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Cartography and Geographic Information Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcag20

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To cite this article: Tomasz Opach & Jan Ketil Rød (2022) A user-centric optimization of emergency map symbols to facilitate common operational picture, Cartography and Geographic Information Science, 49:2, 134-153, DOI: 10.1080/15230406.2021.1994469

To link to this article: https://doi.org/10.1080/15230406.2021.1994469

CARTOGRAPHY AND GEOGRAPHIC INFORMATION SCIENCE
2022, VOL. 49, NO. 2, 134–153
https://doi.org/10.1080/15230406.2021.1994469

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ARTICLE

A user-centric optimization of emergency map symbols to facilitate common operational picture

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ABSTRACT

Common operational understanding among engaged emergency responders is facilitated through shared operational pictures during crisis situations. Sharing is typically achieved through interactive tools, either desktop or web-based, in which map displays play an essential role. That role can be further strengthened if (1) agreed emergency symbols that are used in map-based interactive tools are sufficient to encode multifaceted operational information visually; and (2) the symbols are legible and meaningful for the diverse users of those tools. The authors revisited official emergency map symbols in use in Norway and reconsidered them against current requirements. To this end, they first conducted several meetings with stakeholders to elicit adequate revision requirements. Next, the reconsideration included the extension of the symbol set, symbol modification, and grouping. After the reconsideration, emergency management officers and specialists were interviewed. The interviews confirmed the agreement with the symbol categorization, extension of the symbols, and their modifications. The interviewees also made numerous suggestions to be considered in a follow-up study. Moreover, two concepts – symbol standardization and symbol harmonization – were proposed.

ARTICLE HISTORY
Received 20 April 2021
Accepted 13 October 2021

KEYWORDS
Emergency map symbols; cartographic symbolization; symbol standardization; symbol harmonization; user study; cartographic design

1. Introduction

Interaction between agents involved in a crisis operation is facilitated by a common operational understanding (Björkbom et al., 2013). The creation of a common perception along with a comprehensive insight into a hazardous event needs adequate decision-support tools. Map-based interfaces used to build common operational pictures (COPs) can be used as decision-support. Map-based COPs employ emergency map symbols to encode operational information visually and thus support coordination and information exchange during interagency operations (Chmielewski & Gałka, 2009).

Conceptually and technically, map-based COPs integrate different georeferenced datasets and present an overview of the information to enable situation awareness (Björkbom et al., 2013). However, the integration is difficult to achieve because emergency responders have different task-specific needs and habits regarding the use of map symbols (Kuveždić Divjak et al., 2020). These aspects along with a broad range of mapping scales make emergency map symbols difficult to design (Robinson et al., 2011). It also happens that emergency maps are used by third-party actors such as media or local administration that want to see what is going on. As a result, secondary requirements appear, to have symbols legible also for non-specialists. Literature shows that emergency map symbols are often developed from non-user-centric perspectives and are defined in technological terms that do not adequately capture the users' needs (McNeese et al., 2006). Therefore, although much effort has already been made to design emergency map symbols (Akella, 2009; Kostelnick & Hoeniges, 2019; Marinova, 2018; Robinson et al., 2011, 2012), there is still a need for studies of symbols to be used as a common repository (Robinson et al., 2013).

This study is part of a project with an overarching goal to enhance information sharing for common situational understanding in interagency operations (Munkvold et al., 2019). The long-term ambition is to determine a set of concepts to be symbolized, to elaborate the details in symbol design, and ultimately to propose an operational map symbol package to be used in map-based COPs in Norway. As this ambition extends the scope of a single study, we narrow it down to a specific task. Therefore, the aim of this study is to revisit the emergency map symbols provided by the Norwegian Mapping Authority (NMA) to address current demands regarding information sharing for common operational understanding and thus, to enhance

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Supplemental data for this article can be accessed here.

the symbols' role in facilitating situation awareness. We use the NMA emergency map symbol package as a case, as it is provided by the state agency to be freely used by Norwegian emergency responders. Three issues guided our research efforts. First, we investigated whether the symbols were sufficient to encode required information and, if necessary, we extended them by including missing symbols and redesigned them. Second, we studied whether the considered symbols were recognizable and whether the concepts that the corresponding symbols were supposed to encode were sufficiently precise. Third, and lastly, we grouped the symbols to facilitate an overall understanding and rapid selection of them.

Our study was arranged as a multistep process that followed the design science research (DSR) framework (Peffers et al., 2007). It contained steps for (1) problem identification and motivation, (2) definition of objectives of a solution, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. In the next section on related research, step 1 is achieved through problem identification and motivation. Next, we report on meetings with emergency responders and interviews with COP software producers to identify requirements for the emergency map symbols to be used in map-based COPs, which refers to step 2 of the DSR framework. Step 3 is described in the section on the reconsideration of the NMA emergency symbols. The demonstration and evaluation steps (4 and 5, respectively) are encompassed in the empirical study section, in which we described the interviews with emergency officers from the municipal and county administration, as well as officers from various Norwegian emergency and rescue institutions. The last step on communication (6) is achieved through this article as whole.

2. Related research

2.1. Map-based COPs as a pillar of common operational understanding

Most situation awareness studies concern military cases (Björkbom et al., 2013; McNeese et al., 2006) in which a common, real-time representation of the battlespace has always been of primary importance to commanders who needed standardized maps with standardized map symbols (Hershey, 2012). Shortly after being introduced for military purposes, map-based COPs were successfully used to support civil coordination, such as the coordination of emergency responders (Deschamps et al., 2002). Complex emergency operations require collaboration under a single command as well as between multiple agencies. Engaged parties use maps to display operational information such as position and status of own units, as well as resources administrated by other agencies (Chmielewski & Gałka, 2009), also in cross-border cooperation (Peters et al., 2013). Moreover, in a specific actor's internal organization, various tasks are assigned differently to its command posts, operational leaders, and field teams (Björkbom et al., 2013). Additionally, various actors have different organization and are administrated differently. They also need to follow different symbol standards (Chmielewski & Gałka, 2009; Peters et al., 2013). All of the above-mentioned aspects influence the way in which information is represented in map-based COP tools.

In principle, COP tools combine georeferenced data and display them to enable a common situational understanding among a variety of actors (Björkbom et al., 2013). However, such actors are not always involved in the development of COP tools. McNeese et al. (2006, p. 468) claim that "success results from representations and visualizations that are highly user-centric, rather than just computationally-convenient or designed strictly from a programmer's mindset."

As argued by Wang et al. (2010), a standardized disaster map symbology and color coding can be built up through a comprehensive investigation of different agencies involved in disaster management scenarios. Different map readers can improve the interpretation of the same disaster map, and ambiguity can be avoided. As Greeno and Moore (1993) state, the success of COP interfaces depends on the support of user-centric affordances and visualizations designed according to the principles of situated cognition. Referring to the companies' efforts to engage end-users in the development process, the role of the user-centric approach is visible and of growing importance.

2.2. The need for common emergency map symbols

Cartographic literacy is a substantial aspect of the design of COP map-based interfaces with a user-centric approach (Kuvedžić Divjak & Lapaine, 2014). Using meaningful and legible map symbols to add information to a background map seems to be of major importance, as thematic overlays describe event details such as affected areas, rescue squad positions and human resources in use. Map symbols of any type, also emergency map symbols function as a codified language to facilitate communication (Ramírez, 2018; Ratajski, 1971). Therefore, establishing a common set of map symbols – a "common operational symbology" (Chmielewski & Gałka, 2009) – can enhance communication between emergency responders. Examples include the communication interface developed by Fitrianie et al. (2007), in which icons represent

concepts in crisis environments, and a symbol system for disaster management developed by Marinova (2018), which includes a four-level hierarchical classification of objects and phenomena according to their type and origin. Marinova's solution is a compact system in which colors and shapes are the two main attributes that join groups of symbols together. The role of these two attributes is also emphasized by Wang et al. (2010), who argue that colors and shapes have a strong visual impact on the map reader.

According to Bianchetti et al. (2012), the development of standard map symbols is one method to improve communication efficiency. Based on a study of American and Canadian map symbol sets for national management use, they found that the design of emergency symbols influenced map readers' conception of represented information. While the North American standards are well documented in the literature (Akella, 2009; Bianchetti et al., 2012; Kuveždić Divjak et al., 2020; Robinson et al., 2012, 2011), there have been few studies from Nordic countries on the use of emergency map symbols. Examples include the study by Finish researchers Korpi and Ahonen-Rainio (2010), who discuss the influences of different cultural background factors on both the design and comprehension of map symbols for crisis management. In another study, Opach et al. (2020) analyzed COP map-based tools in use in Norway to gain insights into the tools' emergency map symbols and implemented functionalities.

