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Professional paper

The Role of the Map in a Crisis Management Environment: Applying the Theory of Cartographic Communication and Visualization

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A B S T R A C T

Recent crisis situations have revealed various insufficiencies in existing technologies and policies for effective crisis management. In the field of cartography, these have highlighted the lack of guidelines, standards and symbols to design maps specially adapted for communication in crisis management – particularly from the cartographer's perspective. Our intent here is to examine the concept and value of cartographic communication model in the specific environment of crisis management. Based on the definition of cartographic communication and visualization, an attempt is made to distinguish the roles of crisis management maps, in order to differentiate between situations in which crisis participants use them as means of communication, and those in which they serve as tools to assist visual thought processes. On the selected cartographic examples, we aim to show that the successful cartographic displays have a defined structure, and that it is necessary to take into account the principles of cartographic design in order to achieve the effective communication of information.

Key words*: cartography, crisis management, cartographic communication, geovisualization*

Introduction

The expression, »A picture is worth a thousand words« can be applied to cartography in the sense that complex information can be effectively displayed and communicated by a single picture, i.e. a map. However, there is increasing awareness that the expression is over-generalised in terms of the visual, graphic communication of information, data or knowledge, i.e. when there is a need to explain complex spatial information quickly and clearly – which is the case with crisis management maps. Experience has shown that a great number of pictures, graphic displays and maps are unable to communicate information effectively. Instead, the interpretation of particular maps can turn into a very demanding process.

Figure 1 (left) shows an example of a map of the southern seaboard of the United States of America, which was hit by Hurricane Katrina at the end of August 2005[1], while on the Figure 1 (right), the eastern seaboard hit by Hurricane Sandy in October 2012 is shown[2]. Both maps are intended for people who want to share or discover information about the particular places affected by the hurricanes, in order to gain an insight into the consequences caused. Although both examples illustrate correct spatial depictions of areas affected by hurricanes, they are also hopelessly overloaded cartographic representation, which fail to communicate spatial information effectively.

Unfortunately, many maps specially made for communication and intervention in a crisis situations revealed the fact that there are difficulties in maps produced and used by crisis communities – particularly from the cartographer's point of view. Whether traditional paper maps or digital, interactive maps, in many cases the role of maps in communicating spatial information fails badly.

The limits, demands and challenges of cartographic communication intended specifically for crisis management have not yet been systematically considered and applied in the process of creating maps specially adapted for communication and intervention in a crisis. Ignoring this approach may lead (and leads) to reduced legibility and wrong interpretation of the information displayed

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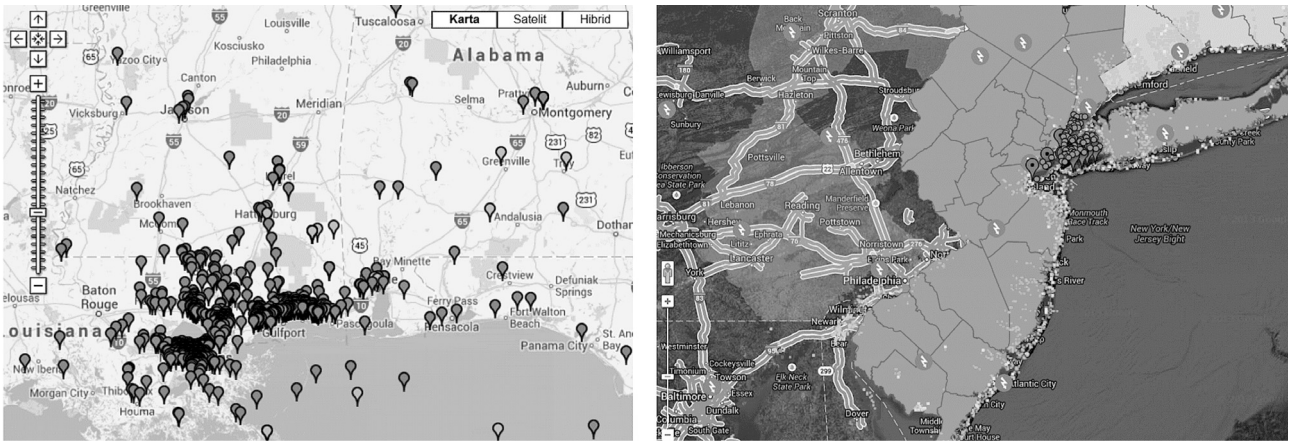

