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APPLICATION OF TRANSPORT SECURITY SYSTEM SYMBOLOGY FOR EMERGENCY MASS NOTIFICATION SYSTEMS

Summary. The visualisation of resources is becoming an increasingly important factor in the operations of crisis management teams. The efficiency of crisis management processes depends on the possibility of data exchange between crisis management teams and people within the range of expected and actual threats. An important part of the information provided to people is the description of the condition of the transport system. The authors of this work carried out comparative analyses of visualisation standards in terms of a selected transport system for six selected countries and organisations. Based on the survey results, they managed to assess the functionality and usability of the visualisation of the Polish transport system. This research was based on a modified model of assessment of software functionality and usability. Methods of determining the functionality and usability of a transport system visualisation can help crisis management teams assess the suitability of IT tools for use in mass notification systems. The literature on this subject lacks a scientific analysis of the Polish method of the visualisation of the transport system. Therefore, this study will clearly fill this research gap.

1. INTRODUCTION

The visualisation of resources is becoming an increasingly important factor in the operations of crisis management teams which directly affects their efficiency in complex environments. In the era when crisis management teams can take advantage of various IT tools for processing diverse data, the ability to operate in an environment of dispersed data and systems is of great importance. Many crisis management entities use dedicated (usually different) IT support systems to process the data collected from different sources. The efficiency of crisis management processes depends not only on the possibility of data exchange between individual crisis management teams but also on the possibility of data exchange between crisis management teams and people who are within the range of expected and actual threats.

An important part of the information provided to people is the description of the condition of the transport system used for crisis management means and resources, as well as for the evacuation of people. The currently used mass notification system involves sending short text messages to the people staying in the endangered area. However, in the era of development and the widespread use of IT tools for geospatial data processing (e.g., Google, OpenStreetMap), the current form of communication seems to be insufficient. The use of data about the transport system in a graphic form (1), such as geospatial data (maps), for notifying people about threats can have a positive impact on safety.

Before determining the scope and type of information to be provided to people, it is important to determine the scope of information about the transport system that is currently available to crisis

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management teams. The latter cannot provide information to which they do not have access or which is beyond the scope of the data processed by them. Another important factor is the visualisation method used by crisis management teams for resources that make up the transport system which will be applied when providing information to the public.

Commonly used visualisation systems use simple vector objects (e.g. points, lines, polygons) to represent complex elements of transport systems (2), (3) or raster objects (icons) (4), (5). Therefore, the modernisation of the mass notification systems in terms of transport system visualisation should start with the modernisation of the visualisation processes used by crisis management teams. The purpose of the present preliminary research was to assess the functionality and usability of the transport system visualisation available at crisis management stations.

For this research, the authors considered a number of transportation models (6) and adopted a simplified model of the transport system (7) with the following elements:

- Transport infrastructure
  - Roads and routes (e.g., roads, bicycle paths, railways, waterways, airways.)
  - Buildings and structures (e.g., stations, ports, stops, airports, ramps, warehouses.)
  - Equipment (e.g., traffic lights, level crossings)
- Means of transport
  - Land transport
    - bicycles
    - cars
    - trains
  - Water transport
    - maritime
    - inland
  - Air transport
    - aeroplanes
    - helicopters

The defined research area for the functionality and usability of the transport system visualisation is shown in the diagram below (Fig. 1).

