

COMPARATIVE ANALYSIS OF TAXONOMY, STANDARDISATION AND AVAILABILITY OF CARTOGRAPHIC SYMBOL SETS FOR CRISIS MAPPING

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ABSTRACT:

Cartographic symbols on crisis maps serve as the means of depicting information about the position, properties, and/or numerical values of objects, phenomena or actions specific to crisis mapping. The aim of symbology for many crisis cartographic visualisations are simple, clear, aesthetically pleasing symbols that can be easily used and understood by a wide range of crisis map users. If they are incomprehensible, illegible, ambiguous, unclassified, and random, if they lack hierarchical organisation and other characteristics which are important when designing a cartographic symbol set, they can fail to deliver the intended message. In addition to effective graphic design, cartographic symbol sets for crisis mapping are facing additional challenges, including consideration of their availability (sharing and promotion, dissemination and promulgation) and standardisation (ensuring the general and repeatable use of map symbols). To determine the extent of these challenges and to assess the current state of the cartographic symbology for crisis mapping we have compiled and compared the prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years. We pay particular attention to those sets that have gone through a new, reviewed or extended edition. We research whether the latest changes incorporated follow the recognised challenges posed to the crisis mapping symbology.

1. INTRODUCTION

A crisis map is a thematic map on which objects, phenomena or actions specific to crisis management are represented according to their importance and highlighted using appropriate cartographic symbols. Cartographic symbols on crisis maps serve as the means of depicting information about the position, properties, and/or numerical values of objects, phenomena or actions specific to crisis mapping. The problem of ineffective mapping that has failed in communicating messages during a crisis has been identified following Hurricane Andrew (in the Bahamas and the southeastern coast of the USA in 1992) and Hurricane Fran (in the USA in 1996) (Dymon, 2003), when retrograde research was conducted on how the maps produced during or immediately after these events were used. This was confirmed once again after major tragedies, such as the “9/11” terrorist attack (in the USA in 2001), the “Christmas” tsunami (on the coasts of Indonesia, Thailand, Sri Lanka, and India in 2004) and Hurricane Katrina (in the USA, 2005). Immediately after these events, problems were identified, such as the lack of cartographic symbols for communication in crisis situations, and visually overloaded maps which reduced legibility and made orientation and understanding essential crisis information difficult (Akella, 2009).

The need to conduct research on cartographic symbols that are specifically adapted for usage on crisis maps was highlighted. It resulted in publicly available cartographic symbol sets that were promoted in recent years within the crisis community. Examples include: *Emergency Response Symbology* (Homeland Security Working Group, Federal Geographic Data Committee, USA, 2005) (ANSI, 2006); *Canadian All-Hazards Symbology For Emergency Management* (Government Operations Center,

Canada, 2015) with its predecessors: *Canadian Disaster Database Symbology* (2007) and *Emergency Mapping Symbology* (GOC, 2015); *Australian All Hazards Symbology* (Emergency Management Spatial Information Australia, Australia, 2007) with a revised edition issued in 2018 (EMSINA, 2018); *OCHA's Humanitarian Icons* (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), International, 2012) with a completely revamped set of symbols released in 2018 (UN OCHA, 2018); *MIL-STD-2525D Common Warfighting Symbology, Appendix G* (Department of Defense, USA, 2008) (DOD, 2014); *Humanitarian Demining Symbols* (Geneva International Center for Humanitarian Demining, International, 2005) (GICHD, 2005); *Symbol System for Disaster Management* (Laboratory on Cartography, Sofia University of Architecture, Civil Engineering and Geodesy, 2017, Bulgaria) (Marinova, 2018); *European Emergency Symbology reference for 2D/3D maps* (INDIGO project, Europe, 2012) (INDIGO, 2012); *Civil Protection Common Map Symbology* (Ordnance Survey, UK, 2012) (Cabinet Office, 2012).

In a recent study (Kostelnick, Hoeniges, 2018) four general challenges related to the development of crisis map symbology were identified through a review of the cartographic literature as well as from survey across the community of humanitarian relief organisations. The challenges include consideration of the following: symbol taxonomies, design issues, standardisation, sharing and promulgation. To determine the extent of these challenges in the current state of the crisis mapping symbology we have compiled and compared the prominent examples of symbol sets that were promoted in the cartographic scientific and crisis mapping community in recent years. We paid particular attention to those sets that have gone through a new,

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reviewed or extended edition and researched whether the latest changes follow the challenges posed to the crisis mapping symbology.