Fig. 1. Map of the southern seaboard of the United States of America, which was hit by Hurricane Katrina in 2005 (left) and eastern seaboard hit by Hurricane Sandy in 2012 (right).

on a map, which can seriously threaten the process of communication. Therefore cartographic communication in crisis situations is recognised as a key and critical factor in crisis management.

The goal of this paper is to investigate the concept and value of cartographic communication models in the specific environment of crisis management. Starting from a basic definition of cartographic communication and visualization, the role of maps in crisis management will be tackled, in order to differentiate when they are used as tools of communication by the participants in a crisis, and when as tools to assist *visualization* in their thought processes.

We will also attempt to establish whether communication in general, and particularly communication through maps, can be of use in crisis management. What role does (carto)graphic literacy play in the community which formed by a wide range of crisis management participants, and which to a great extent focuses on other forms of communication, primarily the use of verbal and numerical information?

Furthermore, the selected cartographic examples will be used to show that every successful cartographic representation has a defined structure, and that for the effective communication of information in crisis situations, the basic principles of cartographic design must be taken into consideration.

Theory and methodology of cartographic communication and visualization

In the context of this paper, the notion of a map is taken in the widest sense, and refers not only to traditional cartographic representations on paper, but to digital static, dynamic and interactive maps (on the internet), Web Mapping 2.0 applications and cartographic depictions on social networks, mobile positioning and location-based services, three-dimensional cartographic models, and other forms of digital cartographic systems (such as ubiquitous cartography, virtual reality and immersive reality).

Each of these maps may be characterized as a coded depiction of geographical reality, which aims to convey information to users, and is used when spatial relations are of primary importance[3].

Cartographic communication

Based on the presumption of effectively conveying spatial relations, cartography can be described as a process of communication between the cartographer and the map user. Their views on cartography as a communication process have been described by[4–6]. Although the details of these depictions vary, all the models share the same basic structure, in which the cartographer selects information from the real world, and decides how to show it on the map (Figure 2). The map user »reads« the map and develops a certain level of understanding, by linking the information shown on the map with knowledge previously acquired.

According to the theory of communication, many factors may hinder information from being conveyed, which may lead to it being lost, or to errors in communication. On the cartographer's side of the system, these obstacles include goals, knowledge, experience and the cartographer's attitudes, then external circumstances, such as the requirements of users, and the process of abstraction, by which information is depicted on a map (e.g. choice of projection, generalisation, classification, symbolisation, etc)[6]. From the point of view of the user, failure to understand the basics of cartography is a crucial problem which can lead to errors in communication, of which the user himself may not always be aware. Fur-

Fig. 2. General depiction of cartography as a process of information communication

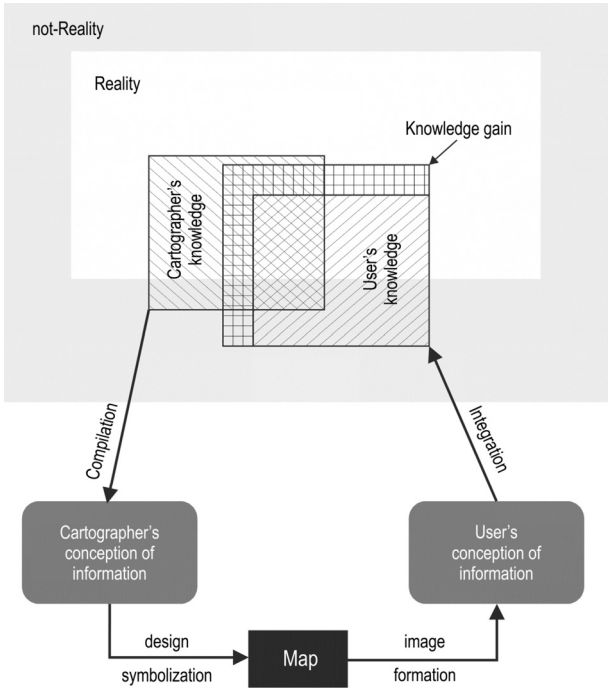

Fig. 3. View of cartography as a process of graphic communication, according to 6.