The emergency symbols offered by the NMA consist of 110 symbols (Figure 1) and can be accessed via a website, where the symbols are arranged in eight themes. However, the themes do not reflect symbol thematic groups. For example, "health sports facilities inside" belongs to the "population" theme, whereas "health sports facilities outside" is part of the "other" theme. Despite easy and free access to the NMA emergency map symbols, Norwegian agencies such as the Norwegian Directorate for Civil Protection (DSB) use the symbols only partially.

2.3. User-centric optimization of map symbols

Cartographic foundation for optimizing map symbols was elaborated by Bertin (1967) in his theory of visual variables. He described the rules of using symbol geometry, size, and color to visually encode a message on map. Later, methodical basis of map symbol standardization was investigated for specific map types (Robinson et al., 2012), for instance, for economic maps (Ratajski, 1971). In the latter, Ratajski proposed the term "map language" relating to the visual semiotics principles (Freitag, 1971; Pravda, 1994). According to MacEachren et al. (2012), semiotics describes a framework for understanding why graphic representations work and revises graphical representations for optimal signification. The justification is based on the basic visual variables that can be manipulated to encode information and meaning. More recently, optimization of map symbols is investigated with the emphasis of contextual map design (Griffin et al., 2017) and with the leading role of user-centric approaches. For example, Robinson et al. (2011) interviewed cartographers and map users from U.S. Department of Homeland Security to understand user needs for map symbol standards in emergency management. User-centric approach has also been used to elaborate the NATO military rules for using map symbols. Most of the NATO joint military symbology concerns specific points, and consists of a frame (a geometric border), a fill, a constituent icon, and optional symbol modifiers (North Atlantic Treaty Organization, 2017).

Despite efforts already undertaken to elaborate common emergency map symbols, user demands evolve continuously, hence the symbols need constant adaptation and improvements (Dymon, 2003; Robinson et al., 2012). User-centric development of map symbols to be used in emergency management tools is an iterative and collaborative process that requires the interaction between symbol designers and users. However, apart from user diversity, the main challenge is that such symbols are used in various phases of an emergency response, when various map scales and map roles are of primary importance to the users who need to coordinate information differently (Robinson et al., 2011). Cutter (2003) identifies four phases of emergency response: planning, immediate response, intermediate response after an event has ended, and long-term recovery. Robinson et al. (2011), referred to those phases when conducting a series of interviews to elicit ideas for map symbols that support emergency management, and they drew the conclusion that the development of a map symbol standard is faced with rapidly evolving domain-specific tasks.

Emergency map symbols need to be optimized taking into account also map background. Users' perspectives regarding the use of various base maps were investigated by Konečný et al. (2011) who conducted a user study to examine background efficiency for specific situations. Moreover, the role of the background was elaborated by Staněk et al. (2010), who examined selected issues of the optimization of cartographic communication within the context of an operational emergency management center.

Coast and fishing			
Anchorage	Diving service	Lifeboat	Man overboard
Shipwrecks	Wharf		
Cultural monuments			
Ancient heritage	Cultural heritage	Protected buildings	Sami cultural heritage
Nature			
Drinking water sources	Habitat biotope	Strong wind E	Strong wind N
Strong wind NE	Strong wind NW	Strong wind S	Strong wind SE
Strong wind SW	Strong wind W		
Other			
Arrow little activity	Arrow medium activity	Arrow greater activity	Arrow greatest activity
Checkpoint	Checkpoint 2	Checkpoint operational	Civil defense
Health sports facilities outside	Other resources		
Outdoor activities			
Campfire	Snowmobile		
Population			
Communication installation	Doctor	Health sports facilities inside	Information
Medical boat	Medical car	Pharmacy	Sports hall
Trace finds			
Social security			
Alarm signal	Alarm signal priority 0	Alarm signal priority 1	Alarm signal priority 2
Alarm signal priority 3	Ambulance aircraft	Ambulance car	Ambulance check
Ambulance station	AED	Chemical diving	Plain-clothed police officer
Communication mobile	Communication stationary	Danger	Dangerous cargo
Dangerous cargo 2	Emergency call center 110	Emergency call center 112	Emergency call center 113
Event	Explosives	Explosives 2	Fire
Fire service	Firefighting vessel	Fire station	Fire engine
First aid station	Flood	Gas station for helicopters	Ground hydrant
Helicopter	Helicopter base	Heliport	Hospital
Turntable ladder	Landslide	Medical office	Military
Military camp	Military unit	Operational manager command post	Origin marking
Origin marking from fixed location	Police	Policeman	Police boat
Police car	Policeman with bicycle	Mounted police	Police station
Police team	Policeman with dog	Policeman with motorcycle	Public gathering
Radioactive	Civil defense rescue dog	Small cabin	
Transport			
Airport	Depot	Fire hydrant	Gathering place
Meeting place	Parking space	Petrol / fuel	Roadblock human activity
Roadblock natural causes	Waiting place		

Figure 1. The set of 110 emergency map symbols provided by the Norwegian Mapping Authority compiled based on the authority's website (https://register.geonorge.no/symbol/symbolpackages/details/765ad2b6-5994-44ff-9ae0-2d759edc309f).

3. Eliciting ideas for emergency map symbols to be used by emergency responders in Norway

3.1. Methods

Two steps constituted our investigations to identify user needs for emergency map symbols: (1) meetings with emergency responders, and (2) interviews with COP software producers. For the first step, two meetings were conducted with emergency responders to gain feedback on map-based COPs' advantages and shortcomings. The first meeting was arranged in Oslo in October 2019 as a two-day workshop with representatives of multiple emergency response organizations. The workshop was divided into three group sessions and the aim was to discuss information sharing for common situational understanding. The workshop was attended by twenty individuals, who represented various agencies and emergency responders, including police, fire department, health services, and the Norwegian Directorate for Civil Protection (DSB). Although the sessions employed different empirical techniques such as brainstorming and a world café, here we only refer to the outcomes of the workshop's brainstorming session. The second meeting was arranged in November 2019 as a Skype meeting with a representative from the Norwegian Coastal Administration (NCA). The meeting was built around a demonstration of the COP map-based tools used by the NCA. The meeting lasted 90 minutes.

In the second step, two interviews were conducted with COP software producers to gain an understanding of how the producers try to fulfill the requirements and expectations of emergency responders. The understanding was needed to gain insights into features that make map-based COPs usable and useful. The first interview lasted 90 minutes and was organized with a representative of Locus Public Safety (www.locus.no), whereas the second lasted one hour and was arranged with a representative of Avinet (www.avinet.no). Both interviews were semi-structured, using a common thematic interview guide. Additionally, the interviews included demonstrations of some of the companies' tools. The interviews were recorded and transcribed.

3.2. Outcomes

3.2.1. Meetings with emergency responders

The Oslo workshop's brainstorming session resulted in three categories related to map symbols: symbolization in general, visualization, and extra information. The symbolization category covered such needs as a common cartographic symbolization and the use of common map backgrounds. Map backgrounds should be available for all emergency responders, on which desired information should be overlaid. In turn, the visualization category was referred to when discussing map or data displays to provide auxiliary thematic information. The need for auxiliary information should be addressed when developing tools tailored to specific requirements, for example, by including specific thematic layers such as electricity, water, waste, and weather. While these thematic layers should serve as a foundation, emergency responders also need symbols for situation-specific descriptions such as weather forecasts and the location of available resources. A complete resource overview across agencies and organizations should be included in the map.

During the meeting with an NCA representative, a demonstration of one of the agency's COP map-based interfaces was given and used to trigger a discussion. The NCA's primary concern are oil spills resulting from vessel accidents, and therefore its map-based solutions are designed to facilitate documentation and effective decision-making. The tool "Coastal Information – Emergency" has an open version that provides common web mapping functionality, and an additional password protected functionality that assigns specific roles to users. This password-protected functionality integrates background maps with thematic overlays, such as environmental characteristics and infrastructure, with situational information such as real-time observations and engaged resources, as well as weather forecasts and drift trajectory simulations. Moreover, "Coastal Information – Emergency" enables selective and targeted information sharing. The tool's developments were comprehensively tested with emergency responders dealing with oil spills. The functionalities include accessing remote measurement data from boats, aircraft, drones, and remote sensing data.