We are guided by the following research questions: (1) What crisis symbology sets exist currently publicly available for use? (2) What do the taxonomy of cartographic symbols in sets and their internal breakdown look like? What graphical variables have been used to support visual and cognitive organisation of the symbols within the set? (3) Is it possible to expand the set with additional symbols? Have the guidelines for the graphic design of new symbols been given? Has an assessment of the design, efficiency, and recognition of cartographic symbols on crisis maps been carried out? (4) How do we know the symbol set exists? How and in which format have the symbols been shared? Have they been promoted? Are there, in addition to the symbols, materials available for learning and training (such as examples of the use of map symbols, manuals for their use, “best practices” guidelines)? (5) Is the set updated? Has it been re-edited? If so, what changes have been implemented?

In this research, our intent is to gain an insight into the existing practices that we encounter in the context of three categories that have been identified by (Kostelnick, Hoeniges, 2018): taxonomy of symbols; standardisation of crisis map symbols; sharing and promulgation of crisis map symbols, i.e. their availability. Challenges placed in the fourth category, i.e. the process of designing the visual appearance of crisis symbols, will be the subject of separate analysis in future research.

2. COMPARATIVE ANALYSIS OF CARTOGRAPHIC SYMBOL SETS FOR CRISIS MAPPING

2.1 Materials and Methods

We collected six existing, publicly available cartographic symbol sets that were published in different countries. Three sets are designed exclusively for crisis management (*Emergency Response Symbology*, *Canadian All-Hazard Symbology*, *Australian All Hazard Symbology*), while two are intended for humanitarian activities (*OCHA's Humanitarian Icons and Humanitarian Demining Map Symbols*), and one for military operations (*MIL-STD-2525D Common Warfighting Symbology*). Regardless of their primary purpose, all listed cartographic symbol sets are publicly available online, they contain symbols for representing objects, phenomena, and actions specific to crisis management and were recognised and promoted in the cartographic scientific and crisis mapping community (Bianchetti et al., 2012, Robinson et al. 2010, Koselnick et al., 2008; Marinova, 2018), which were the main criteria for their selection.

If the symbols in the set are classified into groups, we analysed their *taxonomy* – the division that categorises the objects, phenomena, and action for display on crisis maps and organised them into groups based on their similarity and difference. We analysed how the thematic organisation into categories was transferred into the graphical appearance of the symbols, i.e. which graphic variables (e.g. colour, shape, size, etc.) were used. Transcription in the cartographic symbol set must, on the one hand, be selective to clearly distinguish the affiliation to a particular type, and also, within each type, it must be associative to clearly show its affiliation (MacEachren, 1995).

In terms of *standardisation*, we analysed which measures were taken regarding the general and repeated use of cartographic

symbols from the set. We explored if the possibility of extending the set with additional symbols was provided, and whether there are guidelines, requirements, and rules for graphical design and the rules for implementing these symbols on crisis maps. We researched if an assessment of the design, efficiency, and recognition of cartographic symbols on crisis maps was carried out? Is there any recorded usage of symbols on maps in real-case scenarios? We analysed whether the symbols are intended for use on a certain type of map at a certain scale.

Regarding *availability* we analysed the methods of sharing and promoting, dissemination and promulgation of the cartographic symbol sets. Methods for the dissemination of symbols from existing sets, such as promotions, publications, presentations, workshops, brochures, flyers, posters, websites, exhibitions, conferences, training activities, innovation networks, and more were identified. We made an overview of the technical aspects of how the cartographic symbols were shared, such as the format available for download, if embedded in existing GIS software (ArcGIS and QGIS) or symbol sharing platforms. We also researched and listed which accompanying materials are available, such as learning and training materials, demonstrative examples of the use of symbols on maps, manuals for their use, guidelines for “best practices”, and the like.

We synthesized the results of a comparative analysis and present our findings to each of the issues in following subchapters.

2.2 Taxonomy, visual and hierarchical organisation of cartographic symbols in existing sets

By analysing the existing sets, different approaches to the hierarchical, thematic and visual organisation of cartographic symbols within an individual set have been observed. For example, symbols from the *Canadian All-Hazards Symbology* are organised into three categories, while *Emergency Response Symbology*, *Australasian All Hazard Symbology* and *MIL-STD-2525D Common Warfighting Symbology* are organised into four categories. Symbols in the *OCHA's Humanitarian Icons* set are organised into 16 categories and in the *Disaster Response Map Symbols* set there is no such division. Although the total number of categories and their names differ in the existing sets, general similarities can be found. *Incidents*, *operations* and *infrastructure* are pointed out as three commonly used categories for the thematic organisation of cartographic symbols for communication and action in a crisis. In *Emergency Response Symbology*, *Canadian All-Hazards Symbology* and *Australian All Hazard Symbology* sets, the visual organisation is achieved by connecting a different geometric shape to a particular category of symbols (Figure 1). In a new version of the *Australian All Hazard Symbology* from 2018 new category of observations has been added for features which are affected or impacted by the incident (Figure 1).

