available forces and resources (provincial, district and municipal crisis response teams, rescue and firefighting units of the State Fire Service, etc.);
- population distribution;
- buildings, address points, boundaries of city areas, municipalities, districts;
- communication networks (road, rail, water, air);
- physiography (terrain model, water relations, climate, prevailing wind directions, etc.);
- digital terrain model (DTM).

Most of this data is geo-referenced, which allows for location on maps important events from a crisis perspective.

In crisis management teams' work GIS can be used, among others, to [3]:

- record and present dangerous objects and objects of public utility on maps;
- conduct demographic analyses in potentially threatened areas;
- plan the deployment of population gathering points, command centers, escape routes;
- simulate the propagation of flood wave;
- simulate flooding of certain areas in the event of damage to anti-flood embankments;
- estimate potential damage depending on actions taken during a catastrophe or natural disaster (analysis of variants) or estimate damage after a catastrophe or natural disaster.

GIS technologies can be employed in all crisis situations: constant crisis readiness, increased crisis readiness, crisis readiness and full crisis readiness.

Spatial data is of increasing importance in crisis management. Generally, nearly 80% of decisions in public administration are made in relation to specific locations. GIS uses vector and raster data, enables to query databases, search for shortest routes, cache, carry out overlay, proximity and surface analyses, risk management simulations, and other spatial analyses. Modern spatial information systems use, for example, 3D models, satellite remote sensing, mobile GNSS / GIS solutions, unmanned aerial systems.

In Poland remote sensing data began to be available four decades ago. It was possible to acquire from satellites with equipment installed for recording images of the Earth surface and from aircrafts equipped with special cameras (e.g. laser scanning). Currently, the software able to recognize objects (types of cover/terrain) from photographs obtained by this method is being developed.

Mobile GNSS / GIS solutions enable to have data acquired and verified directly in the field in a professional, quick and cheap way. This is one of the most effective methods for updating and verifying data in reference to small and medium areas. In the case of extensive threats (floods, fires), GPS / GIS technology may be helpful, for example, when reviewing action plans at tactical and strategic levels or during actions themselves (decision-making based on information submitted from the site); it makes it possible to analyze losses caused by time-and-space-related crises. The use of GPS devices mounted in police cars allows a dispatcher to obtain real-time information on their current position and plan services' operations accordingly.

Unmanned aerial vehicles (UAVs), equipped with data recording equipment, are no longer used only by special services and armed forces. Their advantages such as multifunctionality (from reconnaissance to operation), operational capability (quick start virtually anywhere, compact design, portability) and versatility (ability to obtain multispectral images, altitude data and recording images acquired by the camera) decided on their integration with GIS technology. For example, Esri Inc., a leading GIS software manufacturer, in cooperation with GV Video Framework, have created an add-on to ArcGIS for Desktop that enables the practical use of Full Motion Video (FMV) data received from unmanned flying systems. FMV data is a series of multi-spectral images (mostly in R, G, B and IR channels), with UAV orientation parameters saved, allowing for image rectification in the system of geographical coordinates. The FMV data associated with GIS looks like a movie whose sequences are displayed directly on the map and modify their range and shape depending on the position and tilt of the camera from the vertical. This solution allows the GIS operator to observe a faithful picture of the situation, as close as possible to the real situation, which in crisis situations can influence the accuracy of decisions made. FMV technology is used wherever a person is unable to reach or where access is hindered, and when field reconnaissance is too risky or time-consuming. FMV is a substantial part of a coherent operational image creation process. Further integration of FMV and GIS processes is expected, as well as their use for automatic threat detection and analysis of changes [2].
Examples of spatial information systems' application in crisis management:

- the floodplain area analysis (flood risk maps);
- threat maps, e.g. forecasting the impact zones of clouds of released toxic sub stances;
- exploration of the distribution of fires and other occurrences;
- calculation of intersections of roads with threat zones so as to determine the location of order service patrols insulating danger areas;
- identification of address points for evacuation;
- estimation of the number of people in the threatened area;
- the land development analysis, assessment of its exposure to potential threats as well as resources of services, inspections and staff capable of taking action;
- location of potential helicopter landing pads in a crisis situation (Figure 2);

– avalanche risk assessment (Figure 3).