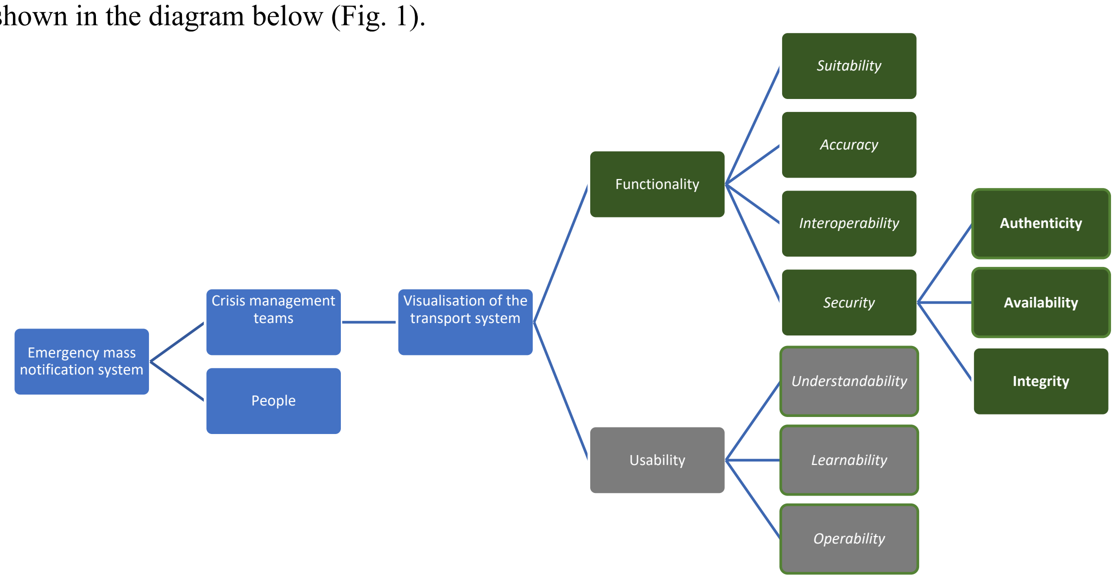


Fig. 1. Research area for the functionality and usability of the transport system visualisation

2. GEOSPATIAL DATA FOR THE VISUALISATION OF THE TRANSPORT SAFETY SYSTEM

The data used in crisis management describing the transport system comes from different sources and can take different forms: descriptive, tabular, or graphical. However, due to the importance of the spatial attributes of this data and its nationwide coverage, only geospatial data was considered (geospatial data is understood as data related to the surface of the Earth). The paper, therefore, deals with geospatial data related to the transport system, as well as the principles of its modelling and visualisation.

The system of crisis management undergoes gradual globalisation (e.g. as part of the European Copernicus Emergency Management Service), which is why analytical processes conducted based on data obtained from various globally available sources are becoming increasingly important. Threat visualisation processes and crisis management resources and measures play crucial roles in the formation of the situational awareness of crisis management teams. Data visualisation may be used for preliminary analyses of a large volume of data or to present specialised analyses. Unfortunately, the globalisation of geospatial data standards (which is the basis for the visualisation of hazards on maps) has been successful only in the case of geospatial data used to represent geographical objects according to cartographic standards. On the other hand, data obtained by crisis management teams is used to visualise hazards, crisis management resources, and measures on maps based on different models, depending on where it is processed.

The analysis of the data of the transport system processed in crisis management systems for the purposes of its geospatial visualisation allows one to identify two categories of data, as described below:

- **Data on the transport system constituting layers of the cartographic map (geographical data)**
  Visualisation of the transport system with respect to this type of data is based on commonly used norms and standards specified for geographical data. In Poland, the IT systems available for crisis management teams process geographical data in a standardised manner (Journal of Laws of 2010, no. 76, item 489) regulated by 12 leading authorities (8). Geographical data on the transport system is collected in dedicated databases in accordance with the standards of the EU INSPIRE project (9), which are based on the Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) standards. Poland has implemented the stipulations of the INSPIRE project by an act (Journal of Laws of 2015, item 2028), and has defined a set of signs used to depict geographical objects.
- **Operational data generated by crisis management entities (data on threats, resources, means, actions and incidents)**
  Crisis management teams also process other types of data generated by individual participants of crisis management processes. Such data on hazards, resources, means, actions, and incidents can be referred to as "operational data". Processing this type of data requires dedicated systems, and in the absence thereof, the data is recorded in descriptive and tabular form. The popularisation of information systems supporting individual processes of crisis management has contributed to the widespread use of geospatial information systems (GISs). The use of this class of systems makes it possible to assign geospatial references to the processed data. Thus, data that was previously collected in tabular form can be assigned attributes that allow for their visualisation on cartographic maps. These are referred to as geospatial attributes. Therefore, it can be assumed that data with geospatial attributes refer to the geometric properties of a spatial object, spatial relationships of a given object with other spatial objects, and the distinguished descriptive attributes of a spatial object that define its basic properties.