ther potential obstacles may be the perceptual and cognitive abilities of the user, his understanding of symbol systems (e.g. his education and previous knowledge of interpreting symbols on maps), his goals, attitudes, time available, intelligence, previous knowledge and prejudices (Figure 3).

Cartographic visualization

As a result of constant changes and rapid developments in technology in the area of cartography and geoinformation systems, the cartographer's view of the world, as depicted by a model of cartographic communication, is slowly losing its significance. By the mid-1990s, cartographers were realigning their research from the model of cartographic communication to the concept of cartographic visualization[7], describing visualization as the visual analysis of a map[8]. Given this definition, maps which were originally intended as serving the process of communication could be seen as serving the visualization of spatial information.

In order to make sense of linking visualization and cartography, we need to emphasise that visualization, like communication, does not only relate to making maps, but also using them. Since the communication approach has dominated cartography for almost two decades, it was only to be expected that any attempt to approach the area of visualization (facilitated by maps) would need to consider how it was linked to communication (via map).

MacEachren[6] defines visualization within the framework of map use, rather than in terms of map production, or research approaches to cartography (Figure 4). The basic idea of MacEachren's model of visualization is that map use can be depicted as a three-dimensional space. This space is defined by using three continuums, units which are infinitely divisible (e.g. according to classic physics, space and time):

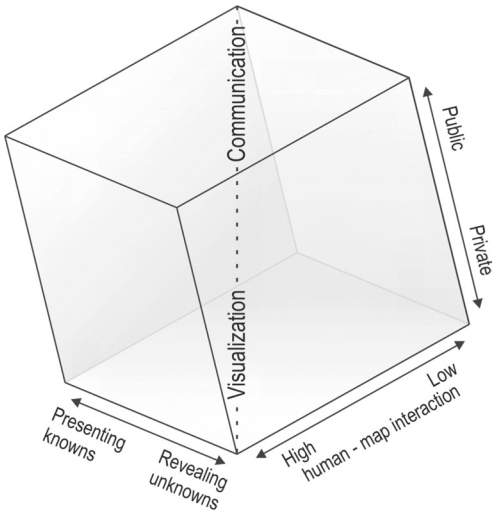

Fig. 4. Cartography depicted as map-use space, with emphasis on relationship between visualization and communication, according to 6.

- the first relates to map use, which may vary from personal (in which an individual creates a map adjusted to his own needs) to public (in which a previously produced map is placed at the disposal of the wider public)
- the second shows map use focusing on discovering the unknown (in which the user may begin with the general goal of looking for »something interesting«), as opposed to using a map which shows something known (when the user attempts to access precisely determined spatial information)
- the third relates to use in which a high level of interaction may be achieved between the map and user (the user can interact the map himself, e.g. effecting a change in a particular map being viewed, quickly switching among many available maps, overlap, combine or join maps, etc.), as opposed to a low level of interaction (the user has limited possibilities of altering map depictions).

We need to emphasise something which is not clearly evident from the model of geovisualization depicted in Figure 4, and that is that MacEachren does not consider research on cartographic communication less worthy or important. As we have already explained, some maps are produced with the goal of communicating a particular message. In his model, McEachren indicates that the line separating visualization and communication is indistinct, and even more, is less and less clearly expressed. Communication is an integral part of any way a map is used, even if visualization is the main goal[6]. Accordingly, even the most banal map intended for communication can serve as a means for mental visualization.

