SECURITY DIMENSIONS
NO. 39 (COMMEMORATIVE); 2021 (84–95)
DOI 10.5604/01.3001.0015.6536

Geographic Information Systems in Management on the Example of a Traffic Incident with a Chemical

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ABSTRACT

The purpose of the article is to present various adverse events that may occur in connection with the loading, unloading and transport of dangerous substances. The focus was on finding the reasons for their formation and an analysis of the quantity and structure of the goods transported was carried out. It also describes the possibility of using the geographical information system, with particular regard to the risk situation during the transport of such substances.

ARTICLE INFO

Article history
Received: 11.02.2021 Accepted: 17.12.2021

Keywords
GIS system, crisis event, traffic incident, crisis

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Introduction

No state or society is free from the risks and dangers of the modern world. There are many threats and with each day they appear, more and more newer, with which man must deal with in order to survive and protect his goods from destruction. Crisis situations are an integral part of human life. However, individuals are not able to deal with them on their own. It is therefore important to set up organizational units to ensure security and to reduce and counteract the risk of threats and, if they occur, provide adequate assistance and response at the right level. Counteracting the dangers that are difficult to predict is not easy. It is therefore important to prepare response plans and procedures in advance in the event of a specific threat. Geographical information systems are helpful in creating such plans and procedures, which, thanks to their capabilities, allow to analyze and visually present the strength and extent of the potential threat, e.g. the spread of flood waves, leakage of dangerous substances causing environmental contamination or gas explosion. The potential of the geographical information system is used comprehensively with very good results. It applies in virtually every area of life, and its components can also be effectively used at every stage of crisis management – in the prevention, preparation, response and reconstruction phases.

Threats can come from a variety of sources. In addition to the crises created by the forces of nature, man has an increasing share of them. Intensive economic development creates a need for better connectivity and communication, which is linked to the development of road transport. However, the road infrastructure in Poland is not in good technical condition.[1] According to the government report on the state of roads in Poland, 82% of public roads are poor county or municipal roads.[2] Only 0.4% of all roads are motorways and expressways.[3] The technical condition of roads is one of the main causes of traffic incidents involving self-driving vehicles.

[1] W. Durski, 'Identyfikacja przyczyn pierwotnych powstawania zagrożeń w transporcie materiałów niebezpiecznych', *Zeszyty naukowe Politechniki Poznańskiej nr 63. Maszyny Robocze i Transport*, no. 63, 2008 pp. 91–96.

[2] M. Borysiewicz, A. Furtek, 'Podstawy analiz ryzyka i zarządzania ryzykiem w odniesieniu do awarii transportowych', *Prezentacja – szkoła tematyczna Zarządzanie Zagrożeniami dla Zdrowia i Środowiska*, 2005.

[3] Generalna Dyrekcja Dróg Krajowych i Autostrad, *GDDKIA.gov.pl*, https://www.gddkia.gov.pl/pl/995/bank-danych-drogowych, (accessed December 2020).

The Importance of GIS Information in Crisis Management

With the development and scientific progress, we are dealing with more and more new technologies. The rapid development of computer science and database management methods contributed to the creation of the GIS. The *Geographic Information System*(GIS) is a system used to collect, store, process and visualize spatial data. In order to build such a system, it is necessary to have adequate computer hardware, software, a collected spatial database and appropriate procedures for processing and sharing information. In addition to the technical part, an important element of the system is the human resource, that is, the people who make up the system and its users. Geographical information systems have been used in most areas of life. Using GIS helps you solve both simple and very complex tasks. In everyday life, it is used for practical tasks, while specialized applications involve the development and analysis of the changes in question concerning specific circumstances.

The interpretation of complex reality provides countless information about real-world objects in terms of their spatial location, shape and other properties, and their time-space relationships. It can therefore be assumed that a significant proportion of objects, phenomena and processes actually take place are spatial in nature, as they are determined by a specific place and time. Any data about spatial objects, including phenomena and processes, that are located or occurring in space is called spatial data. This data, properly analyzed and interpreted, is a source of spatial information, otherwise known as geoinformation.