The subjects of the present research are the visualisation models used for the operational data of the transport system used by crisis management teams in Poland and their comparison to other models used in other countries. Growing global threats (e.g. the COVID-19 pandemic) necessitate the standardisation of the operational data exchange between individual crisis management centres. In order to assess the functionality and usability of the transport system data visualisation system, the authors proposed a research method based on the functionality and usability assessment model defined in ISO/IEC 9126. The authors opted for a slight modification of this model to adapt it to the assessment in question (the ISO/IEC 9126 model was originally created for software quality assessment).

The geospatial data obtained by crisis management teams (data on threats, resources, means, actions and incidents), classified by the authors as "operational data", is usually generated by numerous external entities collaborating in crisis management (e.g. police, fire brigades, border guards, armed forces). Processing these resources and their exchange is mainly carried out using dedicated IT support systems. The IT systems used to process geospatial data in individual ministries and state services differ.

Individual entities involved in the crisis management system use their dedicated IT systems to support data processing, as well as different models and methods of visualisation of this data. The modelling processes of geospatial operational data depend on the adoption of specific assumptions at the stage of real-world virtualisation. The most important part of modelling real objects into their virtual counterparts (computer models) is the classification of real objects into corresponding abstract objects (an abstraction of an entity or phenomenon occurring in the real world) (10). This method of classification represents a way to assign real objects to their virtual equivalents to determine the following modelling stages: the construction of abstract objects, their dimensioning, and the process of locating the objects in relation to the Earth's surface.

3. VISUALISATION OF GEOGRAPHICAL DATA - CARTOGRAPHIC MAPS

In GISs commonly used to process geographical data, a compromise has been reached in terms of data exchange models, which has enabled the visualisation of maps in computer and smartphone applications. With the help of data and service standards developed by the OGC and ISO, as well as the removal of licence-related restrictions applicable to these standards, it was possible to increase the use and availability of cartographic maps in numerical form. However, standardisation enabling the integration of many existing models usually simplifies the exchange model.

In the case of geographical data, a compromise had to be reached in terms of the type of data geometry considered. It was agreed that only three basic geometrical forms would be used for object modelling: points, lines, and polygons (ISO 19101-1:2014). The development and dissemination of standards for geospatial services and geospatial data exchange have allowed individual GIS developers to maintain the hitherto used complex, application-specific data models. Dedicated GISs enable the processing of unique types of object geometry specific to the adopted solutions.

When dealing with geospatial data generated by different GISs, one should verify whether this data has been adapted to a unified standard for geospatial data services and exchange. Web Map Services (WMS) developed by the OGC is currently the only widely accepted open standard method for map visualisation, and it standardises the way web clients download and display maps. WMS have also become an ISO standard. Standards-based interoperability is a good solution to the problem of retrieving data from heterogeneous data sources, but it only concerns the technical side of transmitting the data, not the data itself (11). For example, Morrison's comparative studies of different methods of representing transport networks on maps (conducted in twenty-five cities and eleven countries across Europe) identified four styles of cartographic representation (12): a) French style, b) classic style, c) Scandinavian style and d) Dutch style. It can therefore be assume that the symbolism of topographic maps and the method of their visualisation are slightly influenced by social conditions as a result of country-specific choices regarding the method of classification and symbolisation of topographic objects (13). The way in which geographical objects are modelled also determines the form of visualisation thereof. The convention of using symbols representing geographical objects on paper maps has been considered in the construction of cartographic maps in numerical form and the method of their visualisation.

Individual entities involved in the crisis management system, as well as citizens, commonly use and properly interpret international standards of geographical data visualisation (i.e. the standards developed by the OGC and ISO). Professional geospatial data processing systems are widely available to crisis management teams, as a number of GISs are available on the market under an open-source license (14). However, the availability of geographical data processing tools does not imply the availability of tools for operational data visualisation. Widely available GISs do not enable the visualisation of operational data according to the standards applicable in Poland.

The problem with the shortage of IT tools for such a purpose is not limited to Poland. Many countries and organisations adopt their own models of operational data visualisation. The phenomenological approach proposes several categories of operational data modelling. The European INDIGO project identifies three main models for operational object visualisation (15). One type of model uses an icon, which is a representation that retains a strong resemblance to the real object and is implemented by means of either an image, a diagram or a metaphor. Another type uses an index, which is associated with the object. The third type uses a symbol which follows a defined convention to represent an operational object (if we do not know the adopted convention, we will not identify the object that is represented by a given symbol).