In the *Emergency Response Symbology* set a visual hierarchical status on the damage caused, marked by a particular geometric shape and/or colour of the symbol frame, can be additionally assigned to the symbols from the operations and infrastructure categories (Figure 2). In a new edition of the *Australian All Hazard Symbology set*, the novelties are graphic variables for expressing the ordered (hierarchical) properties. A visual hierarchical status for incidents (*Confirmed* and *Unconfirmed*) and for operations (*Established* and *Planned*) is marked with a full or dotted line. The status of the asset *Potentially Defendable*, *Defendable*, *Not Defendable* is marked with a

circle, a checkmark, or a cross within the symbol frame (Figure 3). Usage of the scale of colours of the same brightness enables the additional selective emphasis of the features effected by the incident: *No Damage* (green), *Slight damage* (blue), *Moderate damage* (yellow), *Severe damage* (orange), *Total damage* (red) (Figure 4).

Following the example of the *Emergency Mapping Symbolology*, a new version of the *Canadian All-Hazards Symbolology* incorporated the use of different frames – diamond for an incident, rectangle for infrastructures, and circle for operations. Frame with dashes represents a disruption to an incident or infrastructure. When the symbolology set is distributed, these frames will be provided for users to combine them with any symbol (GOC, 2015).

In the *MIL-STD-2525C Common Warfighting Symbolology* set, framing the symbols with frames of different shapes, or fills in different colours, *affiliation* is marked – the relationship between an operator and an operative object. The basic categories of affiliation are: *unknown*, *friendly*, *neutral* and *hostile*. A symbol with a light yellow filling is used to denote an unknown affiliation, a rectangle with a light blue filling to denote a friendly affiliation, a square with light green filling for neutral affiliation, and a square with a red filling to denote a hostile affiliation.

Although the symbols in the sets *OCHA's Humanitarian Icons* and *Humanitarian Demining Map Symbols* are thematically organised into categories, this organisation has not been transferred into the graphic appearance of these symbols, as can be seen from the examples given in Figure 5. Since all the symbols in the *OCHA's Humanitarian Icons* set are of the same colour, the associative and selective properties were not achieved. Although pictograms in *Humanitarian Demining Map Symbols* set use frames of different geometric shapes and different colour fills, these variables were not applied to achieve the visual organisation of the symbols but arbitrarily.

2.3 Availability (sharing, dissemination, and promulgation) of the cartographic symbols from existing sets

2.3.1 Availability via web page and format

Emergency Response Symbolology is publicly available on the web pages of the Homeland Security Working Group of the Federal Geographic Data Committee (URL1) from 2004. In addition to symbols, the necessary explanations of the meaning of each symbol are provided. Symbols are available for download in a form of a TrueType font, with the note that they are “a Government work, not subject to copyright protection, and may be published/disseminated without restriction(s)”.

Canadian All-Hazards Symbolology was publicly released by Government Operations Centre Geomatics (GOC) in 2015 in the document (GOC, 2015). It is currently available at (URL2), but the permanent host is required. The symbols are available for download in PNG and TrueType format and ESRI Style file. The license includes the right to use, incorporate, modify, improve, and further develop the symbols. The intellectual property rights arising from any modification, improvement, development or translation of the symbolology or the manufacture of any other products, effected by or for the Licensee, shall vest in the Licensee or such person as the Licensee shall decide (GOC, 2015).

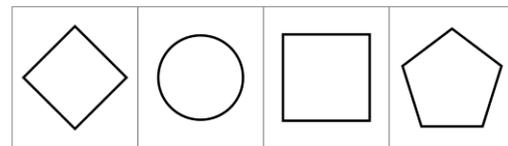


Figure 1. *Incidents* (diamond), *Operations* (circle) and *Infrastructure* (rectangle) are used for thematic and visual organisation of cartographic symbols in *Emergency Response Symbolology*, *Canadian All-Hazards Symbolology* and *Australian All Hazard Symbolology*. Category *Observations* (pentagon) is added in new version of the *Australian All Hazard Symbolology*.

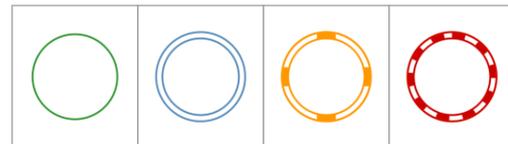


Figure 2. In *Emergency Response Symbolology* a visual hierarchical status on the damage and operational level from *Fully operational* (left) to *Totally incapacitated* (right) can be additionally assigned to the symbols from the categories *Operations* and *Infrastructure*.



Figure 3. Ordered property for representing the status of the asset *Potentially Defendable* (circle), *Defendable* (checkmark) and *Not Defendable* (cross) within the symbol frame is available in new version of the *Australian All Hazard Symbolology*.

