Why technology not always adds value to crisis managers during crisis: The case of the Dutch nation-wide crisis management system LCMS

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ABSTRACT

Technology undeniably plays an important role in supporting crisis managers to respond to crisis. However, when improperly designed or used, technology can be ineffective or even be detrimental to the crisis response. Therefore, in this paper we bring together insights from the scientific literature and identify 5 principles for the design and use of technology to aid crisis managers effectively. These principles might seem trivial but there are several examples of technology used in practice that show the opposite. To illustrate this, we examine as a case study the Dutch nation-wide crisis management system LCMS which is used in the Netherlands by all safety regions and other public organizations to maintain and share a common operational picture supporting large-scale crisis management collaboration. We explain why crisis evaluations and research time and again show that LCMS has failed to add value for crisis managers during crisis by using the identified principles. Implications for practice and research are provided.

Keywords

Technology, crisis management, decision making, situation assessment, decision support system, LCMS.

INTRODUCTION

Scholars have pointed to the important role that (information) technology plays in supporting crisis managers to prepare for and respond during crisis (Comfort, 1993; Comfort et al. 2001; Ho & Kapucu, 2016). A few decades ago, Comfort (1993) identified three core functions that technology could play for crisis managers. First, technology allows the creation of interactive network for crisis managers, enabling communication and focusing attention on the same problem at the same time. Second, technology allows the development of a knowledge base for a given professional community, which can be used by crisis managers to make informed decisions. Third, technology supports the representation of information in graphic form and thereby simplifying complex data and increasing the speed and accuracy of the communication.

Now decades later, these core functions still remain valid, although advances in technology have spawned new applications. However, as we argue in this paper, when improperly designed or used, technology can be useless or even be detrimental to the response to crisis. The aim of this paper is to discuss why technology sometimes does not live up to the expectations. Therefore, in this paper we bring together insights from the scientific crisis literature and identify 5 principles for the design and use of technology to aid crisis managers effectively. These principles might seem obvious, but in practice there are several examples that show that they are not always considered when developing or introducing new technology for crisis managers. To illustrate this point, we use as a case study the Dutch nation-wide crisis management system LCMS which is used in the Netherlands by all safety regions and other public organizations to maintain and share a common operational picture supporting large-scale crisis management collaboration. In this paper we explain why crisis evaluations (e.g. Scholtens et al. 2015; Van Zanten et al. 2017; 2019) and research (e.g. Treurniet & Wolbers, 2020) time and again show that LCMS failed to add value for crisis managers during crisis by using the identified principles.

This paper is organized as follows. First, we will discuss LCMS and its functionality in more detail. Second, in

the research methodology, we will explain how we identified the principles and what data sources we used to compile our case study. Third, we will discuss the principles that we have identified based on the scientific crisis literature and discuss how they relate to our case study. Fourth, we conclude with the implications of our research for future research and practice.

DUTCH NATION-WIDE CRISIS MANAGEMENT SYSTEM LCMS IN A NUTSHELL

LCMS is a nation-wide crisis management system in the Netherlands to maintain and share a common operational picture supporting large scale intra- and inter-organizational crisis management collaboration. LCMS is used by all 25 safety regions, national and local water authorities, military police and emergency health care organizations. LCMS is aimed at supporting intra- and inter-organizational decision-making during crisis by facilitating the development of an up-to-date, consistent and common operational picture. LCMS can be used to share information within an organization as well as between organizations (LCMS, 2020).

LCMS provides several functionalities. First, is offers the situation picture which can be regarded as the heart of LCMS (LCMS, 2020). This picture gives a quick overview of all relevant information from and for all actors and organizations involved. It consists of a textual and geographical part. LCMS Text is developed for composing and arranging a coherent, clear and actual situational picture. To support information managers, the default content of the textual fields includes a number of themes that are typically deemed relevant in crisis management. This includes meteorological information, safety and emergency workers and victim overview. LCMS Plot is created to build and maintain a geographical picture of the situation. For each participating team a separate drawing layer is available (LCMS, 2020).

RESEARCH METHODOLOGY

Literature review

The five principles are derived from a literature review in which we examined two streams of research.

The first stream of research consists of Naturalistic Decision Making or NDM studies (Lipshitz et al. 2001; Klein, 2008; Schraagen & Van de Ven, 2008; 2011; Zsambok & Klein, 2014). NDM examines how experienced people make decisions under complex and challenging conditions such as uncertainty and time pressure. It is based on research in amongst others firefighting, aviation, rail, oil and gas, combat operations and medicine. NDM differs from traditional research on decision making in that it looks how decisions are made in practice (e.g. by putting decision makers in environments that closely resemble the reality of a crisis or investigating decision making during real crisis by conducting interviews and applying the critical decision method of Klein et al. 1989) as opposed to studying decision making in laboratory settings. NDM also differs from research on user interface and usability design which is usually concerned with questions like 'can the user make the tool do what it is intended to do?' (e.g. Tan et al. 2020). Although this is undeniably an important condition for technology to be effective, NDM goes further and considers whether technology actually helps crisis managers to make better decisions about the crisis response.