The roles of maps in crisis management

Since crises, emergencies and catastrophes are always accompanied by space and time components, there is a strong awareness of the importance of maps in the community formed by those involved in crisis management. Given this fact, and also the wide range of uses of geoinformation systems, in the last two decades, the number of maps produced for crisis management has grown considerably. This has been confirmed by research[9] illustrating the huge diversity in cartographic solutions produced to support decision-making in crisis management. The research analysed selected cartographic examples (risk maps and planning and preparedness maps, crisis intervention and evacuation maps, damage assessment maps) which have emerged under the influence of various innovative technologies, such as the internet, multimedia and telecommunications services.

Based on this research, it can be concluded that crisis management maps have been given two important roles:

(1) during or immediately after a crisis, they serve all participants in the crisis as means of communication, but

(2) in the phases before and after a crisis occurs, they also serve to assist their visual thought processes.

The diversity of ways in which maps are used in crisis managements is best illustrated with the help of MacEachren's model of the »space« of map use (see Figure 4). In this model, there are no clearly defined boundaries for map use; however, there are extreme situations which are easily recognisable.

Following MacEachren's model, we have listed in Table 1 eight extreme ways in which maps are used in crisis management. Figure 4 shows that the tip of the cube marking the point at which the discovery of unknown information, and the high level of interaction between the user and the map in the private domain meet, defines cartographic visualization (upper left field in Table 1). The tip of the cube marking the point at which the depiction of known information and the low level of interaction between the person and the map in the public domain meet, defines cartographic communication (lower right field in Table 1).

The design principles according to which they are produced also affect these differences in the role of maps in crisis management. Therefore cartographers today use different visualization methods to depict objects and phenomena, in order to adapt maps to the specific tasks and demands of individual phases of crisis management.

For example, hazard maps and risk assessment maps are used in the period before a crisis occurs, when preventive measures are carried out with the aim of reducing the likelihood of the crisis occurring, or alleviating potential damage. The basic task of such maps is to spread awareness and information about the hazards which may be caused by a potential crisis in a certain area. Following the crisis, hazard assessment maps are usually produced, showing the affected area. These maps are important in planning activities to be undertaken with the aim of returning the affected area to its original condition.

On the other hand, during or immediately after the occurrence of a crisis, intervention maps are used. Messages exchanged via intervention maps by people responsible for action in a crisis play an important role in crisis

TABLE 1
EXAMPLE OF EIGHT EXTREME MAP USES, DEFINED ACCORDING TO MACEACHERN´S MODEL OF GEOVISUALIZATION, ADAPTED TO CRISIS MANAGEMENT

	High level of interaction		Low level of interaction	
	Discovering the unknown	Presenting the known	Discovering the unknown	Presenting the known
Personal use	A geophysicist depicts the results of field measurements on a map, but in doing so alters the boundaries of the classes of measurement data, by analysing how the results obtained affect the occurrence of natural disasters (e.g. earthquakes) in an observed area.	He uses an interactive interface which allows rapid examination of a collection of different thematic maps (e.g. geological, traffic, noise, etc.), and how they may be overlapped, combined and joined, to show the effect of traffic on the environment.	A member of the protection and rescue services draws an earthquake hazard zone on a topographic map, in order to find out building density in particular zones and assess the extent of potential consequences.	A fireman draws by hand fire access paths and water sources on a topographic map.
Public use	Organised, interactive, simulation exercise on the internet with different crisis event scenarios (e.g. fire, flood or terrorist attack) in which experts from various crisis action services participate simultaneously.	A meteorologist shows the widening fronts of a destructive hurricane on a weather forecast chart, warning the public of potential dangers.	A dynamic, photographically realistic three-dimensional visualization of a spreading flood wave based on assessed data is shown to the public, with the aim of spreading awareness among those who live and work in areas under threat.	Maps with positions marked »You Are Here« showing exits in case of crises are made available to the wider public in public institutions (e.g. schools, shopping centres, etc.).

management. They are a source of information for all participants in the crisis and help respond to the crisis situation and mitigate the consequences. Since cartographic communication via intervention maps takes place in the unique environment exposed to risk and significant losses, the pressure of time and stress, the cartographer faces a huge challenge in finding the right procedures and methods for communicating spatial information effectively on such maps.