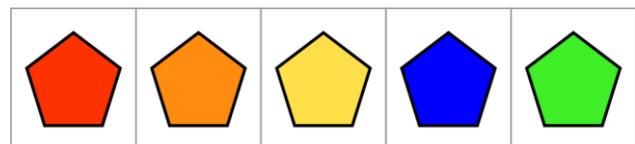


Figure 4. A scale of colours of the same brightness for additional selective emphasis of the features effected by the incident is available in a new version of the *Australian All Hazard Symbolology*.

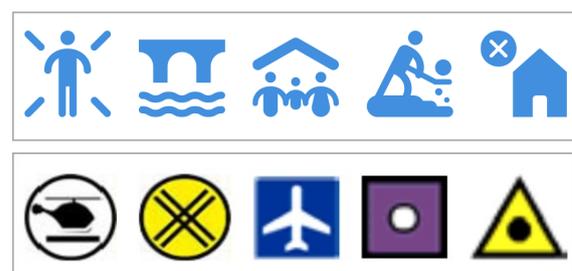


Figure 5. Thematic organisation has not been transferred into the visual appearance of the symbols in *OCHA's Humanitarian Icons* (top) and *Humanitarian Demining Map Symbols* (bottom). The associative and selective properties of cartographic symbols were not achieved.

Predecessors of the *Canadian All-Hazards Symbology* set are *Emergency Mapping Symbology* from 2010 and *Canadian Disaster Database* from 2007. The design style used for *Emergency Mapping Symbology* involved very bright colours, gradient fills and a colour scheme to indicate the category for each symbol. The intended purpose of this style was to facilitate legibility on different web maps. The *Canadian All-Hazards Symbology* design differs from the *Emergency Mapping Symbology* as it was created for a different purpose. The *Canadian All-Hazards Symbology* was prepared primarily for desktop mapping, while still enabling effective web use. It was designed to stand out well on vector-based maps, as well as maps with raster backgrounds, such as topography or satellite imagery (GOC, 2015).

Emergency Mapping Symbology is no longer available, the sources on which it was distributed have been turned off, and traces of its existence can be found today only in scientific cartographic resources (e.g. Bianchetti et al., 2012). The *Emergency Mapping Symbology* set involved a large taxonomy covering a total of 249 events, infrastructures and operations. After consultation with the Government of Canada operations centres, *Canadian All-Hazards Symbology* used that taxonomy and expanded it to accommodate additional requirements.

In 2007, Public Safety contracted the development of symbology for use on the *Canadian Disaster Database* interactive web map. The design style followed that of the US *Emergency Response Symbology*. The *Canadian Disaster Database* symbols were utilised by the Government of Canada's Government Operations Centre (GOC) Geomatics group in many of its mapping products over the years. Over time, an expanded set was required by GOC Geomatics to incorporate more events and increase consistency across their mapping products.

In 2018 the *Australian All Hazards Symbology* set had its second edition. The process, the symbol set, related documents and the entire project history can be found on the website of Emergency Management Spatial Information Australia (URL3). A range of new symbols have been submitted and considered by Emergency Management Spatial Information Australia (EMSINA) since the adoption of the set in 2010, and in September 2018 an updated set of *Australian All Hazards Symbology* was released. This included an addition to the symbology framework and 15 new emergency management symbols. Symbols are available for download at (URL3) in KML, PNG, ESRI Style, TrueType fonts, SVG, and XML formats, and are customised for use in Avenza, ESRI, GeoServer, Google, Map Info, which is a major breakthrough compared to the previous version of this set which was only publicly available as a PDF document. While the old version was licensed under *Creative Commons Attribution 3.0 Australia* which permitted free use, copying, distribution, and customisation, terms of use for the new version has not been found.

The *OCHA's Humanitarian Icons* set is publicly available on the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) web site since 2012 (UN OCHA, 2012). Symbols are available for download free of charge as a PDF document, individual PNG and SVG files or as AI and PPT files with referencing "Source: OCHA" whenever possible. In 2018 OCHA released a completely revamped set of 295 (and counting) symbols, the result of a long and meticulous redesign process.

The *MIL-STD-2525* norm is publicly available on the web site of various military institutions (e.g. URL4) since 2008 and can be viewed and downloaded as a PDF document. *MIL-STD-2525 Common Warfighting Symbology*, in addition to detailed definitions and descriptions of military operations, contains six sets of military symbols subdivided into appendixes. The appendix G contains symbols for the management of extraordinary situations and is the subject of this research. It consists of a general section which sets out the objectives, references, definitions, general and detailed requirements and conditions of this symbol collection for acting in emergency situations. The official document containing the cartographic symbol collection is released in PDF format (DOD, 2014).

On the web site of the Geneva International Center (URL5), since 2015 there has been a publicly available report (GICHD, 2005) with a corresponding set of *Humanitarian Demining Symbols* in which, in addition to the graphic appearance, there are necessary interpretations of the meaning of each symbol. Symbols are available for download as TrueType font or ESRI style file, under the *Creative Commons* licence that permits free use, copying, distribution and customisation of symbols.