3.2.2. Interviews with COP software producers

First, we interviewed a representative of Locus Public Safety, which offers solutions for command posts and emergency mobile units. The solutions' geographic and map-based components are "integrated from external mapping companies," according to customer specifications. The tools' multiagency data access was not supported, due to lack of legal frameworks and system requirements from customers. It was emphasized that tool development is a multistage process with mutual interaction between user groups and system designers and, as the interviewee stated, "it is very rare that something that is really good comes without a proper effort." Agencies often do not recognize the benefits of seeing extra information on their map displays until they are provided with such information.

The representative of Locus Public Safety stated that symbolizing data in map-based interfaces, that dynamically integrate various data sources, was a challenge, as "too much data shown on a map means no information, but only data and noise." The company tries to follow symbol design solutions based on familiarity (e.g. from maps published by Norwegian authorities). Moreover, the company has also elaborated its own standardized symbol scheme, which is among others, implemented in TransMed. Regarding background maps, the company has a map variant in which the amount of information is reduced if the map is zoomed out. This helps to emphasize real time data content. The latter is typically visually encoded by means of symbols from the emergency symbols set shown in Figure 1. Additionally, the symbols are color-coded in red, yellow, green, and white, depending on the event priority. Several agencies use the same symbology. However, there is still a need for a common symbology, for example, when a specific area has been contaminated and first-response agencies need to know that they need protective clothing. Furthermore, the way the same information is presented in command posts and in the field differs. For example, in outdoor solutions colors are saturated and strong, and therefore one can read a map display with fewer details when moving, in sunlight, and/or from different angles of view.

The second interview was held with a representative of Avinet, which delivers several map-based decision support tools for directorates, county governors, and county councils in Norway. Their tool development process is typically stepwise and requires constant collaboration with the customers: as the interviewee stated, "together we find a solution." This means that during a development process the functionality evolves based on specific needs reflected in offered interactive functions. Furthermore, the interviewee explained that the development process was challenging since it was not just about providing data and functionality to responsible agencies during an emergency. Such interfaces were also used by third-party actors such as the media, to gather necessary information. The interviewee stated: "Third-party actors [...] have the benefit of knowing what is going on with an oil spill that has moved on and so on. So, that is an important part [...] to gather information there and then, but also to be able to disseminate it." Although Avinet has developed tools for various agencies, the NCA was the main user of the company's map-based solutions for information sharing. In the NCA, the need for map-based interfaces for emergency management and situation awareness was recognized quite early. The main reason was that some major ship accidents had resulted in oil spills that had environmental consequences on differing scales. Therefore, Avinet's solutions were needed to "register places where oil spills were detected and their aftermath in relation to what actions were required and what resources were available to help cope with the damages."

No specific repositories with standardized symbols were used by Avinet; rather, the customer decided how specific information should be represented on a map. However, Avinet needed to adapt such demands to map conditions. For example, the needs expressed by a customer could lead to problems with map interpretation, since according to the interviewee, "[one] often needs to see a lot of information at the same time, and one may get a lot of the data from third-party sources. [Then,] the third-party objects are represented with a certain color that the third-party has determined as required." However, as the interviewee explained, a given color cannot be used in an emergency or planning context that already employs the same color to encode a specific message: "if you 'sew together' many actors you will have a conflict." Therefore, a common symbol library would help to avoid misunderstandings.

3.3. Identified requirements

No specific user needs regarding emergency map symbols were elicited through the meetings and interviews described in the preceding section on outcomes. Only generic suggestions were given, with the main idea of a common operational symbology to be available as an open access repository. Although the emergency symbols provided by the NMA are known by stakeholders, such stakeholders often use their own symbols. Furthermore, in Norway, there are several providers of map-based emergency tools, and the lack of system interoperability is evident. This issue is not caused by technical restraints but by organizational ones. The surveyed COP map-based tools lack common solutions (i.e. they implement various types of symbology). This issue can be solved by applying the principle of "different systems – same data," but further efforts are needed to standardize content and its graphic representation used by various systems.

4. A revision of the emergency symbols provided by the Norwegian Mapping Authority (NMA)

To address the findings revealed in the previous section and suggest a common operational map symbology, we narrowed down our efforts to the revision of the emergency symbols package shown in Figure 1. We undertook three steps and modified the symbols by: (1)

grouping them, (2) adding symbols we found were missing in the set, and (3) redesigning some of the existing symbols. In our work, we were inspired by the work of Ratajski (1971), who defined "the language of a map" that he subsequently used to standardize signs on economic maps. However, to do so, first, he had to classify the contents of economic maps, since "classifications adopted by economic and planning organizations in various countries do not fulfil the requirement of being cartographic" (Ratajski, 1971, p. 141). Furthermore, we were also inspired by the work of the Homeland Security Working Group of the Federal Geographic Data Committee (HSWG FGDC) that resulted in the map symbol standards for emergency management used in the USA (Robinson et al., 2011, 2012). Partly, our work therefore reflects the solutions elaborated by the HSWG FGDC.

4.1. Grouping symbols

We elicited relevant distinctions and relationships that characterized the nature of the concepts of the NMA's 110 symbols. That helped us to disambiguate concepts with different interpretations in different contexts, and then to elicit three main symbol groups with a total of 14 themes (Table 1). The first group "Reporting and context" contained 4 themes with 21 features to be used to symbolize either the cause of actions (the themes "Events" and "Natural disasters") or actual or potential sources of disasters ("Risks"), along with the environmental context ("Wind"). The second group "Operations," consisted of 62 concepts of map symbols organized in five themes concerning services ("Emergency services," "Emergency call centers"), and resources and supporting information ("Operational information," "Alarm signals," and "Status") either available during or implemented due to an emergency management situation. Lastly, the third group, "Infrastructure," comprised five themes with a total of 27 map symbols for visual encoding of concepts concerning basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and telecommunication systems.

4.2. Adding new symbols

We investigated the symbols provided by HSWG FGDC to search for symbols of potential value to the Norwegian context. From our three groups, we identified concepts that would make the groups complete and comprehensive. As a result, 12 new symbols were added to "Reporting and context" (marked in red in Figure 2), 18 to "Operations" (Figure 3), and 9 to "Infrastructure" (Figure 4). Regarding "Reporting and context," most of the new symbols were added to "Events" (Figure 2). Four of the symbols concerned events reported "at fixed location" that differs substantially from the events that occur outdoors. We also supplemented the category with six new "accident" symbols, including car or railroad accident. Finally, "Freezing rain" and "Heavy snowfall" were added to "Natural disasters," since those often occur in Norway.

In the category "Operations," most new symbols were added to "Operational information" (Figure 3). Five of the symbols concerned damaged objects such as damaged roads and railroad tracks. "Emergency

Table 1. Elicited symbol groups with subgroups.

Group name	Subgroup/theme		Symbols		
			Default set	Added	Modified
Reporting and context	Events		6	10	3
	Risks		5	–	2
	Natural disasters		2	2	–
	Wind		8	–	8
Operations	Emergency services	Medical service	12	1	7
		Fire service	7	4	2
		Police	12	2	3
		Military	3	2	2
		Civil defense	2	1	1
	Operational information		14	8	6
	Emergency call centers		3	–	3
	Alarm signals		5	–	5
	Status		4	–	–
Infrastructure	Telecommunication		3	–	2
	Protected areas		5	–	1
	Tourism and sport		6	–	2
	Services		2	3	–
	Transport	Land	2	2	–
		Water	4	2	–
		Air	5	2	3