As part of the country's crisis management system, Poland has adopted a model of visualisation of operational objects based on symbols. Other countries (e.g. the USA) have adopted a method of representing objects using icons when standardising visualisation processes. Of great importance for visualisation models based on symbols is the precise definition of a convention that determines the construction of the symbols used. The Polish convention is based on the military visualisation standard. In this case, the form of particular components of symbols reflects the operational properties of objects and does not entail visual similarity to the object that the symbol represents. Such a model requires knowledge of the adopted convention by all entities involved in the crisis management system. If the system user does not know the adopted convention, he or she will not be able to correctly identify the visualised objects. This problem is exacerbated when data is obtained from other countries that have adopted their own visualisation standards.

4. ANALYSIS OF TRANSPORT SYSTEM VISUALISATION STANDARDS IN SELECTED COUNTRIES

The model of operational data visualisation (including the transport system) adopted in Poland is based on the military standard, which was developed by NATO for joint operations of all types of armed forces. The Polish model is based on the APP-6A version of NATO's STANAG 2019 (16). Poland implemented this standard in its Armed Forces in 2003.

The visualisation model adopted in APP-6A has become the basis for the development of principles of visualisation of signs for the needs of all units subordinate to the Minister of the Interior and Administration (e.g. police, border guards, state fire services, civil defence). The unification of the standards for operational situation visualisation in all units subordinate to the Ministry of Internal Affairs and Administration helped to increase the efficiency of the entire crisis management system.

The adoption of the military standard by the Ministry of Internal Affairs and Administration and its adaption to meet civilians' needs required several changes. The main modification consisted of the introduction of a new graphic modifier for the symbols of units subordinate to the ministry in question. This modifier was used to identify the affiliation of a given unit to the appropriate formation of the Ministry of Internal Affairs and Administration. There are also differences in the definitions of symbols representing specialised units of the ministry in question.

Standards of operational object visualisation for the purposes of crisis management have also been developed in other countries and organisations, and they have been adapted to the specific needs of users. The current comparative analysis of visualisation standards considered Poland (PL), the United States of America (USA), Australia (AU), and Canada (CA), as well as the United Nations (UN) and the European Union (EU). The analysis was based on the following data:

- ***PL** – A set of basic adopted operational signs appropriate for the organisational units of the Ministry of Interior and Administration and the organisational units subordinated or supervised by the Ministry of Interior and Administration* (Journal of MSWiA of 2008, no. 5, item 16)
- ***USA** - Emergency Response Symbology* (17)
- ***UN** - United Nations Office for the Coordination of Humanitarian Affairs, set of 295 humanitarian icons* (18)
- ***EU** - INDIGO - European Emergency 2d/3 Symbology Reference* (19)
- ***AU** - Australian All Hazards Symbology* (20)
- ***CA** - Canadian All-Hazards Symbology* (21)

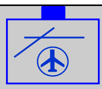
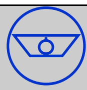
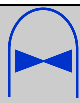
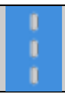
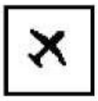
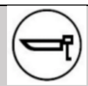
The available literature on the subject includes comparative analyses of visualisation systems that highlight differences in operational object visualisation in particular countries. Kostelnick and Hoeniges (22) identified differences at the level of taxonomy development, symbol design issues, promulgation, the sharing of map symbols and the standardisation of symbols within and among organisations.