However, although there are cases in which it has been demonstrated that cartography can successfully support the phases before and after the occurrence of a crisis, providing various methods for adapting map representations to the needs of users, by various methods of cartographic visualization, examples of recent crises have shown that the experts who are developing crisis management systems often overlook a cartographic principles developed over centuries, which rest on usability and perception, and concentrate exclusively on the technical aspects of such systems[10,11]. In other words, they think their task is over when the information is displayed on the screen. Although the importance and strength of analytical cartography is often achieved in such systems, there is still a need for good, appropriate design.

Examples of effective cartographic communication in crisis situations

In most cases, including the production of crisis management maps, the phase of designing the visually graphic elements of the map is crucial, and forms a critical part of cartographic communication. It concerns creative methods which are individual to each cartographer, in which he subjectively adds or removes, suppresses or highlights certain characteristics of objects shown on the map. Although there are rules and principles on how to create an effective map, they are often rather vague and undefined, due to the fact that the same problem can be depicted on the map in many different ways.

The principles of cartographic design differ from the rules. In »classic« cartographic textbooks, e.g.[12–14], various principles are listed, which take into account the eye, brain and understanding the core problem, in order to create a successful link between cartography and visualization. These principles relate for example to respecting the guidelines for minimum size for text and symbols on maps, graphic density (the number of objects shown on the map), precision of location, placing of toponyms, etc. All these contribute to the process of designing the map, but cannot guarantee a good outcome.

The Design Group of the British Cartographic Society, at its working session at the University of Glasgow (British Cartographic Society, 1999), stated that the rules of cartographic design can be learnt, but the principles need to be acquired. »Map concept before production«, »hierarchy in connection with harmony« (the larger, the more visible, and what is more important, more noticeable), »sacrifice for the sake of simplicity« (map content determines scale, or scale determines content, where each determines the level of generalisation (sacrifice), »engage the emotions to encourage understanding« (only by feeling yourself what the user feels can you see what the user will see) – these are just some examples of how widely these principles may be defined. On the other hand, these principles give a good idea of how cartography can be used in the communication process, if used properly.

The following examples show two different maps, specially adapted for communication in crisis situations. Both maps use several different means for depicting complex information, with the aim of avoiding overloading the map, cognitively speaking.Both examples implement basic cartographic methods, based on conventional graphic variables (such as size, colour hue, pattern, colour value, direction and shape), which are applied to designing cartographic symbols. By presenting these examples, an attempt is made to demonstrate the different ways of communicating spatial information.

The European-Mediterranean Seismic Hazard Map

The map in Figure 5 shows seismic hazard zones in the European/Mediterranean region, in terms of peak ground acceleration with a 10% chance of being exceeded in 50 years for stiff soil condition[15].

A simple map, with a shaded relief and the administrative borders of the countries along with their capital cities, was selected as the basis for producing and using the main content of this thematic map. The thematic information about earthquake hazard was divided into three classes (low, medium and high) and depicted on the map by using shades of green, yellow and red which corresponded to the statistic variables measured. The choice of colours was in line with the intuitive visual colour language which is more or less universal. The overall impression of the map is that it is clear and visually easy to read. The user is not confused by unnecessary additional information, and so can concentrate on the message conveyed. Of course, not all cartographic depictions can be created with such simplicity; however, it is evident that a message can be conveyed clearly and directly if the depiction is not overloaded with information.

Interactive cartographic information system for visualization and communication of natural hazards data and associated uncertainties

The interactive cartographic information system for visualization and communication of communication of natural hazards data and associated uncertainties was selected as a successful example of multidimensional, complex cartographic visualization, with an interactive function (Figure 6). The system is intended for experts in natural disasters, providing support in decision-making[16].