2.3.2 Availability at Other Locations and Attempts of Sharing in other Formats

The comparative analysis showed that cartographic symbols are most commonly shared via the organisation's website in different proprietary formats. The most common formats are the raster PNG, and vector SVG format. Vector formats, such as SVG, allow symbols to be scalable and customisable and colours to be selected for foreground, background, and frames.

Technical resources also included predefined style files for ESRI's ArcGIS for all analysed symbol sets and for QGIS (in the case of *OCHA's Humanitarian Icons* and *Australian All Hazards Symbology*) that could be loaded into standard mapping software to promote easy sharing within and among organisations.

The *OCHA's Humanitarian Icons* set is the only representative of cartographic symbols for crisis and humanitarian mapping within the Noun Project (The Noun Project, 2014) – a platform that offers a crowdsourced collection of universally recognisable icons for visual communication.

Symbols from the *Emergency Response Symbology* set are built-in in *Symbol Store*, a visual-enabled, web-based interactive tool designed to help mapmakers share point symbols (Robinson et al., 2013). The initial idea behind *Symbol Store* was to allow users to browse symbols by keyword, category tags, and contributors and to facilitate discovery, retrieval and sharing of map symbol sets between users. Symbol sets can be downloaded as ESRI Style Files so that they can easily be imported into new or current ArcGIS map projects.

Joint Military Symbology XML (JointMilSyML or JMSML) is an XML schema, and associated instance data, designed to document the contents of MIL-STD 2525D and NATO STANAG APP-6(C). The Military Overlay is supplied as a project template for ArcGIS Pro and it allows creating military standard symbols quickly by using and adapting existing feature templates, creating a military overlay with military standard symbols and sharing the overlay as either a static image or a web map (DOD, 2014). It is hoped that future defence and intelligence systems will be engineered to take advantage of this

technology and, in so doing, accelerate the delivery of new military symbology, reflected in updates to these standards, to warfighters.

2.4 Standardisation (General and Repeated Use) of Cartographic Symbols from Existing Sets

2.4.1 Standardisation of Map Symbology

To date, essentially only one set of truly standardised emergency symbology exists. That is *Emergency Response Symbology* used in the United States and standardised by the American National Standards Institute (ANSI, 2006).

After public release, cartographic symbols of the *Emergency Response Symbology* triggered the great interest of crisis management experts and emergency service workers. Various software producers wanted to include cartographic symbols into their software, which would increase their availability and consistent use on crisis management maps. However, since the symbols were adopted as a standard of *American National Standards Institute*, their use implies the payment of a fee, which has rejected many users who are still using their free version. Standardised set has been officially used among the emergency management and first responder communities at all levels of need in the United States (i.e., national, state, local and incident) (URL1).

MIL-STD-2525D Common Warfighting Symbology is a norm setting out rules and requirements for defining and displaying military operations, and all units of the US Department of Defense (DOD) have been obliged to apply it since 2008. It is also available for use by non-DOD entities (e.g., first responders, United Nations, and multinational partners).

The equivalent to this standard are two NATO publications: *Allied Procedural Publication APP-6A – Military Symbols for Land Based Systems* and *Allied Procedural Publication APP-6B – Joint Symbology* from 1998, in which graphical symbols for marking units, positions and control measures in tactical operations are defined. Content of NATO's publications and standards *MIL-STD-2525* of the Department of Defence is basically the same, but the *MIL-STD-2525* standard has been developing faster, and therefore the analysis in this paper refers to that standard.

2.4.2 Standardisation of Usage

In the *Emergency Response Symbology* it is stated that they are intended for use on digital and paper maps, in large and medium scale. It is not recommended to use symbols on small scale maps, but if necessary, it is advisable to use its simplified version or geometric shape that indicates the symbol category (URL1). In the *Australian All Hazard Symbology* it is stated that the symbols are intended for use on paper and digital topographic maps and aerial images, in small, medium and large scale. More detailed standardisation of their use in the studied resources was not found. However, the novelty in version released in 2018 is the inclusion of five scale-dependent symbols for facilities (*Fire-Fighting Facility*, *Ambulance Facility*, *State Emergency Service Facility*, *Life-Saving Facility* and *Police Facility*) for their use in smaller scales. Also, for the new added category *Observations* in which, frame fills in different colours of the same intensity, selectively outline the information on the damage caused, alternative variants for the black and white variants of the symbols are also foreseen

(EMSINA, 2019). In the *Canadian All-Hazards Symbology* it is stated that they are primarily intended for desktop mapping, while still enabling effective web use (GOC, 2015). Symbols from the *OCHA's Humanitarian Icons* set are intended for use on a wide range of information *OCHA's* humanitarian community products, which usually include maps, written reports, infographics and websites, while symbols from *MIL-STD-2525D Common Warfighting Symbology* are intended for use on paper military topographic maps, digital military information systems, “graphics” and “working maps” (DOD, 2014). Symbols from the *Humanitarian Demining Map Symbology* set are intended for use on topographic maps and aerial images in digital and paper form, in large, medium and small scale, and are specially adapted for use in the mine action information set (*Information Management System for Mine Action IMSMA*) distributed by the Geneva International Humanitarian Demining Centre (GICHD, 2005).