Comparative research by Divjak, Đapo, and Pribičević (23) focused on four factors: symbol taxonomies, symbol design, availability, and standardisation. However, the cited studies did not analyse the visualisation systems used in Poland. The authors limited their research to the following selected elements of transport infrastructure and means of transport:

- Transport infrastructure
  - Roads - motorway
  - Buildings - airport
  - Equipment - traffic lights
- Means of transport
  - Land transport - trucks
  - Water transport - ships (motorboats)
  - Air transport - helicopters

Table 1

Comparison of operational symbol standards used in crisis management for selected transport system facilities

Country							Availability
	Road	Airport	Traffic light	Truck	Motorboat	Helicopter	
PL							http://e-dziennik.mswia.gov.pl/DUM_MSW/2008/5/DMSW2008_005.pdf,
United States	**No linear elements**		None			None	https://webstore.ansi.org/standards/incits/ansiincits4152006, https://www.fgdc.gov/HSWG/ref_pages/NaturalEvents_ref.htm.
UN			None				https://brand.unocha.org/d/xEPytAUjC3sH/icons
EU	**No linear elements**		None		None		http://indigo.diginext.fr/EN/content.php?page=Downloads/Symbology,
AU			None				https://drive.google.com/file/d/1i2RhHTgiC0NrvFNJekXGMfiMaqqVtbAm/view
CA	**No linear elements**		None				http://goccogpubca.canadaeast.cloudapp.azure.com/share/GOC-COG/CAHS-SCTR/Documentation/PS-SP-%231272768-v6A-CAHS_Explained.pdf

Source: Own elaboration

Comparative analyses of visualisation standards in terms of selected transport system data revealed significant differences in the possibility of visualisation of objects in individual standards (Table 1**Błąd! Nie można odnaleźć źródła odwołania.**). The Polish standard offers a much greater level of detail of the transport system visualisation than other standards. This is due to the adoption of a visualisation model based on the idea of symbols, which facilitates the process of creating new symbols. Since this model is based on a set of rules defining the meaning of symbols, the construction of a new symbol requires only the strict application of these rules. This model even allows users to create ad hoc symbols. In the case of an icon-based visualisation model, an icon proposal should be designed and subjected to a user recognition test.

The remaining countries and organisations have developed their visualisation standards based on the use of an icon-based model (visual similarity of signs to the represented objects). This entails a significant simplification of linear and surface object visualisation (e.g. roads, lines, regions). Only the

Australian standard provides for the possibility of visualising these types of objects. In addition, a summary of selected signs presented in Table 1 shows discrepancies in the form of icons representing individual elements of the transport system.

5. ASSESSMENT OF THE FUNCTIONALITY AND USABILITY OF THE TRANSPORT SYSTEM VISUALISATION

The Polish standard for the visualisation of operational objects (data about threats, resources, means, actions and incidents), which is based on the phenomenological category of "symbol", requires the popularisation of the adopted convention. In order to correctly determine the meaning of individual symbols, the users of the systems should be appropriately trained to identify them. Thus, the assessment of the functionality and usability of the adopted solutions is crucial.

The authors decided that the best method for such an assessment, in relation to the visualisation of the transport system, would be to survey a randomly selected sample of members of crisis management teams. Specifically, this research was conducted on a random sample of forty members of crisis management teams of the voivodship level (there are sixteen crisis management teams at this level in Poland). This research was based on a modified model of assessment of software functionality and usability. The modification of the model consisted of a precise definition of requirements for each of the components defining the functionality and usability of the transport system visualisation.

The functionality of the transport system visualisation was assumed to be the degree to which users' needs are met in terms of visualisation. This parameter was measured based on the following variables:

- **suitability**: the ability to graphically represent the transport system (transport infrastructure and means of transport). A suitability index of 1 means that the entire transport system described verbally can be represented graphically with signs; an index of 0 means that no part of the transport system described can be represented graphically using signs (**Błąd! Nie można odnaleźć źródła o dwołania.**).
- **accuracy**: the possibility of precisely determining each of the following elements:
  - transport infrastructure (roads, buildings, equipment)
  - means of transport: land transport (bicycles, cars, trains), water transport (maritime, inland) and air transport (aeroplanes, helicopters)

  Accuracy also relates to several attributes:
  - time (Fig. 3Fig. 3Fig. 3);
  - position (
  - **Błąd! Nie można odnaleźć źródła odwołania.**);
  - type of object (Fig. 5).