Spatial information can be presented in many forms such as map, aerial or satellite imagery, city plan, address reGISter or object reGISter. In addition to geographical features, spatial information also includes complex processes and phenomena occurring in space. Therefore, a complex form of spatial information requires an appropriate system in which it can be stored and analysed. According to the definition of the Polish Spatial Information Society, it should be "an orderly *set of interconnected elements*, which has a certain structure and can be considered as a whole."[4] It is a Geographic Information System (GIS) that covers all issues related to the creation, collection, processing and use of geographic information. This name in Poland is often used interchangeably with the term "spatial

[4] Polish Association for Spatial Information, *PTIP.org.pl*, http://www.ptip.org.pl/, (accessed December 2020).

information system" (SIP), but it is worth knowing the difference between the two concepts. The word "geographic" refers to objects located in space, and "spatial" includes both objects in space, as well as phenomena and processes occurring in space. According to the definition of the Polish Spatial Information Society (2015), the spatial information system is:

1. a system for obtaining, collecting, verifying, integrating, analyzing, transferring and sharing spatial data. It broadly covers methods, technical measures, including hardware and software, spatial database and organization, financial resources and people interested in its operation;

2. software with functions corresponding to its definition in point 1. manufactured and offered by specialized companies (…).[5]

An important aspect is the fact that a spatial information system is not an IT system based solely on software and hardware. SIP is **an information system**, which means that in addition to the required technology and infrastructure (software, hardware) its indispensable components are the appropriate organization(personnel and methods of organization) and, above all, the spatial database playing a key role in the system. In the past, geographic space was described using traditional maps, which were usually handmade. The techniques of information technology allowed to improve this process, and with the development of GIS systems created appropriate tools for digital visualization of **space**. Maps created by spatial information systems are digital and interactive maps. All elements and layers that make up a map are logically related to each other based on the spatial relationships between them. The GIS system not only allows you to combine data from different sources (vector, raster, descriptive data) but also allows you to perform advanced spatial analysis, visualization of data in the form of different models.

The basic parameters describing a crisis event are place and time, hence any information generated about crisis events is spatial information. Therefore, spatial information systems are important in all phases of crisis management and are increasingly used as a tool to support decision-making. With geoinformation tools, it is possible to identify threats spatially, model

[5] S. Białousz et al., *System baz danych przestrzennych dla Województwa Mazowieckiego*, Warszawa, Oficyna Wydawnicza Politechniki Warszawskiej, 2004, p. 165.

their course, predict the effects of events, or develop threat scenarios. Spatial information occurs in every phase of crisis management. Examples of spatial information processing products used in different phases are m.in.: interdisciplinary spatial analysis, hazard forecasts and maps, sensitivity and risk, terrain and site models and visualizations, hazard models and visualizations, crisis management zoning plans, evacuation plans, loss maps, and recovery plans.[6] GIS technology is huge and has been widely used in many areas, including forwarding.

Use of GIS information at a selected crisis event

Based on the analysis of traffic incident statistics, it should be concluded that their number increases every year. In this number there are also events involving dangerous chemicals for the population and the environment. The rapid response of the emergency services avoids undesirable effects on the health and life of local communities in the "path" of the chemical.

The multitude of these events makes it possible to specify the operational, technical and organizational activities of the emergency services. The proper decisions taken by the decision-makers in charge of these activities have a major impact on the smooth operation of the emergency services, which are increasingly complemented by GIS-based analysis.

Road transport is usually carried out on short and long routes, where the transport of dangerous materials of interest to us is carried out in unit packages such as cylinders, small tanks, etc. on commercial vehicles or trucks and bulk packaging in tank trucks.

For the transport of petrol to service stations in urban areas, the routes are usually fixed, while in the case of hazardous materials (e.g. gaseous materials) they are supervised.

In the event of major disasters involving hazardous gaseous substances, the emergency services shall act by sealing the damaged tank or, in the absence of such an option, to pump the controlled substance or to bring it into the atmosphere in an environmentally sound manner.

Based on a traffic incident involving a dangerous substance, an example of the use of GIS information was provided to illustrate the extent of the hazard resulting from the transfer of the dangerous substance into the

[6] J. Gaździcki, 'Technologie i infrastruktury informacji przestrzennej w zastosowaniu do zarządzania kryzysowego', *Roczniki Geomatyki*, vol. IV, issue 1, 2006, p. 22.

atmosphere. The MARPLOT, ALOHA and Arc GIS applications will be used in the analysis.

Example:

Data (examples) used in the analysis:

- the location of the event,
- date and time of the event,
- the type of chemical,
- meteorological parameters,
- source (e.g. point, spill, tank, pipeline).

Information collected from a witness and meteorological data

Location of the event: Słupsk, roundabout “Solidarity”.

Date: 20.11.2020 ; 11:30 p.m.

Substance: chlorine (determined upon arrival of emergency services).

Weather: cloudless night, temp. 8 ^{o}C, wind speed 3 m/s blowing from the east, no inversion, humidity25%.