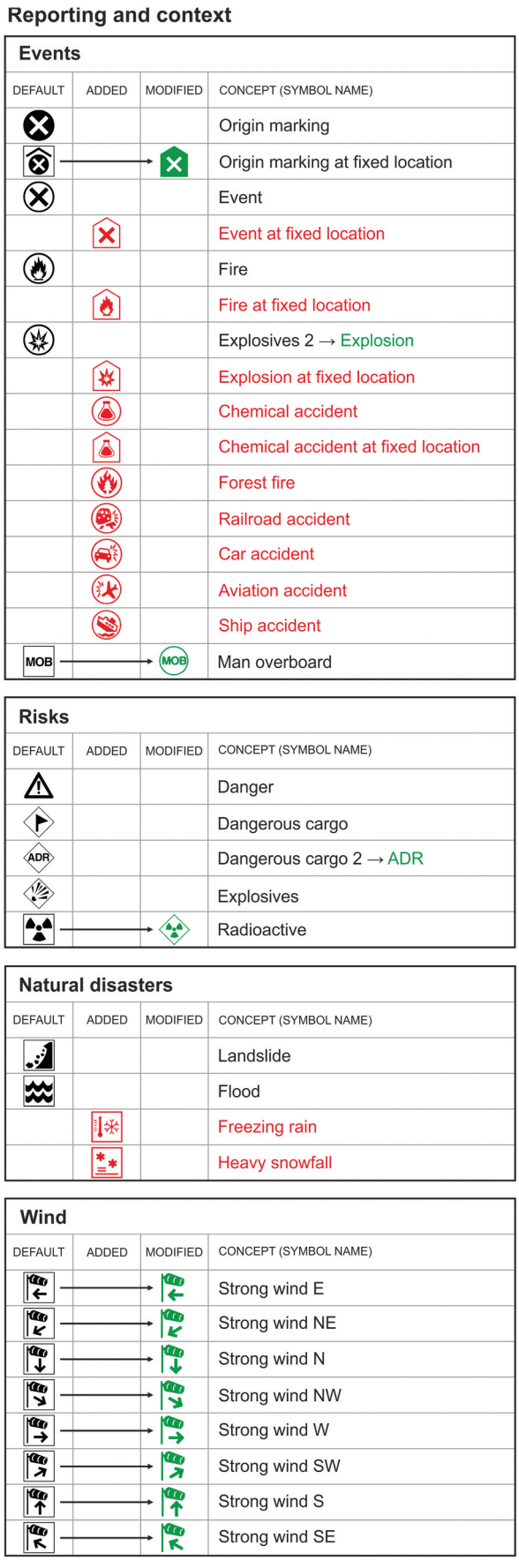

Figure 2. Subgroups of "Reporting and context" along with the added and modified symbols.

services" were supplemented with 10 new symbols that concerned emergency equipment such as "Police helicopter" or "Firefighting aircraft," and emergency staff such as "Soldier" of "Firefighter." Lastly, in the "Infrastructure" category (Figure 4), three new symbols were added to "Services" and six to "Transport."

4.3. Modifying existing symbols

In the "Reporting and context" group, the 13 alterations led to the unification of the symbol forms and, in two cases, to revised symbol names. Hence, "Events" are either shown with a house-shaped symbol if they are reported at a "fixed location" or enclosed in a circle in other cases. "Risks" are shown with diamond-shaped symbols to resemble the hazard pictograms by the international Globally Harmonized System of Classification and Labeling of Chemicals (GHS) (Winder et al., 2005). In the system, two sets of pictograms are used for (1) the labeling of containers and workplace hazard warnings, and (2) the transportation of dangerous goods. We used diamonds for all symbols except for the triangle-shaped symbol used for "Danger," which resembles the "Potential danger" pictogram used in the German standard for safety colors and safety signs (Deutsches Institut für Normung, 2012). The original square-shaped frame for symbols in the "Natural disasters" theme was kept, whereas in the "Wind" theme, we removed the symbol frames because a wind symbol represents an area, not a specific point location.

In the second group, "Operations," we modified the form of 28 symbols and the name of one symbol. All "Emergency services" were framed either in a house-shaped symbol for fixed locations or in a square in all other cases. We also redesigned several symbols. For instance, we used "officer heads" to symbolize resources from sectors such as "Military," "Police," and "Fire service." These symbols are to be used at a strategic level, on maps at relatively small scales that enable only a small number of symbols to be shown due to limited map space. Therefore, the strategic level requires flexible symbols of a generic nature. Regarding "Operational information," we replaced six circular symbols with their square-shaped alternatives. We also replaced character-based symbols, such as "M" encoding a meeting place, with pictogram symbols, assuming that the latter are more reader-friendly and self-explanatory than the former. For "Alarm signals," we removed their geometric frames, as done for the wind symbols and for the same reasons, as the symbols relate to large areas. Lastly, we framed all "Emergency call centers" in a house-shaped symbol.

Operations

Figure 3. Subgroups of "Operations" along with the added and modified symbols.

The third group "Infrastructure" had eight symbol modifications, of which six concerned the alteration to a "house-shaped" symbol frame. Moreover, the heliport symbol that originally resembled the hospital "H" symbol was replaced with a pictogram symbol. Lastly, we decided to use a frameless symbol for helicopters, based on our assumption that generic symbols for transportation means (e.g. snow scooters) should be shown as frameless to save map space.

5. Empirical study

5.1. Three aims

The three aims of the empirical study reflect the symbols' revisions described in the preceding section. First, we wanted to gain a broad understanding of whether the 110 emergency symbols offered by the NMA were sufficient for Norwegian emergency actors who use map-based COPs to describe complex emergency situations. At that point, we

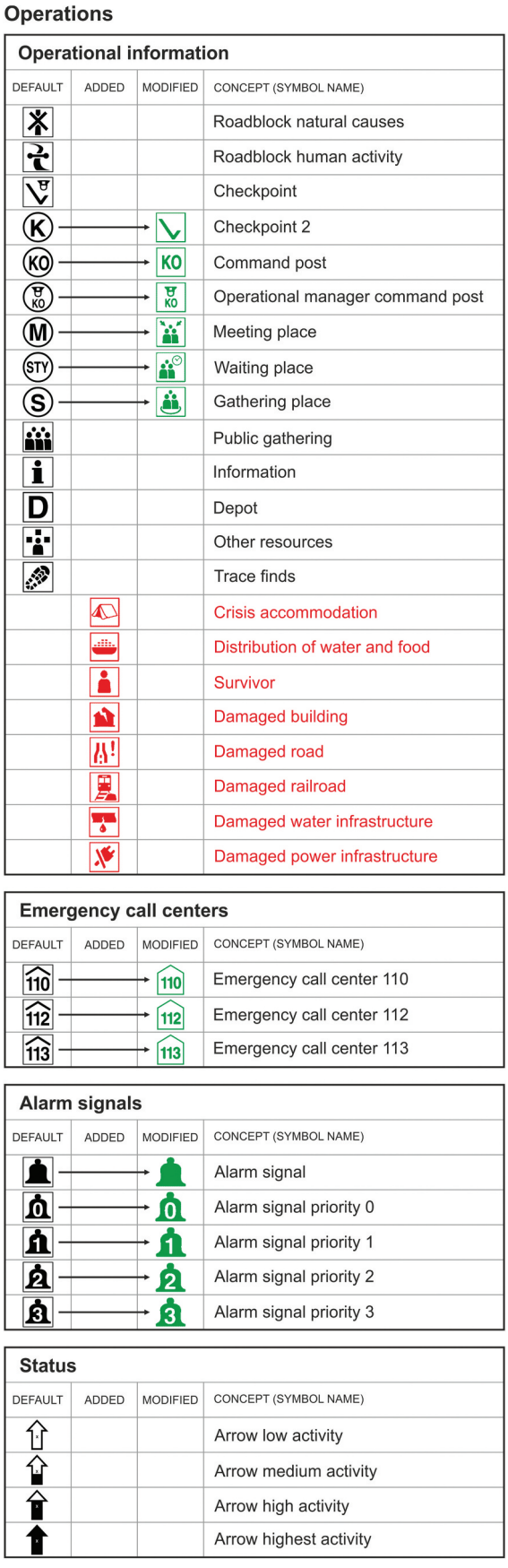

Figure 3 (continued). Subgroups of "Operations" along with the added and modified symbols.

wanted to know whether suggested new symbols (Q2 in Table 2) and modified existing symbols (Q3) could be of value to the comprehensiveness of the whole set. Second, we wanted feedback on whether the proposed symbol grouping made sense (Q1). Finally, we wanted to know whether further symbol alterations, such as symbol differentiation by size and color to reflect object status or hierarchy could improve the effectiveness of the symbol set (Q4).

5.2. Method and empirical material

Ahead of each interview, we sent the empirical material to the participant who was asked to familiarize himself/herself with it. After approximately one week, a semi-structured interview was organized (see supplemental online material for the guide that we used for the semi-structured interviews), with the same empirical material used as a common thematic interview guide.

The empirical material included two documents: a short introduction to the interview, as well as the four questions to be posed (see Table 2), and a combination of extended versions of Figures 2, 3, and 4 containing all the NMA's emergency symbols arranged in a table according to the suggested three groups. Moreover, the NMA symbols were supplemented by several new symbols and were presented in two forms, the default one proposed by the NMA and the form suggested by us.

5.3. Outcomes of the interviews

Six persons were interviewed individually. The interviewees consisted of emergency officers from the municipal and county administration, as well as officers from various Norwegian emergency and rescue institutions. At the beginning of each interview, we asked the interviewees to rate their proficiency from 1 (expert) to 7 (no skills) in their general map use skills, mapping skills, and their mapping skills related to COPs for crisis management. The average rates were relatively high and scored 1.9, 2.3, and 2.7, respectively. Thus, the interviewees rated their mapping skills related to COP for crisis management as lowest.

The data analysis was split into four parts based on the four interview questions. These are reported in the following four subsections.