  An accuracy index of 1 means that for all elements subject to visualisation, the following factors can be precisely determined: time, position, and type of object. An accuracy index of 0 means that for no element can these factors be specified.
- **interoperability**: the ability to convert the transport system visualisation from one standard to another standard. An interoperability index of 1 means that the whole transport system visualisation can be converted to another standard. An interoperability index of 0 means that no element of the transport system visualisation can be converted to another standard. The interoperability assessment is based on two tests:
  - what part of the transport system visualisation obtained from external sources can be identified without using symbol dictionaries (Fig. 6);
  - what part of the transport system visualisation obtained from external sources can be adapted to the visualisation used in a given crisis management position (Fig. 7).
- **security**: assessed in terms of the following three facets:
  - availability: the accessibility of the symbols for the transport system visualisation. An availability index of 1 means that all symbols required to represent the transport system are available. An availability index of 0 means that none of the symbols required to represent the transport system is available (Fig. 8);

- authenticity: the possibility of verifying each symbol of the transport system visualisation in terms of its authenticity. An authenticity index of 1 means that it is possible to verify all symbols of the transport system visualisation. An authenticity index of 0 means that it is not possible to verify any symbol of the transport system visualisation (Fig. 9);
- integrity: the possibility of verifying each symbol of the transport system visualisation in terms of its integrity. An integrity index of 1 means that it is possible to confirm the integrity of the whole transport system visualisation. An integrity index of 0 means that it is not possible to confirm the integrity of any part of the transport system visualisation.

For the analyses, a five-point Likert scale has been adopted. The values on the scale were as follows: very low [0, 20], low (20, 40], medium (40, 60], high (60, 80], very high (80, 100]. The values of the indexes were calculated by the mean value. The bolded sections of the figures represent the intervals containing the mean.

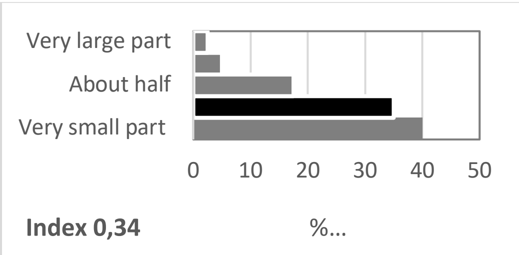


Fig 2. Suitability – The part of the transport system described by text that can be represented graphically by signs.
Source: Authors' calculations

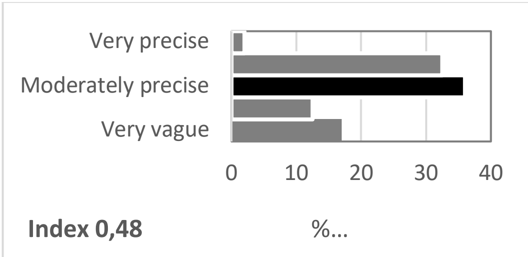


Fig. 3. Time accuracy – How accurately we can determine the time of the symbols representing transport infrastructure and means of transport
Source: Authors' calculations

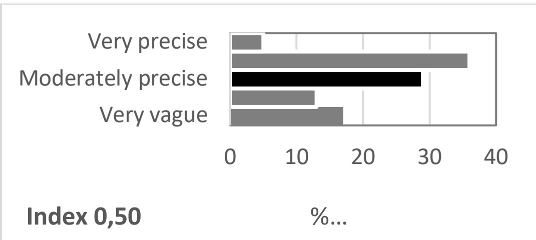


Fig. 4. Position accuracy – How accurately we can determine the positions of the symbols representing transport infrastructure and means of transport
Source: Authors' calculations

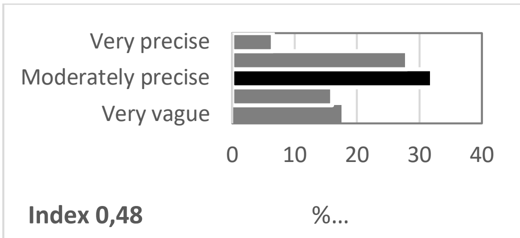


Fig. 5. Type of objects accuracy – How accurately we can determine the type of object for the symbols representing transport infrastructure and means of transport
Source: Authors' calculations