In particular, we devoted attention to the scientific literature related to four primary NDM theories that, to our knowledge, have been used extensively to describe and explain decision making during crisis: Recognition-primed decision making (Klein, 2009), Endsley's theory of situation awareness (Endsley, 1995), macrocognition and sensemaking (Schraagen et al. 2008) and distributed decision making models (Rasmussen et al. 1991). These theories are well documented in the scientific literature including implications to the use of technology. Reviewing these theories led to the identification of principle 1 (Technology supporting crisis response should also be regularly used before the crisis), principle 2 (Technology should help crisis managers to better make sense of already available data), principle 3 (Technology should support crisis managers distributed way of decision making) and principle 4 (New technology for crisis managers should reduce or keep cognitive task demands at the same level).

The second stream of research is concerned with the body of knowledge related to self-reliance of citizens and first responders during crisis. As research has shown that the effectiveness of crisis response and disaster relief activities significantly relies on the self-reliance of citizens (e.g. Helsloot & Ruitenberg, 2004), we argue that technology should take emergent behavior of citizens into account and preferably enhance it.

We have collected relevant scientific literature in several ways. First, we used search engine scholar.google.com by combining various search terms such as 'technology', 'information technology', 'information systems', 'naturalistic decision making', 'crisis management' and 'self-reliance'. Second, we used the same search terms to search the databases of relevant journals, such as the ISCRAM proceedings, Journal of Contingencies and Crisis

Management and Human Factors. Third, we obtained a number of relevant papers by looking in the reference list of papers found after applying search method 1 and 2. We used the following inclusion criteria. Included papers must be published in a peer-reviewed journal, conference proceedings or book Since technology is a broad concept, we have mainly focused on information systems and crisis management systems aimed at supporting crisis managers or teams.

Case study

LCMS was selected for the case study as both authors have acquired much experience with observing exercises and evaluating real events in which the system was used. We used Google's search engine to collect data about the functioning of LCMS during exercises and real events. We applied (combinations of) the following search terms: 'LCMS', 'crisis', 'crisis management', 'evaluation LCMS' and 'information management'. We included the following data sources: publicly available internal evaluations (e.g. conducted by safety region) and publicly available external evaluations (e.g. conducted by the Dutch Safety Inspectorate or a consultancy firm).

PRINCIPLES FOR EFFECTIVE TECHNOLOGY DURING CRISIS

Based on the scientific crisis literature we identified 5 principles that technology should meet in order to aid crisis managers during crisis effectively. These principles are not new but they have not been brought together as such. Since technology is a broad concept, the focus in this section lies on information and crisis management systems aimed at supporting crisis managers and teams. Every principle will be used to explain why (internal and external) evaluations show that LCMS in many cases adds little value for crisis managers. Examples of these evaluations including illustrative citations are provided per principle.

Principle #1: Technology supporting crisis response should also be regularly used before the crisis

NDM research has shown time and again that crisis managers tend to fall back on ingrained behavior during crisis (Lipshitz et al. 2001; Zsambok & Klein, 2014). Likewise, based on analysis on many large-scale emergencies, disasters and crises, Scholtens (2007) points out that crisis managers are likely to revert to what is standard practice when time is of the essence. This is also true for the technology crisis managers will use in the response to crisis. A good example is the use of WhatsApp. Crisis evaluations show that this technology is widely used by crisis managers including crisis management teams (Boin et al. 2020; Van Duin et al. 2019). Even though sometimes dedicated crisis information sharing platforms exist (e.g. LCMS), crisis managers tend to use what they are familiar with on a day to day basis.

LCMS does not comply with this principle because the system is only (rarely) used by crisis managers during a major emergency, disaster or crisis. It should therefore come as no surprise that many evaluations show that LCMS is not (properly) used during (the initial phase of the) crisis or that it does not work because of technical issues. Table 1 provides a few examples. Evaluations show that crisis managers forget to fill or maintain LCMS with relevant data, do not always look into the system to collect the latest information or stick to communication means that they use on a daily basis such as telephone or radio.