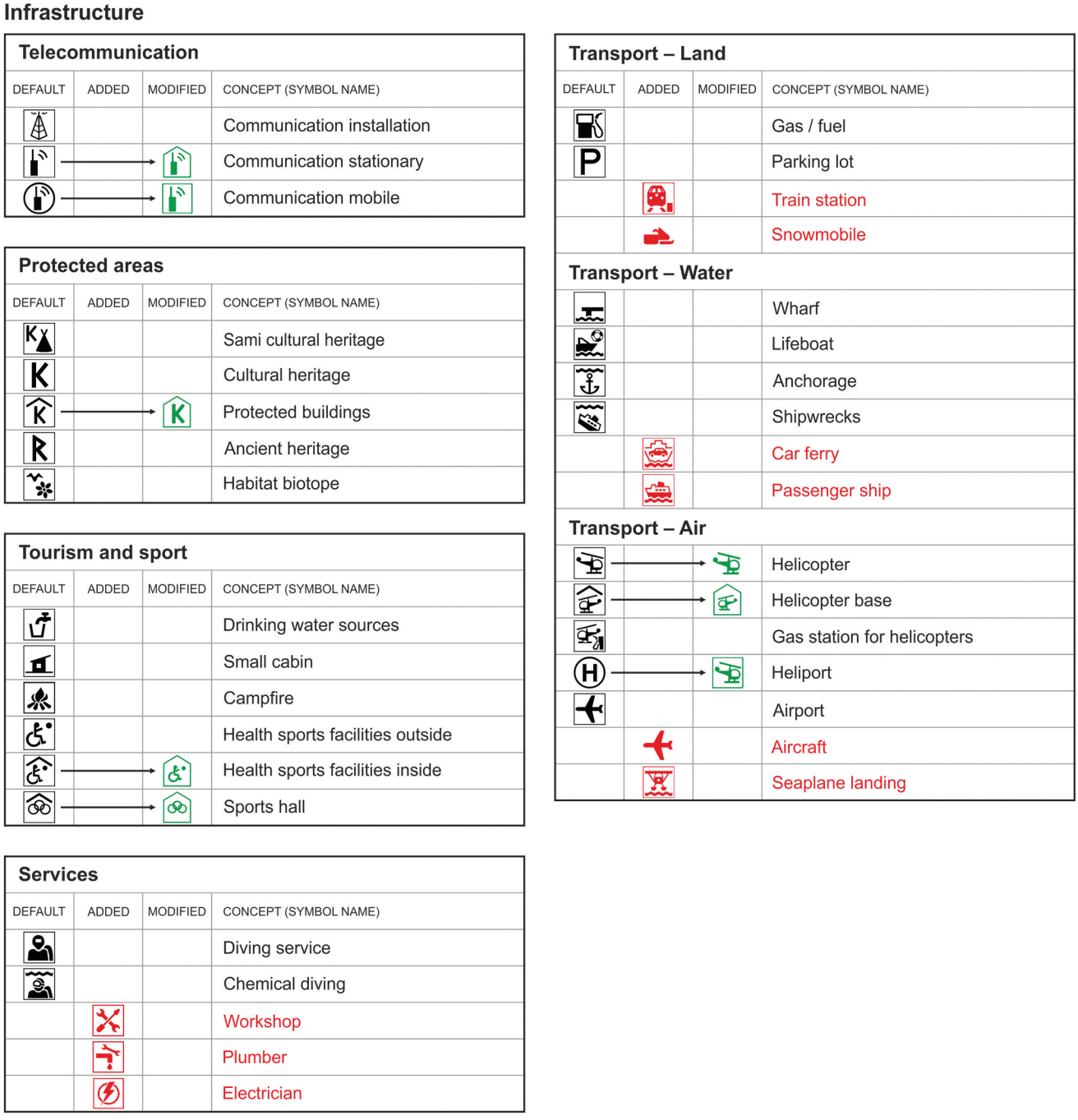

Figure 4. Subgroups of "Infrastructure" along with the added and modified symbols.

5.3.1. Q1 – Grouping of emergency symbols

In Q1.1, all participants confirmed that the grouping made sense to them, as "the names and the categories are very descriptive" (interviewee #3). Moreover, interviewee #6 claimed that "Medical service," "Fire service," and "Police" were primary "Emergency services," while "Military" and "Civil Defense," together with specialized services such as "Mountain rescue," could constitute a new theme called "Supportive emergency services." Next, in Q1.2, we asked whether the symbols grouping helped the participants to gain a quick overview of available symbols. In this case, the interviewees generally agreed with our suggestion, and interviewee #2 concluded that "When grouping is logical and well organized, the symbol selection can be made more quickly." Interviewee #4 expressed skepticism about having too many symbols, which might impede gaining insights into the whole set, particularly for those who do not use the symbols often. Therefore,

symbols that are seldom used need to be self-explanatory. Interviewee #3 expressed confusion about lack of differences between the geometric frames of the symbols in various subcategories, such as those constituting "Emergency services."

In Q1.3, we wanted feedback on whether the symbols grouping helped users to find the symbols they needed. Half of the participants expressed some doubts. Interviewee #3 asked for an explanation of the meaning of the group "Reporting and context." The same interviewee was also confused by the triangle-shaped symbol "Danger" that did not fit with other symbols. Interviewee #4 expressed the following:

> One thing is that those who create the situation picture understand the symbols, but the symbols must also be understood by those they are presented for, and these are perhaps the most important group. I have concerns about whether maps with emergency symbols will be understood because there are very many symbols that will not be understood by those reading the maps.

Similarly, interviewee #5 commented on the lack of intuitiveness of some symbols, citing the "Railroad accident" symbol as an example. The interviewee admitted that low-resolution screens might fail to display unintuitive symbols clearly, especially if the latter are displayed in low quality images.

5.3.2. Q2 – Number of symbols

We collected various statements, sometimes contradictory, regarding the question whether the added 39 map symbols made the emergency symbol package more complete (Q2.1). Interviewee #5 claimed that "How complete one should make such symbol packages is a tricky issue" and added the following:

> I believe simplicity is a good principle for everything we do. I think that you are on the right track in being able to standardize the symbols and to make available an appropriate number of symbols at an appropriate level of detail [...] For example, it may not be necessary to provide in symbol form details of a traffic accident with information as to whether a truck or other vehicle was involved.

In turn, interviewee #4 said "is almost impossible to create 110 symbols that are self-explanatory and having a limited selection of symbols may therefore be important." The same interviewee added that "it is very important to limit the number [since] with many symbols, it becomes more difficult to design all symbols to be intuitive [However,] to say that 100 is enough, or that 200 is enough, I do not know." By contrast, interviewee #2 said "Different events and different agents may want to have a different set of symbols easily available."

Apart from the comments of general nature, there were also specific suggestions. One example is interviewee #4's criticism of the symbol

Table 2. A concise list of questions used to guide the interviews in the empirical study.

Question title and instruction	Detailed questions
Q1 Grouping of emergency symbols We have experimentally organized the emergency symbols offered by the Norwegian Mapping Authority (NMA) in three groups that resemble the grouping by the FGDC HSWG.[2] Please familiarize yourself with the proposed three groups and answer the questions Q1.1–1.3.	Q1.1 Does the proposed grouping make sense? Please elaborate your answer. Q1.2 Does the grouping help you to get a quick overview of available symbols? Please elaborate your answer. Q1.3 Does the grouping help you to find the symbols you need? Please elaborate your answer.
Q2 Number of symbols The symbols by the FGDC HSWG include more symbols than the symbol package used by the NMA. We have added several new symbols to the package. Please familiarize yourself with them and answer the questions Q2.1–2.3.	Q2.1 Do the new symbols make the symbol package more complete? Please elaborate your answer. Q2.2 Are there any symbols that you miss and that you would suggest including? Please elaborate your answer. Q2.3. Are there any symbols that are not needed? Please elaborate your answer.
Q3 Symbol modifications We have modified several symbols. Please familiarize yourself with the modifications and answer the questions Q3.1–3.3.	Q3.1 Do you understand what the symbols mean? Please elaborate your answer. Q3.2 Do the modifications make the grouping of symbols more distinct and easier to select a certain symbol? Please elaborate your answer. Q3.2 Do you have suggestions for other modifications? Would other approaches be useful, such as the one used in Germany? Please elaborate your answer.
Q4 Symbol differentiation Neither size nor color is used to differentiate the NMA's emergency symbols. As a result, there is no hierarchy among the symbols. Please answer the questions Q4.1–4.3.	Q4.1 Among the NMA's emergency symbols, are there any symbols that are more important than others? Please elaborate your answer. Q4.2 If yes to Q4.1, what would be the best way to emphasize symbols graphically to show their importance above other symbols? Please elaborate your answer. Q4.3 Are there any other reasons (e.g. operational status) for symbol differentiation, other than hierarchy, that is important? Please elaborate your answer.