The “IT System for Protecting the Country against Emergencies” (ISOK) has been developed in Poland since 2013 [4]. It is intended to be an IT platform, a tool for crisis management support.

Figure 2 shows the map section of potential helicopter landing pads prepared by the analysts of the Earth Observation Team from the Space Research Center of the Polish Academy of Sciences for the purposes of international EU exercises Carpathex 2011, which were supposed to check and coordinate rescue operations in preparation for the UEFA EURO 2012 tournament. Simultaneously there were simulated: the flood, the large-scale forest fire, the railway catastrophe involving the passenger train and the train transporting chemicals, the technical catastrophe and chemical contamination on the industrial premises. Key infrastructure elements for the helicopter operation such as buildings, trees, chimneys, pipelines, poles and power lines were marked on the satellite orthophotomaps. The safest helicopter ground locations were identified [4].

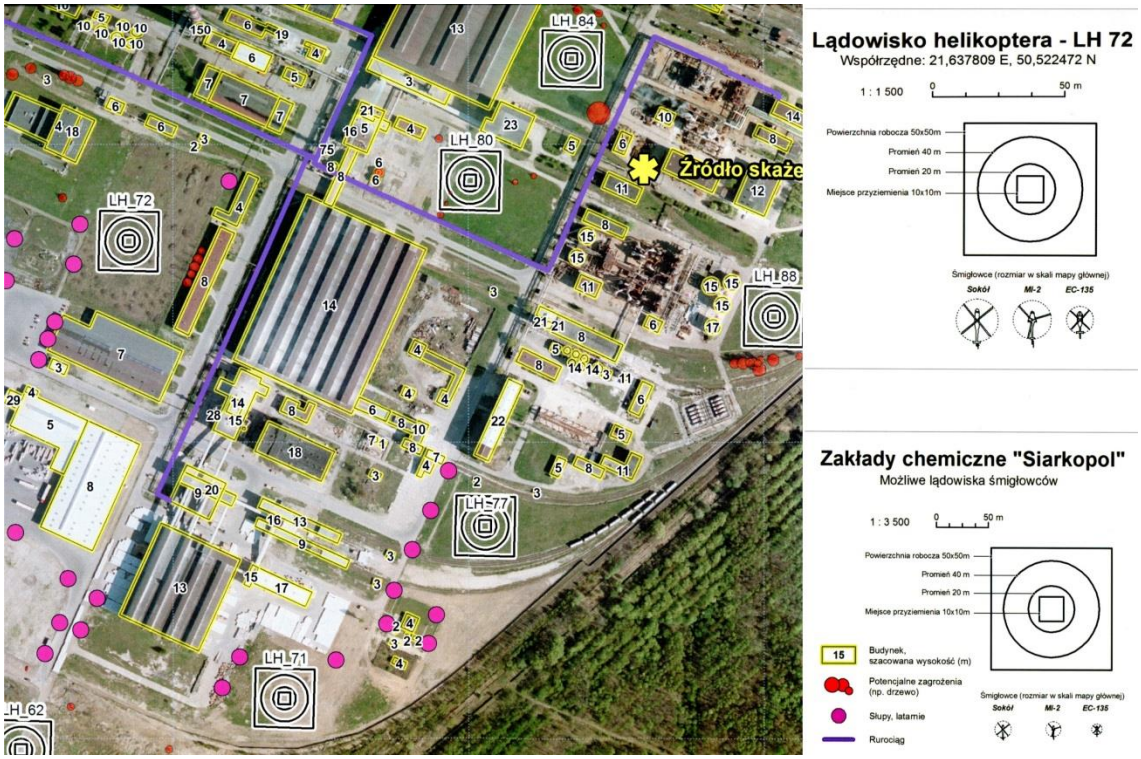

Fig. 2. The map of potential helicopter landing pots

Source: [4]

Another application of GIS in crisis prevention is the avalanche risk location and the assessment of the possible impacts. Figure 3 represents the example of the avalanche path development using GIS tools under the project ‘Influence of Snow and Terrain Conditions on the Size of Avalanche Risk Areas in Selected Carpathian and Sudeten Mountain Massifs’. The photo shows the range of the avalanche in the Silesian Gorge of the Small Pond, which in 2003 caused the death of one person, and two others were

seriously injured. Detailed analyses of such cases allow for the calibration of numerical models and adjusting them to the conditions occurring in the mountain ranges. The conducted research has also proved that the ranges and effects of potential avalanches are predictable [1]. In the years 2013-2014 the Student Scientific Group of Young Surveyors of the Wroclaw University of Technology also carried out the project "Assessment of Avalanche Risk in Selected Regions of the Giant Mountains".