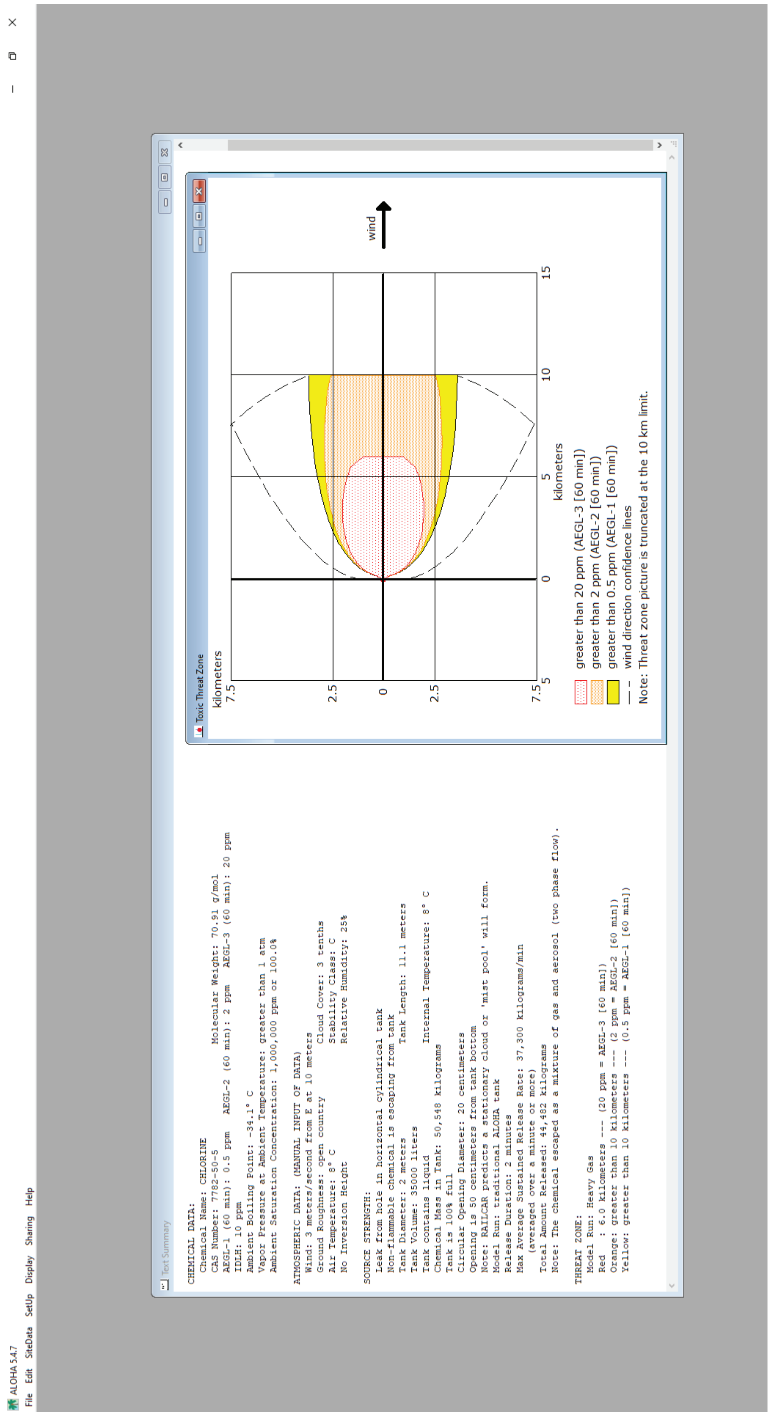
Tank with a capacity of 35,000 l, diameter about 2 m, damage in the form of a hole about 20 cm in size, at a height of about 0.5 m from the bottom surface of the tank.

Fig. 1. Event location

Source: Own elaboration based on marplot application.

The analysis involving the hazardous substance chlorine was carried out in the ALOHA application. The analysis obtained danger zones and their ranges.

Fig. 2. Threat zone coverage analysis



Source: Own elaboration based on ALOHA application.

The next step is to import the threat range data into the MARPLOT application.