"Distribution of water and food," which he found unintuitive. Lastly, interviewee #3 stated that it was important to use the same frame shapes consistently, such as circles, squares, diamonds, and houses, and that, for example, "circles should be reserved for events that do not occur at fixed positions or in man-made constructions," as then, the user could follow

> the logic in how the symbols are built up, and it becomes easier to answer the question on whether the extension of symbols make sense. If the background form of the symbols is used logically and consistently, it would make sense to include more symbols.

Although in response to Q2.2 (about missing symbols) interviewee #6 was satisfied with our suggestions and interviewee #2 claimed that there were enough symbols, most interviewees provided some extra symbol that they considered were missing in the set. Interviewee #4 missed two symbols: "Task leader command place" and "Evacuated relatives center." Furthermore, the same interviewee pointed out the lack of distinction between "Medical helicopter" and "Rescue helicopter," which differ in terms of their capacity and equipment. Interviewee #1 confirmed the usefulness of some of our new symbols such as "Damaged building," "Crisis accommodation," "Distribution of water and food," and "Damaged power infrastructure," and said that some additional new symbols would be needed, for example, "Damaged fiber-optic infrastructure." Moreover, the same interviewee concluded that "there should be symbols for all possible events." Additional symbols were suggested by interviewee #3, who regretted the lack of symbols for other vehicle types than snow scooters, planes, and helicopters. Interviewee #3 suggested including visibility and wind speed in the information about environmental context and was surprised by the frameless symbols for vehicles. Interviewee #5 suggested adding symbols that would "lead to a mass injury, which could happen due to terror and intentional incidents."

We also asked about redundant symbols (Q2.3). Interviewee #4 had three suggestions. First, "the number of symbols should be limited"; for example, the forest fire symbol could be replaced by the fire symbol. Second, as "heavy snowfall" does not immediately cause a natural disaster, unlike an avalanche, the corresponding symbol should be either removed or moved out of the subgroup (theme) "Natural disasters." Third, as there is no practical difference between a road blocked due to human activity and a road blocked due to natural causes, there is no need for two different symbols. Interviewee #4 also found police symbols too various and numerous. Similarly, in the case of symbols encoding firefighters, the interviewee said that "there is a total of three symbols. One would be enough." Regarding the latter point, interviewee #6 held same opinion: "it seems redundant to have three rather similar symbols for fire service, firefighter, and firefighter team." The same interviewee, along with interviewees #3, #4 and #5 also expressed doubts about alarm symbols and status symbols, which were unknown to them.

5.3.3. Q3 – Symbol modifications

The interviewees reported some issues regarding their understanding of the symbols' meaning (Q3.1). Interviewee #5 complained about the low level of intuitiveness of "Railroad accident," interviewee #6 suggested using "a tiny little house with an enormously amount of snow on the roof" to show "Heavy snowfall," whereas interviewee #3 compared our modifications with the symbol style used in Germany (Deutsches Institut für Normung, 2012) and concluded:

> What matters is being determined and consistent, that the layout has a definition, and that actors in emergency preparedness use the same set of symbols. The more similar the symbol settings, the better.

Interviewee #4 noted that our modification of "Waiting place" resulted in a change of meaning, since the original symbol was used to show a waiting place only for members of task forces. The same interviewee also suggested differentiating between "Gathering place" for injured people and "Gathering place" for dead people. Interviewees #1 and #4 were confused by the use of two different symbol styles for events in any location and events at fixed locations. For instance, interviewee #4 said that there were inconsistences regarding the concepts symbolized as "at fixed location" and those symbolized as at any location, such as "Helicopter base" and "Airport," respectively.

In Q3.2, we asked whether the modifications made the grouping of symbols more distinct and made it easier to select a certain symbol. The general response was that whatever rule was used, it should always be used consistently. The interviewees seldom elaborated their responses to Q3.2. One exception was interviewee #1, who, despite agreeing with the division of objects at a fixed location and from anywhere, said that users might use those symbols contrariwise.

As other symbol modifications would be feasible, we asked about that in Q3.3. Interviewee #1 was against further modifications, since too many symbols with a more complex structure "will be too complicated [...] It needs to be kept simple. Your three main

categories are sufficient, [they are] manageable and still simple." The same perspective was expressed by interviewee #2, who said that the symbols "should not be too complicated and require a lot of training to use." When asked about the German approach (Deutsches Institut für Normung, 2012), the same interviewee concluded that such a complex division "requires time to learn the meaning of the different shapes and will be forgotten soon." An interesting suggestion was made by interviewee #5, who said that for further modifications, "perhaps it would be a good idea to follow the logic being used for road signs." Another valued suggestion was made by interviewee #6, who noted that only one symbol from the "Risks" category was triangle shaped. Therefore, it might be a good idea to use the same shape for other symbols in the category to make them visually consistent. Interviewee #3 similarly referred to consistency and recommended seeking inspiration from the APP-6A NATO standard for military map symbols.

5.3.4. Q4 – Symbol differentiation

In Q4.1, we asked whether any symbols were more important than others and therefore needed to be highlighted visually. If the participant responded "yes," we subsequently asked (in Q4.2) about the best way to emphasize such symbols in visual form.

Although Interviewee #3 disagreed with Q4.1 and concluded: "I do not think any hierarchy is necessary," most of the interviewees agreed and had specific suggestions. Interviewee #1 noted that "perhaps not more important, but there are symbols that will be used more often." Interviewee #2 similarly responded that having a group of prioritized symbols could be a good idea, and provided an example: "a symbol for a fire could have a subset of symbols associated, so those who need to make maps during an event would be able to find the symbols needed to handle that situation." Interviewee #4 claimed that the symbol for "Operational information" in the "Operations" category was the most important symbol. Moreover, the same interviewee pointed out several other symbols that seemed to be particularly important, such as the symbols for the positions of various task units, the position of the command post, and wind conditions. Interviewee #5 declared that "sector-specific needs" influenced the perception of privileged symbols relating to the health sector, such as ambulance car and ambulance helicopter, as well as doctors, pharmacies, and defibrillators (AED). However, the same interviewee stated "[I am] not sure if they need to be particularly available or emphasized in maps."

Regarding emphasizing the symbols, apart from color (interviewee #5), size was considered as another visual variable (Bertin, 1967) suitable to make symbols visible (interviewees #1 and #2). According to interviewee #6, "it may happen that some symbols may drown" (meaning they might be rendered less visible). Therefore, modifying symbol sizes could help to differentiate symbols that represent different priorities.

In the final question, Q4.3, we wanted to learn of any other reasons than hierarchy that could be of importance to symbol differentiation. Interviewee #6 noted that the importance of a symbol could depend on the phase of an operation, when "some symbols are needed more than others and thus are more important [and therefore] perhaps it would be wise for you to work through some scenarios and to see how the use of the symbols would work in an event." Interviewee #5, who represented a medical service, said that it would be of value to their sector to color symbols based on the emergency level of the assignment, such that "the color emphasizes the importance or priority of a response."

6. Post-interviews symbol revisions and discussion

6.1. The final revision of the symbols

We used suggestions collected during the interviews to revise symbols. The outcome of the final revision was 135 symbols (Figure 5). Circles, houses, and diamonds were used as the leading frame shapes for "Reporting and context," squares for "Operations," and pentagons for "Infrastructure." The "Visibility" subcategory was added to "Reporting and context," while the subcategories "Emergency call centers," "Alarm signals," and "Status" were removed from the set. Moreover, several default and suggested symbols were removed from the set during the final revision. For example, we removed the symbols for "Forest fire," "Freezing rain," "and "Snowmobile." We added seven new symbols, which included: three symbols for three levels of visibility, "Evacuated relatives center," "Avalanche," "Water pump," and "Damaged fiber-optic infrastructure." Lastly, we used a numeral grouping system to organize the set and make it easier for users to gain an overview of all symbols.

Apart from the above practical outcomes of our study, the meetings and interviews resulted in three generic summarizing points: (1) symbol development as a collaborative process; (2) the importance of the "keep it simple" principle; and (3) the difference between symbol standardization and symbol

harmonization. Moreover, the suggested set of symbols needs to be evaluated with a large number of individuals, for example, in a test emergency situation. Such a follow up empirical study is planned in combination with the testing of the operational functionality of map support. The latter issue, after the symbol design, is the second primary aspect of our project.