The main advantages of the interactive system are the simple, permanent access to data via the internet and functionality. The interactive functions provide help in the selection of data which is of interest, and in choosing and adapting means of visualization. The cartographic depictions in 2D and 2.5D are carefully designed so as to

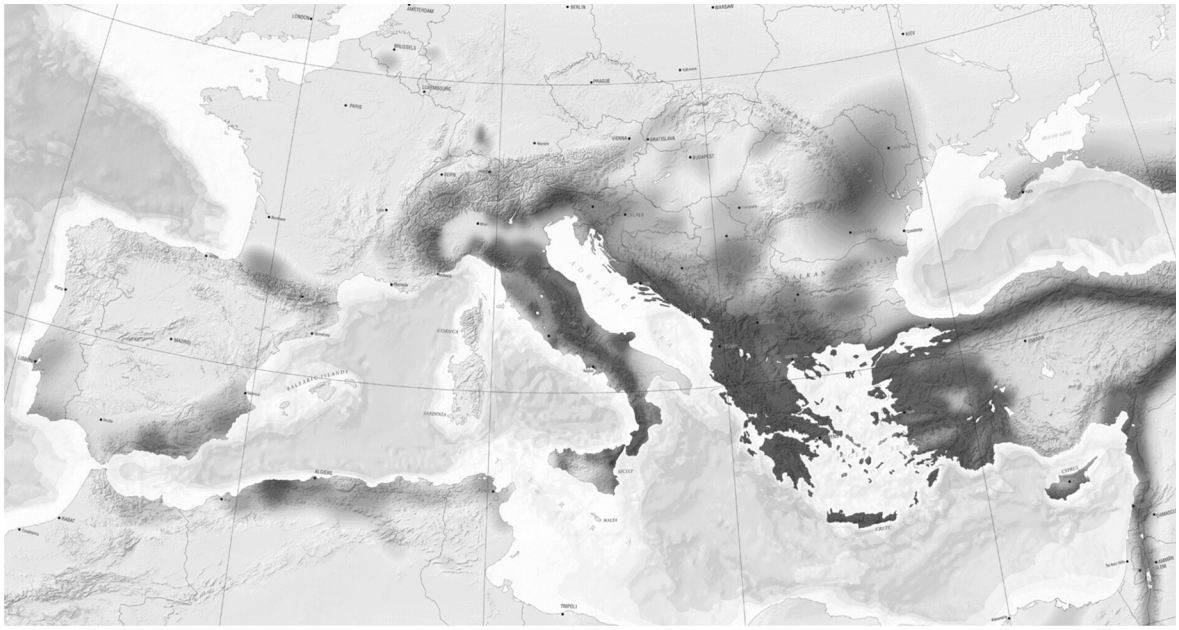

Fig. 5. European-Mediterranean seismic hazard map, produced by European Seismological Commission in 2003, section.

facilitate communication and interpretation of complex data sets. Apart from multivariational groups of data regarding natural hazards, produced on the basis of assessment, the system shown also provides methods for visualising potential hazards.

Figure 6 shows the graphic user interface system with a selected map in 2D view. The map shows a thematic layer with data on maximum air pressure, along with the corresponding standard deviation. The effect of air pressure is categorised in five classes, and shown in various shades of blue. Standard deviations of maximum air pressure are shown in a cartodiagram in an additional layer, in which the size of the red circle corresponds to the level of standard deviation. The selection of individual cartographic symbols creates a new space containing the exact values of the results estimated, along with in-