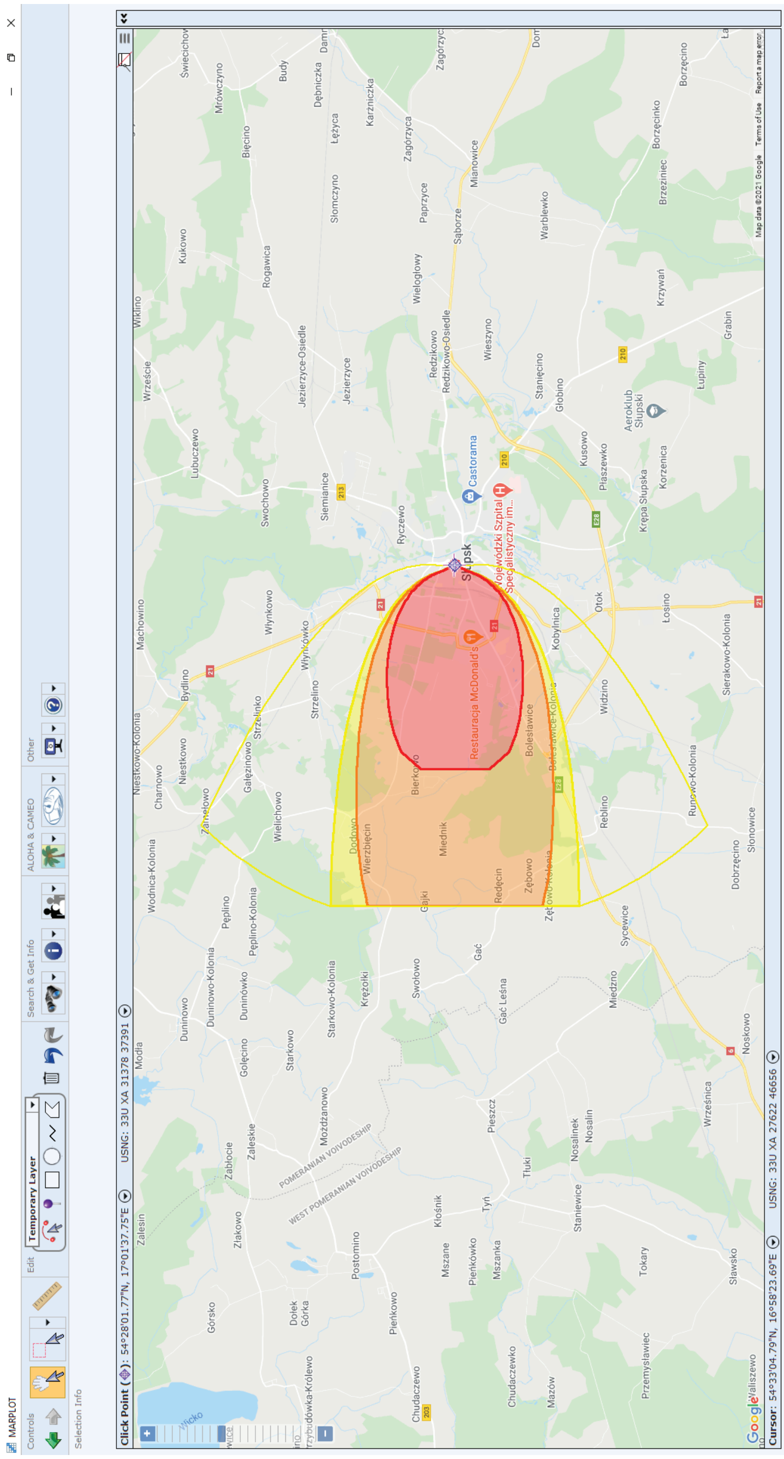


Fig. 3. Threat zones imported from ALOHA to MARPLOT

Source: Own elaboration based on marplot application.

One of the most important activities covered by the analysis of the above event is to indicate the number of objects that are exposed to the inadvisable effects of chlorine, and thus to people who have found themselves as a result of this event in different danger zones. This analysis allows for a quick decision on the evacuation of populations from individual danger zones. It was carried out using the Arc GIS application.