In addition to the ways of use stated here that are mostly general, more detailed guidelines and rules for proper application of cartographic symbols on crisis maps have not been found.

2.4.3 Extension of the Set with New Symbols

Homeland Security Working Group responsible for the development of *Emergency Response Symbology* points out that the set does not include all the symbols required to represent the object, phenomena, and crisis-specific action. If there is a need for new symbols, they will try to incorporate them into an existing set depending on the available resources and capabilities (URL1). However, guidelines for extending the existing set with new symbols are not publicly available.

The current version of the *Australian All Hazard Symbology* set does not include all the cartographic symbols needed to manage different crises. It is stated that the existing symbols are limited to action in certain types of crisis and provide a basis that will be extended in the future to meet the wider needs of national security and crisis management (URL3). The 2010 version contained a total of 83 symbols. Between 2011 and 2017 EMSINA remained active in collecting information about new and/or improved *Australian All Hazard Symbology*. A dedicated symbology officer was elected in 2015. This person in collaboration with a small EMSINA working group revised the method of collecting and approving symbols in 2016. The latest version of the 2018 set contains a total of 127 symbols. However, the guidelines for extending the existing set with new symbols do not exist or have not been published in the available resources. However, a workflow for new *Symbology* proposals (URL3) has been clearly stated.

The *OCHA's Humanitarian Icons* set is being periodically extended with new symbols as necessary (UN OCHA, 2018), and when other versions of the set were released, a major step forward was made in the effort to standardise the guidelines for extending the existing set with new symbols. In 2018 OCHA released a completely revamped set of 295 (and counting) symbols, the result of a long and meticulous redesign process. The first version from 2012 contained a total of 241 symbols. While the 2012 set grew organically as the illustrations were developed to meet internal design needs, the new series has been drawn from scratch following standardised design rules. The document *OCHA Graphics Stylebook* (UN OCHA, 2018) was released. The given guidelines are not intended to be restrictive or to limit creativity; they are simply to help establish

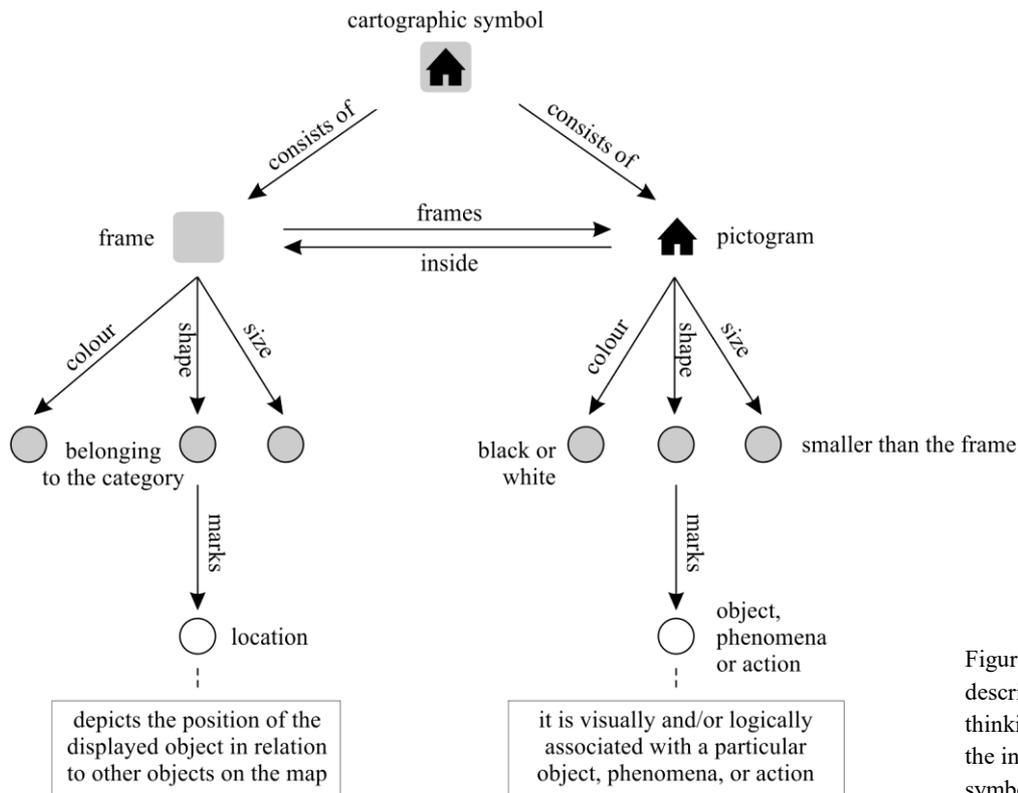


Figure 6. Cognitive scheme describing a recognised pattern of thinking and behaviour of users in the interpretation of cartographic symbols for crisis mapping

some rules for all designers so that there is consistency across the icon family. Because of this, all the new icons look similar in terms of visual complexity and appear to belong to the same “family”. Moreover, the original set has been extended to include new themes (for instance cash transfer) and individual icons have evolved to reflect changes that occurred since 2012 (in technology, for example).