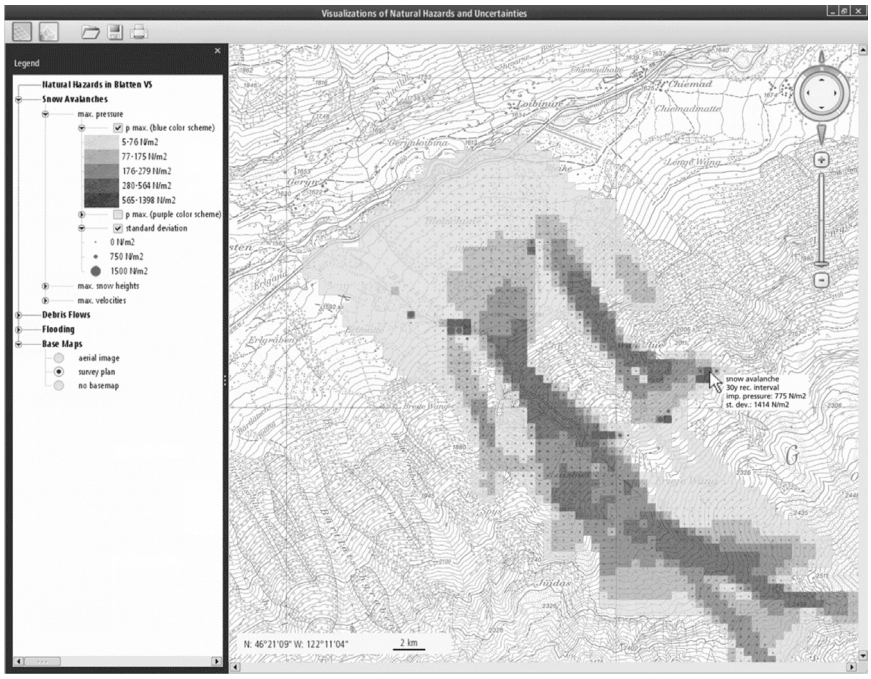

Fig. 6. Graphical user interface of the interactive cartographic information system for visualization and communication of natural hazards data and associated uncertainties.

formation available on data uncertainty. This function facilitates the analysis of the data shown, given that the generalised cartographic depiction, on which it is possible to distinguish only a limited number of classes, is completed by data which are given at the highest available level of spatial resolution.

Conclusion

This paper investigates the concept and value of models of cartographic communication and visualization in the specific environment of crisis management. By means of a theoretical basis of these models, the differences in the principles used to create the maps are emphasised, as they play a primary role in facilitating the conveyance of knowledge, or communication between the small number of people who produce the maps and the large number of users (as is the case with intervention maps for crisis management), in contrast to maps whose primary role is to help individuals or larger groups of people to think spatially (as is the case with maps used before and after crisis events).

The selected cartographic examples show that cartography can support the effective communication of spatial information in crisis situations – if used correctly. The success of communication depends, among other things, on the cartographer – his communication skills, the principles of cartographic design he has mastered, and the rules he has learnt. On the other hand, the user must be capable of understanding and interpreting the symbols shown on the map in terms of their actual significance.

Therefore cartographic literacy is recognised as a valuable tool which, if correctly applied to crisis management maps, can have a powerful influence on modern communications within the crisis management community.

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ULOGA KARTE U ZAJEDNICI KRIZNOG UPRAVLJANJA: PRIMJENA TEORIJE KARTOGRAFSKE KOMUNIKACIJE

S A Ž E T A K

Nedavne krizne situacije otkrile su mnoge nedostatke u postojećim tehnologijama i politikama za učinkovito krizno upravljanje. Na području kartografije ukazale su na nedostatak smjernica, standarda i kartografskih znakova za oblikovanje karata posebno prilagođenih komunikaciji u kriznom upravljanju – pogotovo iz perspective kartografa. Cilj rada je ispitati koncept i vrijednost modela kartografske komunikacije u specifičnoj okolini kriznog upravljanja. Na osnovu definicija kartografske komunikacije i vizualizacije nastoji se uvidjeti uloga karte u upravljanju krizom kako bi se razlučilo kada ona sudionicima krize služi kao sredstvo za komunikaciju, a kada kao sredstvo za pomoć njihovom vizualnom procesu mišljenja. Na odabranim kartografskim primjerima nastoji se pokazati da svaki uspješan kartografski prikaz ima određenu strukturu, te da za učinkovito komuniciranje informacija treba uzeti u obzir osnovna načela kartografskog oblikovanja.