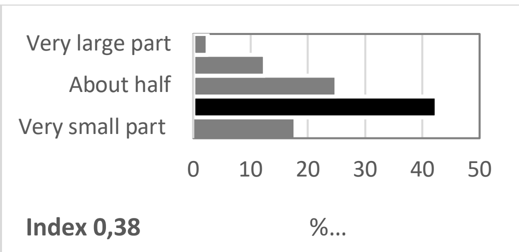


Fig. 6. Interoperability 1 – The part of the transport system visualisation obtained from external sources that can be identified without using symbol dictionaries
Source: Authors' calculations

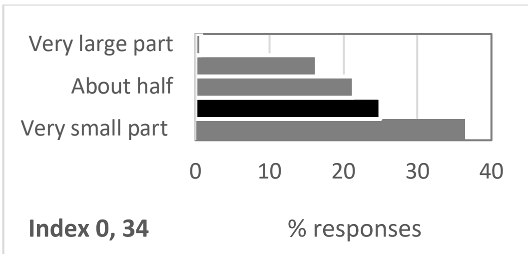


Fig. 7. Interoperability 2 – The part of the transport system visualisation obtained from external sources that can be adapted to the visualisation used in a given crisis management position
Source: Authors' calculations

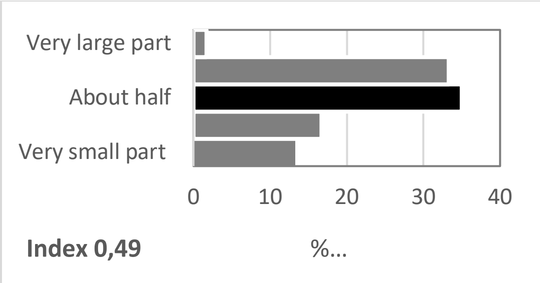


Fig. 8. Availability – The part of the symbols used for the transport system visualisation that is available
Source: Authors' calculations

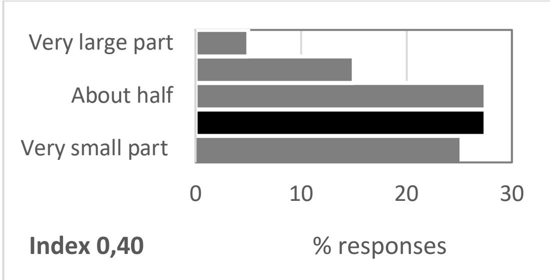


Fig. 9. Authenticity – The part of the transport system visualisation that can be verified in terms of authenticity
Source: Authors' calculations

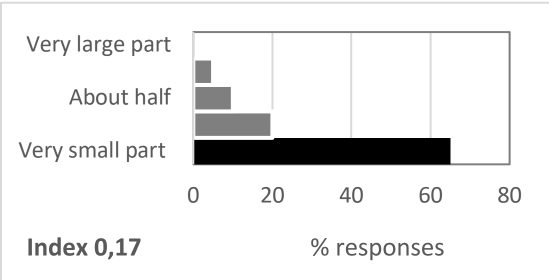


Fig. 10. Integrity – The part of the transport system visualisation that can be verified in terms of integrity
Source: Authors' calculations

The following variables were used to assess the usability of the transport system visualisation, which is understood as the degree of difficulty in its use:

- understandability: the correct identification of all visualised elements of the transport system. An understandability index of 1 means that all the symbols have been correctly identified. An understandability index of 0 means that no symbol has been correctly identified (Fig. 11);
- learnability: the degree of complexity and the ease of assimilation of rules for modelling the symbols representing the transport system. A learnability index of 1 means that the symbols are intuitive and do not need to be learned. A learnability index of 0 means that the symbols are so complex that they cannot be learned (Fig. 12);
- operability: the possibility of using available IT tools for visualisation. An operability index of 1 means that the whole transport system can be visualised with the available IT tools. An operability index of 0 means that no element of the transport system can be visualised using any available IT tools.