6.2. Symbol development as a collaborative process

Our study addressed three of the four challenges of map symbols for crisis mapping determined by Kostelnick and Hoeniges (2019), namely taxonomy development, symbol design issues, and standardization of symbols within and among organizations. The main observation that arises from our results is a lack of common perceptions of the symbols among organizations. Some overlapping thoughts and remarks appeared, yet most comments were different and multifaceted, which we believe was a result of the interviewees representing different sectors with specific needs to be reflected in contextual cartographic design (Griffin et al., 2017).

The tasks of emergency agencies evolve, in the same way as their duties and information needs evolve. Therefore, one cannot expect users to provide designers with ready-to-use symbol suggestions. It is evident that the development of emergency symbols to be used by various agencies is a collaborative and never-ending process that requires designing across map use contexts (Griffin et al., 2017). Our findings support those from the study conducted by Robinson et al. (2012), namely that the symbol development is a collaborative and time-consuming process, in which the elicitation of symbol suggestions is triggered by discussing symbol proposals with users. Although we used several steps to ensure the success of the final version of our symbols, many suggestions for further modifications were collected during the interviews. Therefore, an optimal symbol set should be treated as an "asymptote," an aim one may approach but not achieve. Hence, our lesson learned is that no matter how much time and efforts one uses to develop interagency emergency symbols, there will always be suggestions for further modifications.

6.3. The importance of the "keep it simple" principle

It is essential to find a compromise between the individual needs of collaborating agencies in terms of required map symbols and the among-agencies needs resulting from their mutual expectations, which means the need for an awareness of other agencies' symbol needs. In the context of a common COP, while a given emergency responder may need several specific map symbols to represent their own resources on a common map, others may think differently and wish to keep the symbols of collaborating agencies as sparse as possible. Therefore, the "keep it simple" principle seems to play a substantial role when developing a common operational symbol set. Although the principle has been elicited by Tufte (1983), based on his research on graphical integrity in data visualization, his suggestion of "when in doubt, always keep is simple" can be applied to visual representations of any kind. Keeping emergency map symbols simple and using only necessary symbols will not only save time and the analytical capacity of collaborating agencies, but it will also make the symbols easily understandable by a wide audience of collaborating agencies.

There are also two other practical implications of our research. The first is conceptual consistency meaning that map symbols need to conceptually correspond to each other, across various emergency services, for example, the concept of "station" (ambulance station, fire station, police station). Hence, for every additional service, one can use the template "<service name> station." The second practical implication is commonly known in the literature (Kostelnick & Hoeniges, 2019; Ratajski, 1971) and concerns the use of common graphical elements in a symbol set. In our case, examples include such elements as car, officer head, or roof.

It is naïve to believe that a fixed and standardized set of map symbols, such as the standardized set of military map marking symbols in use by NATO, can be designed for other contexts than military such as map-based COPs used in diverse and multifaceted civil emergencies. Since the "civil" purposes may be much more heterogenous than the military, a certain level of flexibility needs to be kept regarding symbol design, due to various users who have different priorities and who, typically, would like to "always keep it simple." Any suggestion to increase the numbers of symbols needs to be considered carefully. Fewer symbols for representing several entities does not prevent a map display from suffering from visual clutter (Ellis & Dix, 2007). Either way, the entities will need to be represented on the map. The only difference will be that the entities will be visually encoded by means of fewer map symbols. Another solution is to move overlapped symbols out of a cluttered map area. For example, according to the standard NATO APP-6 (North Atlantic Treaty Organization, 2017), if a group of objects is at one

1. Reporting and context

1.1 Events

- 1.1.1 Origin marking
- 1.1.2 Origin marking at fixed location
- 1.1.3 Event
- 1.1.4 Event at fixed location
- 1.1.5 Fire
- 1.1.6 Fire at fixed location
- 1.1.7 Explosion
- 1.1.8 Explosion at fixed location
- 1.1.9 Chemical accident
- 1.1.10 Chemical accident at fixed location
- 1.1.11 Railroad accident
- 1.1.12 Car accident
- 1.1.13 Aviation accident
- 1.1.14 Ship accident
- 1.1.15 Man overboard

1.2 Risks

- 1.2.1 Danger
- 1.2.2 Dangerous cargo
- 1.2.3 ADR (Dangerous cargo 2)
- 1.2.4 Explosives
- 1.2.5 Radioactive

1.3 Natural disasters

- 1.3.1 Landslide
- 1.3.2 Flood
- 1.3.3 Avalanche

1.4 Wind

- 1.4.1 Strong wind E
- 1.4.2 Strong wind NE
- 1.4.3 Strong wind N
- 1.4.4 Strong wind NW
- 1.4.5 Strong wind W
- 1.4.6 Strong wind SW
- 1.4.7 Strong wind S
- 1.4.8 Strong wind SE

1.5 Visibility

- 1.5.1 Moderate visibility
- 1.5.2 Poor visibility
- 1.5.3 Very poor visibility

2. Operations

2.1 Operational information

- 2.1.1 Checkpoint
- 2.1.2 Checkpoint 2
- 2.1.3 Command post
- 2.1.4 Operational manager command post
- 2.1.5 Waiting place
- 2.1.6 Meeting place
- 2.1.7 Survivor
- 2.1.8 Gathering place
- 2.1.9 Public gathering
- 2.1.10 Evacuated relatives center
- 2.1.11 Information
- 2.1.12 Depot
- 2.1.13 Other resources
- 2.1.14 Crisis accommodation
- 2.1.15 Distribution of water and food
- 2.1.16 Roadblock natural causes
- 2.1.17 Roadblock human activity
- 2.1.18 Damaged building
- 2.1.19 Damaged road
- 2.1.20 Damaged railroad
- 2.1.21 Damaged water infrastructure
- 2.1.22 Damaged power infrastructure
- 2.1.23 Damaged fiber-optic infrastructure

2.2 PES* – Police

- 2.2.1 Police
- 2.2.2 Police station
- 2.2.3 Police car
- 2.2.4 Police boat
- 2.2.5 Police helicopter
- 2.2.6 Policeman
- 2.2.7 Police team
- 2.2.8 Plain-clothed police officer
- 2.2.9 Armed policeman
- 2.2.10 Policeman with motorcycle
- 2.2.11 Policeman with bicycle
- 2.2.12 Mounted police
- 2.2.13 Policeman with dog
- 2.2.14 Policeman with snowmobile

2.3 PES* – Fire service

- 2.3.1 Fire service
- 2.3.2 Fire station
- 2.3.3 Fire engine
- 2.3.4 Turntable ladder
- 2.3.5 Firefighting vessel
- 2.3.6 Firefighting aircraft
- 2.3.7 Firefighting helicopter
- 2.3.8 Firefighter
- 2.3.9 Firefighter team
- 2.3.10 Fire hydrant
- 2.3.11 Ground hydrant
- 2.3.12 Water pump

2.4 PES* – Medical service

- 2.4.1 Hospital
- 2.4.2 First aid station
- 2.4.3 Medical office
- 2.4.4 Ambulance station
- 2.4.5 Ambulance checkpoint
- 2.4.6 Ambulance car
- 2.4.7 Medical car
- 2.4.8 Medical boat
- 2.4.9 Ambulance aircraft
- 2.4.10 Ambulance helicopter
- 2.4.11 Doctor
- 2.4.12 Pharmacy
- 2.4.13 AED

2.5 SES – Civil defense**

- 2.5.1 Civil defense
- 2.5.2 Civil defense staff
- 2.5.3 Civil defense rescue dog

2.6 SES – Military**

- 2.6.1 Military
- 2.6.2 Military camp
- 2.6.3 Soldier
- 2.6.4 Military unit
- 2.6.5 Military equipment

3. Infrastructure

3.1 Telecommunication

- 3.1.1 Communication installation
- 3.1.2 Communication stationary
- 3.1.3 Communication mobile

3.2 Services

- 3.2.1 Diving service
- 3.2.2 Chemical diving
- 3.2.3 Workshop
- 3.2.4 Plumbier
- 3.2.5 Electrician

3.3 Transport – Land

- 3.3.1 Train station
- 3.3.2 Gas / fuel
- 3.3.3 Parking lot

3.4 Transport – Water

- 3.4.1 Wharf
- 3.4.2 Lifeboat
- 3.4.3 Anchorage
- 3.4.4 Shipwrecks
- 3.4.5 Car ferry
- 3.4.6 Passenger ship

3.5 Transport – Air

- 3.5.1 Airport
- 3.5.2 Heliport
- 3.5.3 Helicopter base
- 3.5.4 Gas station for helicopters

3.6 Tourism and sport

- 3.6.1 Health sports facilities outside
- 3.6.2 Health sports facilities inside
- 3.6.3 Sports hall
- 3.6.4 Drinking water sources
- 3.6.5 Small cabin

3.7 Protected areas

- 3.7.1 Sami cultural heritage
- 3.7.2 Cultural heritage
- 3.7.3 Protected buildings
- 3.7.4 Ancient heritage
- 3.7.5 Habitat biotope

* PES – Primary Emergency Service
** SES – Supportive Emergency Service

Figure 5. The set of 135 symbols resulting from the post-interviews revision.

location, object grouping can be applied. Then, map symbols are enclosed on a map using a bracket and their exact location is indicated by a line from the center of the bracket. Furthermore, NATO APP-6 does not provide absolute symbol dimensions. Instead, it determines relative symbol frame sizes. Therefore, to indicate precise symbol location or to reduce visual clutter in an area with multiple objects, map symbols can be reduced in size. Although similar approaches as those implemented in NATO APP-6 may be used for emergency symbols, their empirical verification would be necessary to elaborate on their effectiveness.