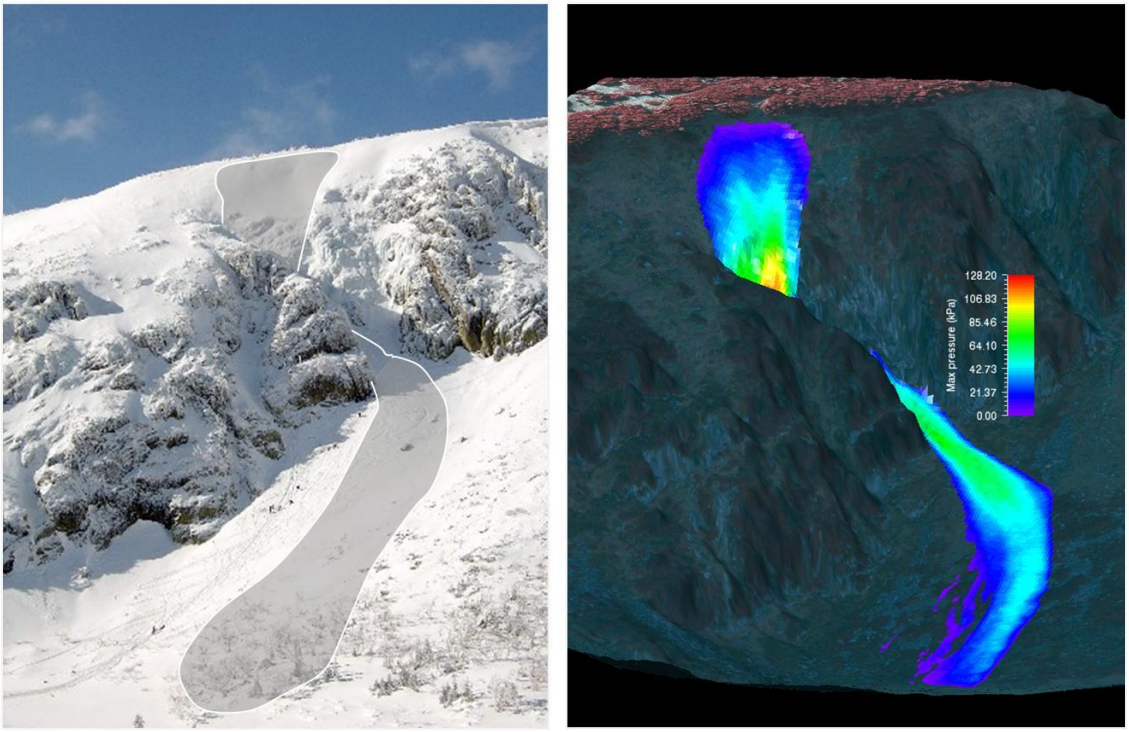

Fig. 3. The example of the avalanche path development using GIS tools

Source: [1]

CONCLUSIONS

Geographic information systems are increasingly used in crisis management. The key advantage of GIS is the capability to analyze a large amount of data that not only provides explanations of the causes of threats, but also predicts the development of crisis situations. On the other hand, GIS helps minimize the so-called "information noise", which reduces the response time in the event of a threat.

GIS is an important tool of help and decision optimization in crisis situations; it makes it possible to increase the effectiveness and efficiency while coordinating actions, emergency services and crisis management units. Full use of GIS possibilities is can take place in integrated crisis management systems, if data is updated frequently.

According to the analysis of crisis management tasks at various levels, GIS is applicable to many of the tasks set out in the Act. There is a need for access to up-to-date spatial information and a good potential for GIS technology in each public administration

body designated for these tasks. The cooperation of all organs requires the creation of a common information exchange platform. This is possible in GIS technology.

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BIOGRAPHICAL NOTE

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