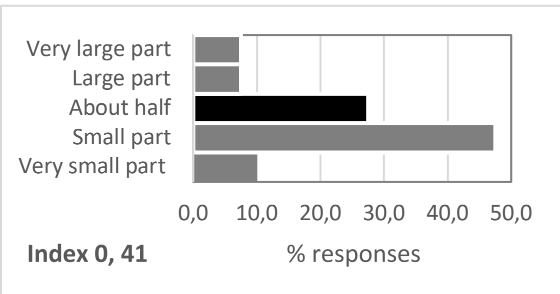


Fig. 11. Understandability – The proportion of characters representing the transport system that is identified correctly
Source: Authors' calculations

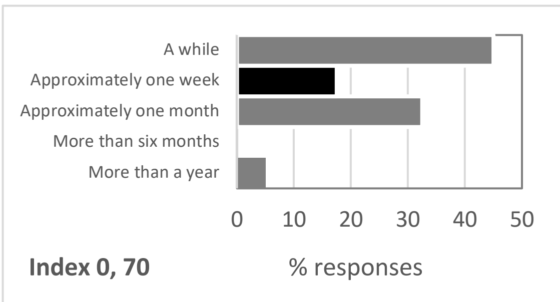


Fig. 12. Learnability – The time required to learn the symbols used to visualise the transport system
Source: Authors' calculations

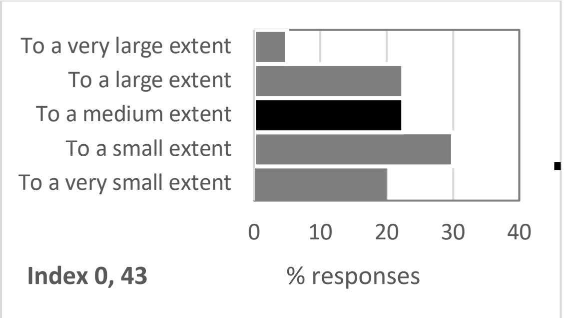


Fig. 13. Operability – The degree of use of IT tools for the visualisation of the transport system
Source: Authors' calculations

The indexes calculated by the adopted method allowed us to assess the functionality of the transport system visualisation as low and its usability as medium (Table 2). The functionality index of 0.39 indicates low functionality, and the usability index of 0.51 indicates medium usability. The quantitative indexes were converted into qualitative ones in accordance with the adopted scale: very low [0,20], low (20,40], medium (40,60], high (60,80], very high (80,100].

Table 2

Calculated values of functionality and usability factors

Type of factor	Value of the factor
Suitability	**0.34**
Time accuracy	0.48
Position accuracy	0.50
Type of object accuracy	0.48
Accuracy	1.46/3 ≈ **0.49**
Interoperability 1	0.38
Interoperability 2	0.34
Interoperability	0.72/2 = **0.36**
Availability	0.49
Authenticity	0.40
Integrity	0.17
Security	1.06/3 ≈ **0.35**
Functionality	1.54/4 ≈ **0.39**
Understandability	0.41
Learnability	0.70
Operability	0.43
Usability	1.54/3 ≈ **0.51**

Source: Authors' calculations

6. CONCLUSIONS

The dynamically changing situation caused by global threats poses new challenges for crisis management teams due to the need to collect increasingly large information resources from various sources. These challenges also test the ability of crisis teams to use available IT tools to quickly analyse large amounts of diverse data. The ability to perform rapid temporal and spatial analyses of available data may determine the quality of decisions made. This is particularly important concerning data related to the transport system, which plays a significant role in all phases of crisis management. The visualisation of transport system elements is an important aspect of such analyses. One could expect the use of a visualisation system consistent with the system used in the military by Polish crisis management teams to significantly increase the efficiency of decision-making processes. In order to verify this hypothesis, the authors of this paper examined the functionality and usability of the transport system visualisation used by Polish crisis management teams. The research revealed that the users assessed the functionality of the visualisation system as low, and its usability was assessed as medium. This may be partly because crisis management teams at the voivodeship level do not have access to IT tools that support the Polish visualisation standard. The most popular dedicated crisis management support system is Arcus 2015, developed by the Wielkopolska Voivodship Office and made available for use in eight other voivodships. However, this system does not support the Polish visualisation standard (24). Furthermore, the most popular open system in Poland for processing geospatial data (i.e. QGIS) does not support the Polish standard of visualisation.

The research also revealed discrepancies in how other countries and organisations visualise elements of their transport systems. Differences in modelling and visualisation methods may hinder data exchange between crisis management centres located in different countries.

Despite the selective nature of the analyses conducted in this study, the results point to the need to improve the transport system visualisation process within Polish crisis management teams.

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