6.4. Symbol standardization or symbol harmonization?

Although symbol standards exist, such as the APP-6 NATO standard and the Civil Protection Common Map Symbology (https://www.ordnancesurvey.co.uk/support/symbols-for-emergencies.html), standardizing emergency map symbols to be used by multiple agencies is a hardly feasible task. While standardized symbols are used in a very specific contexts, such as military operations in the case of the NATO APP-6 standard, by specific user groups with defined tasks and purposes, and on maps at specific scales and with specific design rules (Hershey, 2012), emergency map symbols are used by various agencies, with diverse tasks conducted using maps at various scales (Robinson et al., 2011) and with various background layers. Therefore, the term "symbol standardization" used in previous studies of map symbols for crisis mapping (e.g. Bianchetti et al., 2012; Kostelnick & Hoeniges, 2019; Robinson et al., 2012, 2011) seems to be debatable. One may claim that the term "symbol harmonization" better reflects the efforts of designing a repository of common operation emergency map symbols. Standardization makes all the things of one particular type the same as each other; it implies full-scale adoption of things, with no changes. While harmonization is the process of making, for example, two or more systems or sets of rules more similar, so that they work better together.[1] Harmonization implies general adoption with some minor modifications to fit a particular situation.

The map symbol design cube shown in Figure 6 conceptualizes the difference between considered map symbol standardization and symbol harmonization. In addition to the three dimensions included in Figure 6, there are other aspects that relate to the map symbol design such as cultural issues that need to be addressed regardless of whether symbol standardization or harmonization is to be done. Furthermore, varying habits of emergency responders across country boundaries may

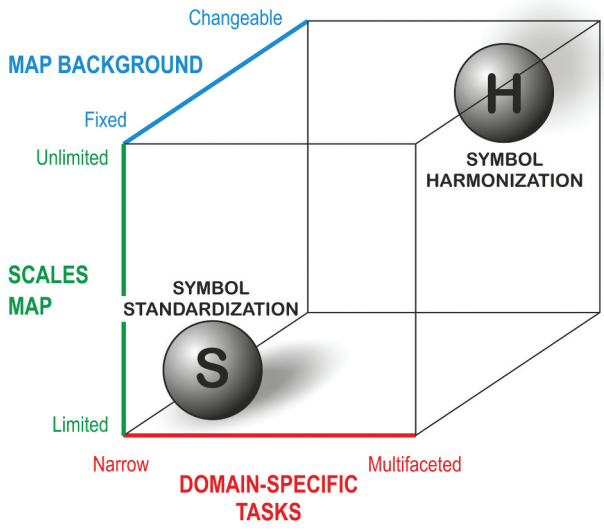

Figure 6. The difference between the process of map symbol standardization and harmonization.

have even stronger practical implications in symbol design than cultural issues (Peters et al., 2013). We think that standardization is feasible regarding a narrow context, such as NATO military purposes, demining (Kostelnick et al., 2008), the transport of dangerous goods (Friedmannová, 2010), and economic management and planning efforts (Ratajski, 1971), in which map scales are limited, a background layer is fixed, and domain-specific tasks are clear. By contrast, symbol harmonization is the process to be used if background maps are changeable, map scales can shift freely, and domain-specific tasks are multifaceted.

In the context of cartographic symbology, both standardization and harmonization could occur within a domain or across domains. Therefore, harmonizing a set of emergency map symbols can be achieved through making similar different sets of symbols that are needed by various agencies and are of importance to their specific tasks. For example, while a given agency may need only one abstract symbol such as "firefighter" to be used on a medium-scale map to visually encode a variety of the agency's field teams, another agency may need several exact symbols such as "policeman with motorbike" or "policeman with dog" that represent different types of field teams on a large-scale map. Hence, although the symbols of the two agencies can be harmonized visually, for example, by using the same colors or the same frame shapes, their standardization regarding their concepts seems to be unfeasible due to their different purposes and contexts. Another example is the use of "officer heads" to symbolize command posts on a medium-scale map. Then, the use of "officer heads" does not mean that all

engaged agencies need to have such a symbol in their symbol repositories, but only those agencies that need it. Similarly, there is "police helicopter" and "ambulance helicopter," but there is no "fire service helicopter" in Norway, and therefore having such a symbol in a repository would be useless.

Another aspect concerns how harmonization can be achieved to satisfy cultural or environmental contexts. As symbol harmonization allows mapmakers to keep some flexibility in symbol design, addressing cultural issues seems to be more feasible in harmonization than in standardization. Examples include the design of the symbol for a Red Cross vehicle that, for Islamic countries, can be replaced by the symbol of a Red Crescent vehicle. In such a case, the symbol frame shape, color, and the vehicle component are kept. However, the symbol's leading graphical element is altered from cross to crescent. In another example, hazard symbols can share the same frame shape and color, but they can be supplemented by specific variants, depending on geographic and environmental context such as spots of permafrost erosion or risk of freezing rain.

The uniqueness of various crisis actions such as an oil spill removal or a quick-clay landslide requires different actor configurations, which prioritize different information and display it differently. As such, organizing customized map symbol sets regarding different crisis situations seems to be a reasonable approach, as agencies are provided with necessary harmonized symbols but are not overloaded with those symbols, which although included in the set, can be omitted.

7. Conclusions

Meetings with stakeholders and interviews with software producers were conducted to elicit user needs regarding emergency map symbols for COPs for Norwegian emergency responders. The needs were conceptualized in the alterations of the emergency map symbols provided by the Norwegian Mapping Authority. As a result, we grouped the symbols into three categories: "Reporting and context," "Operations," and "Infrastructure." Furthermore, we added 39 new symbols and modified 49 symbols that were already in the set. The revisited set of symbols was subsequently shown to stakeholders who were interviewed to collect their feedback on the modifications. Thereafter, we used the collected feedback to make the revision, which resulted in the final set of 135 symbols.

Although the modifications were generally approved by the interviewees, task-specific needs and the range of mapping scales turned out to be the two main factors influencing the lack of a common perception of proposed emergency map symbols and thus, the lack of an agreement regarding symbol details such as symbol meaning, style, and grouping. The task-specific needs of a given emergency agency result in a focus on those map symbols that are of primary importance to the domain of which the agency is a part. The range of mapping scales implies the need for symbols to be used at various levels of abstraction, for example, levels that can symbolize several objects at once on a medium-scale map, but that can also represent exact objects on a large-scale map.

The development of emergency map symbols for multiple agencies should be termed harmonization rather than standardization. Symbol harmonization leads to a common set of emergency map symbols, yet symbol diversity is to certain degree feasible, meaning that collaborating agencies can, to some extent, retain their own symbolization preferences and priorities.

Notes

1. https://www.ldoceonline.com/dictionary/harmonize, access date 2021.06.17.
2. Federal Geographic Data Committee Homeland Security Working Group.

Acknowledgments

This study was conducted as part of the INSITU project that is funded by the Research Council of Norway (grant no 295848). Some parts of this article have been based on the work in progress paper published in the ISCRAM 2020 conference proceedings (Opach, T., Rød, J. K., Munkvold, B. E., Radianti, J., Steen-Tveit, K. & Grottenberg, L. O. (2020). Map-based interfaces for common operational picture. *Proceedings of the International Conference on Information Systems for Crisis Response and Management*, 506–516.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the project "Sharing incident and threat information for common situational understanding" (INSITU), funded by the Research Council of Norway's SAMRISK program on societal security and safety [Grant number NRC 295848].

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [T.O.]. Transcribed interviews used in our study are not publicly available due to their containing information that could compromise the privacy of interviewees.

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