2.4.4 Assessment

Assessing the symbol design and recognisability from the *Emergency Response Symbolology* set was conducted in two ways, and test methods and detailed results were published (URL1; Akella, 2009). In the first case, the assessment of the appearance of each symbol was conducted by the *Homeland Security Working Group* during December 2003 and January 2004, in an on-line open-type survey in which various crisis management and emergency services volunteers participated. Survey results were published in the report on the web site of the *Homeland Security Working Group* (URL1). For each symbol from the set, the participants of the survey needed to state if they *accept* or *reject* graphical design and short definition of a single symbol. Symbols that did not reach the 75% acceptance threshold have been reviewed and redesigned (e.g. in category *incidents* 11 symbols have not been accepted, in the category *natural events* 7, in the category *activity* 4, and in the category *infrastructure* no symbol was accepted). Those symbols that met the set threshold were accepted as a standard of *The American National Standardization Institute ANSI INCITS 415-2006 Homeland Security Mapping Standard - Point Symbolology for Emergency Management*. In the same period (Akella, 2009) conducted test of recognition of 15 randomly selected symbols from the category *Incidents* and 13 symbols from the category *Operations*. Since there are no clear guidelines or norms to test the recognition of cartographic symbols for a crisis, (Akella, 2009) adopted the standard

recommendations *ANSI Z535.3 National Standard for Criteria for Safety Symbols* which prescribes general criteria for the assessment and use of safety symbols indicating specific hazards. Fifty Californian fire-fighters participated in the testing and it was found that only 6 of the 28 rated symbols achieved an 85% recognition level, which is prescribed by the standard.

Assessment of the symbol design of the *Humanitarian Demining Map Symbols* was conducted when the symbols were in the initial version. Professional pyrotechnicians participated in the testing and their comments and feedback were taken into account in the transformation of the symbols in the newer versions of the system (Kostelnick et al., 2008).

For other symbol sets covered by the existing literature and other available resources, there is no evidence that the design, effectiveness, or recognisability of the proposed cartographic symbols was assessed.

3. DISCUSSION

In this paper, a comparative analysis of six existing, publicly available cartographic symbol sets that have been promoted since 2005 in the scientific cartographic community and the crisis management community was conducted. An overview of the taxonomy, visual and hierarchical organisation, availability (sharing, dissemination and promulgation) and standardisation (general and repeated use) of cartographic symbols gave an assessment of the current situation in the field of cartographic symbols for crisis mapping from which the following conclusions can be drawn.

For a proper understanding of the cartographic symbol set, i.e. to achieve the optimal map function for communicating information in a crisis, it is necessary to form the symbols by following the appropriate organisational structure. Although the

data that is required to be displayed on the map has sometimes already been provided to the cartographer in a proper organisational structure, in the case of data for communication and acting in a crisis, such structure does not exist. However, the analysis of the existing sets has shown that some similarities can still be found in the way the organisation of cartographic symbols into groups was made in *Emergency Response Symbology*, *Canadian All-Hazards Symbology*, *Australian All Hazards Symbology* and *MIL-STD-2525D Common Warfighting Symbology*).

The visual organisation of the symbols in the set should be such that crisis management participants (who are at the same time both cartographers and map users) can spontaneously notice it (Bianchetti et al, 2012). This can be achieved by using the appropriate colours and different shapes for framing cartographic symbols as it has been made in sets *Emergency Response Symbology*, *Canadian All Hazard Symbology* and *MIL-STD-2525C Common Warfighting Symbology*.