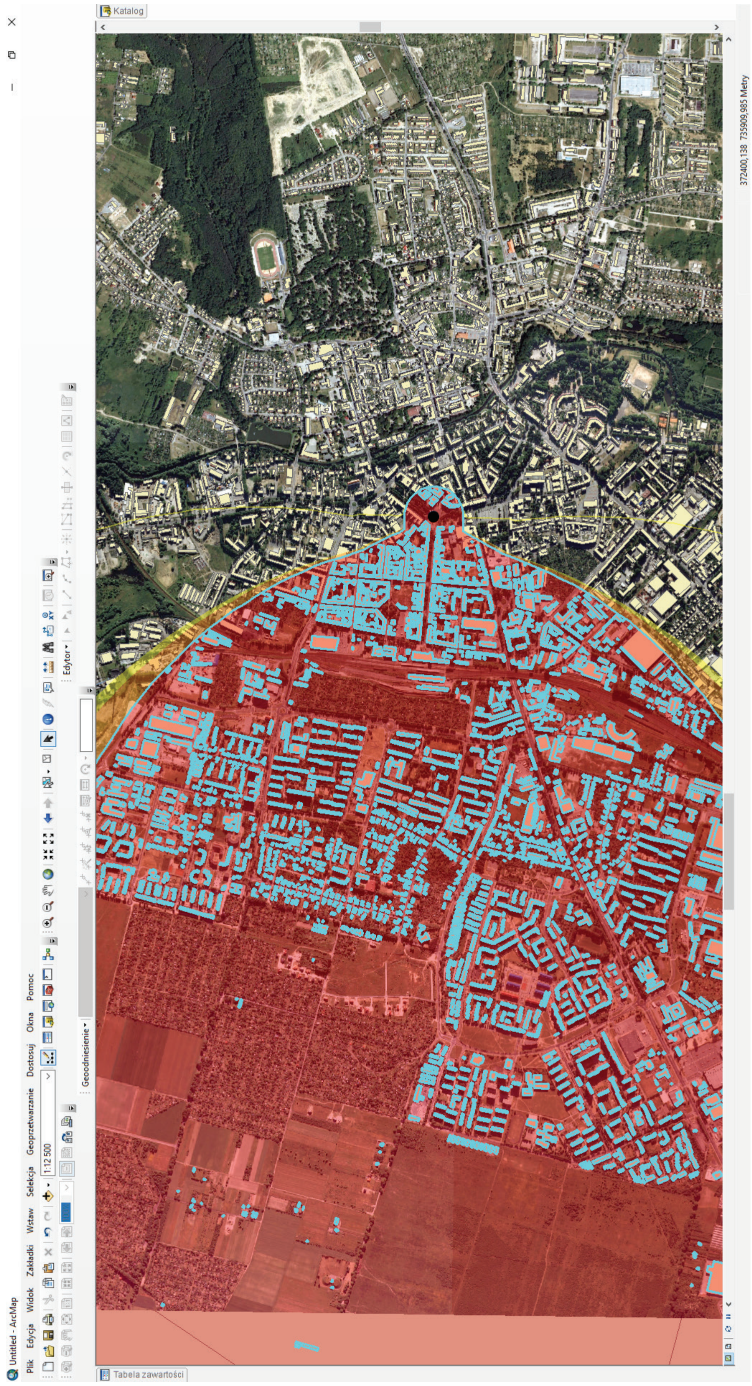


Fig. 4. Extracted objects in the red danger zone made with the geoprocessing tool "BUFFER"

Source: Own elaboration based on Arc GIS application.

Data obtained from the analysis showed that 2,496 facilities are in the danger zone – the red most vulnerable to adverse health and life effects of people in the zone. It is also a signal to the emergency services to take action to evacuate the population from the affected area as soon as possible.

Conclusions

The reasons for failure involving dangerous substances can be many. Most of them belong to the group of "other events," which often means reasons that are difficult to identify. The human factor is particularly fraught with high risk. For this type of transport event, a geographical information system is useful. It can provide basic assistance in preventing, supporting and reducing the effects of events that occur or may occur. Thanks to it, it is possible to perform spatial analyses of the place of the event during the ongoing rescue operation, keep a re GISter of transport events, simulate the propagation of the contaminated cloud, the extent of the threat or the location of medical units sent for rescue purposes.

Geoinformatics technologies have quickly become tools for the daily work of researchers, naturalists, foresters, officials and services related to the national security sector. The results of the project and examples of domestic and foreign practice show that GIS technology can be successfully used as a tool in the process of analyzing hypothetical phenomena as well as current crises.

Applications:

This article's review of the state of play and experience in geospatial data management shows the need to focus further work on the real development of geoinformation society, as a society that benefits widely from geoinformation through publicly available geospatial data infrastructure services.

1. Initiatives and work are currently underway around the world to improve the management of geospatial data by building geospatial data infrastructures at different levels and territories, taking into account dynamic technological developments,
2. The analysis used in this article can be used successfully in all institutions and services conducting monitoring as well as contamination analysis. In addition, it can be used to assist emergency services.

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Cite this article as:

G. Diemientiew, 'Geographic Information Systems in Management on the Example of a Traffic Incident with a Chemical', *Security Dimensions*, no. 39 (commemorative), 2021, pp. 84–95, DOI 10.5604/01.3001.0015.6536.