Cartographic symbols for communicating in crisis should be designed to take advantage of the well-known tendencies of human perceptual organisation that lead to an approximately automated interpretation of certain relationships through the ability of mental structuring. In psychology and cognitive sciences, such systems of organising and perceiving new information or the mental structure of some pre-created ideas are described in the schemes. The cognitive scheme in Figure 6 describes a recognised pattern of thinking and behaviour of users in the interpretation of cartographic symbols for communication in a crisis in *Emergency Response Symbology*, *Canadian All-Hazards Symbology*, *Australian All Hazards Symbology* and *MIL-STD-2525D Common Warfighting Symbology*. The same template could be applied in sets *OCHA's Humanitarian Icons* and *Humanitarian Demining Map Symbols* in the case of their customisation for crisis mapping. Following such a cognitive scheme, the user uses logic in the interpretation of cartographic symbols on a crisis map that tells them that the graphic appearance of the symbol is divided into two parts: *frame*, which is to a certain extent a constant part of the cognitive scheme (that is, it receives the finite number of geometric shapes of certain colours), which frames the *pictogram* – a variable part of the scheme that takes on a new form every time. The user visually and/or logically interprets various forms of pictograms, and each shape associates with a particular object, phenomena or action. The frame around a pictogram is sometimes a red square, sometimes a blue rectangle, and in an unconscious process, the user's brain organises such objects into groups, by applying the similarity principle – similar objects form a group. The frame location on the map indicates the position of the displayed object relative to other objects on the map.

Apart from the quality, the identified objects can also be distinguished by their ordered properties. By analysing the existing cartographic symbol set, it was noted that the ordered property was not present in the first versions but was included in second editions of the sets *Australian All Hazards Symbology* and *Canadian All Hazards Symbology*. As a result, for example, infrastructure objects can always be distinguished as *destroyed* or *undamaged*, roads as *passable* or *impassable*.

It is obvious that, in the case of the map symbols for communication in a crisis, tradition, homogeneity, uniformity, and standardisation – both in the graphic design of symbols and in their application on crisis maps are crucial. Standardisation

(in the sense of ensuring unambiguous and consistent application) of cartographic symbols on maps for communication and acting in a crisis would mean gradually adaptation of users to their meaning, thus making them more successful in use on the maps for communication in a crisis.

The *Emergency Response Symbology* is arguably the most globally recognised standardised approach to emergency management mapping symbology and is also formally recognised as an American National Standards Institute (ANSI) standard. As the *Emergency Response Symbology* was the pioneer symbology standard for emergency management, later attempts, including the *Canadian* and *Australian All-Hazards Symbology* sets, were inspired by the American forerunner and frequently try to build as much as possible on this system.

In addition to the graphical design of a particular cartographic symbol, it is necessary to provide to the crisis management participants (who are at the same time “cartographers” and users) rules and guidelines for the use on the map. To be able to expand the system with new symbols it is necessary to standardise guidelines for graphic design of cartographic symbols. The guidelines must specify the minimum size below which the readability of individual symbols will no longer be possible and predict the use of symbols on the maps of different scales since the scale dictates the size of the cartographic symbol and the amount of detail that can be represented by a pictogram on a particular symbol. We are aware that guidelines for determining the visual appearance of a particular symbol can only provide general notes, and the guidelines for obtaining good readability specific notes in the design of cartographic symbols. For this reason, people who will design new symbols should still have some (basic) knowledge of how to apply the given guidelines.

Apart from easy understanding and memorising, confirmation of the success of cartographic symbols is their availability and maximum ease of use on crisis maps that will only be created in the future. Incorporation of symbols in the software (e.g. symbols of the *Emergency Response Symbology* are available in ESRI's ArcGIS software), and uploading the symbols on platforms (for example, symbols from *OCHA's Humanitarian Icons* are available in the platform *The Noun Project*) can help in recognising the set as the de facto standard in the crisis and humanitarian community.

The results of this research showed that the current methods for public online sharing mostly include sharing via the organisation's website. Future research in the field of crisis mapping should seek to develop additional resources (such as crowdsourced, open-source web-based repositories and platforms for accepting, storing and disseminating symbols) that would further encourage the sharing of symbol sets among organisations and promote standardisation with regard to ensuring unambiguousness and the general and repeated use of these symbols on crisis maps.

It is necessary to put efforts in different forms of promotion, such as publishing, presenting, workshops, brochures, flyers, posters, conferences, and training activities. Sharing, promotion, dissemination and promulgation of the cartographic symbols undoubtedly imply investments such as costs of training, raising awareness, and changing standard practices and procedures. The establishment of funding mechanisms, as well as the establishment of a clear structure of management of implementation activities, should help in mitigating these costs.

Relying on good practices in existing cartographic symbol sets for crisis mapping can also mitigate transition costs and encourage the adoption of existing symbol sets.

A comparative analysis has revealed that certain changes were implemented in new, reviewed or extended editions of existing sets. Better visual organisation is achieved in the *Canadian All Hazards Symbolology* set, special symbols for expressing associative and selective properties are added in *Canadian* and *Australian All Hazards Symbolology* sets, learning and training materials like demonstrative examples of using symbols on maps are provided with *Emergency Response Symbolology* and *Canadian All-Hazards Symbolology*, graphical guidelines are made for extending the *OCHA's Humanitarian Icons* set. Hopefully, the results of this comparative analysis of prominent cartographic symbols for crisis mapping can be of assistance to less unified and coherent standards and symbolologies currently in use, many of which, though they have not been standardised yet, still have important information to convey.

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