Year	Evaluation	Example
2019	Veiligheidsregio Zuid-Limburg (2019) (internal evaluation)	*"In the first phase of the incident and prior to the first meeting of the operational crisis management team it provided difficult for the crisis communication process to obtain basic information. LCMS was not filled. As a consequence, crisis communication was not issued on time"* *"Members from different teams expressed their amazement at the failure of LCMS plot on mobile devices such as iPads"*
2015	COT Instituut voor Veiligheids- en Crisismanagement (2016) (external evaluation)	*"To support crisis management, the National Crisis Management System (LCMS) is used for information management. In this situation LCMS has been used differently. For example, the system was not used by the emergency dispatch center, while one of the action centers had recorded the results of an inventory of capacity at hospitals in the region in LCMS."*
2011	Veiligheidsregio Zuid-Holland-Zuid (2011) (internal evaluation)	*"In addition, many things were coordinated via mobile telephony, which meant that not everything could always be logged and / or included in the LCMS."*
2011	Inspectie Openbare Orde en Veiligheid (2011a) (external evaluation)	*"Information management is not unambiguously dealt with during the handling of the incident. Some organizations cannot access LCMS. Other organizations that are connected do not use it or only make limited use of it. Information also becomes available*

		too late or is not shared."
2017	Van Zanten et al. (2017) (external evaluation)	*"Interviewees of the crisis management team indicate that they have made limited use of the possibility to look in LCMS"*
2012	Veiligheidsregio Utrecht (2012) (internal evaluation)	*"The strategic crisis management team used information from LCMS but did not add any information or decisions into the system. The contribution of the strategic crisis management team was hence not shared with other teams."* *During the exercise, information was directly exchanged verbally by various officials. This information was not shared with the team in all cases, nor was it recorded (in LCMS or otherwise)."*
2015	Scholtens et al. (2015) (external evaluation)	*"The crisis team also did not take notice of the advice written down in LCMS"*
2011	Inspectie Openbare Orde en Veiligheid (2011b) (external evaluation)	*"According to the safety region, LCMS contains insufficient and outdated information. Because it is not possible to get in touch by telephone or via LCMS, the Rotterdan-Rijnmond safety region sends a liaison to the area."*

Table 1: Examples of evaluations addressing principle 1.

It should be noted that this finding is not restricted to the Netherlands of LCMS. For instance, based on research in the Unites States, Ho & Kapucu (2016) observe that during crisis crisis managers tend to use the technologies they are used to use. The authors state that despite the rapid growth of new technologies, phone calls and face-to-face meetings remain the prominent communication channels used by the majority of crisis managers.

Principle #2: Technology should help crisis managers to better make sense of already available data

Uncertainty is a defining characteristic of crisis and therefore crisis managers need to deal with it when responding to crisis (Boin et al. 2016). Often enabled by technology, one commonly used approach to reduce uncertainty is to gather more information and to disseminate it across the response network. Consider, for instance, the use of drones mounted with cameras by some Dutch fire brigades. This approach of gathering more information may work well for some types of uncertainty, but for others it can increase uncertainty and reduce performance (Klein, 2009). Klein (2009) argues that gathering more information does not work in cases where uncertainty is caused by either a lack of trust (can I trust the information I receive?), conflicting information (what information is true?) and lack of understanding (what does the information mean?). And even if uncertainty is caused by simply not having the required information, gathering more information can be risky and lead to information overload. For instance, Marusich et al. (2016) found in several experiments that increased task-relevant volume did not improve task performance. In one of the experiment, the authors even found that task-relevant information volume reduced self-reported situational awareness and led to poorer task performance and situation awareness (Marusich et al. 2016). Therefore, as Klein (2009) points out, in complex environments it is not about gathering more information but to find ways to better understand the information that is already available.

Technology can help to better make sense of available data but it also can make it worse (Klein, 2009). As just discussed, technology should take into account and prevent the risk of information overload, that is to flood crisis managers with information which is not relevant for the task at hand. Therefore technology should be designed in such a way that it prevents the provision of too much and irrelevant information to crisis managers.

LCMS does not fully comply with this principle. Although the use of LCMS does not necessarily has to lead to information overload, evaluations show that information noted in LCMS often does not help to get a common operational picture. Wolbers & Boersma (2013) studied the use of LCMS and stress that the development of a shared understanding of the situation requires more than simply assembling and presenting information from various response organizations into LCMS. According to Wolbers & Boersma (2013), information shared by response organizations is not univocal and a shared understanding of the situation only emerges when the different organizations take time to provide their interpretation of the information and negotiate its relevance for others. Notably, this process of jointly interpreting information and negotiating the relevance for others takes considerable time which often is not available in the first few chaotic hours of crisis (Scholtens et al. 2014).

Table 2 provides some examples of evaluations that indicate that LCMS did not support in a better understanding of the available information. It shows that crisis managers are sometimes confused by the relevance or accuracy of information which sometimes led to a lack of confidence.

Year	**Evaluation**	**Example**

2011	Veiligheidsregio Zuid-Holland-Zuid (2011) (internal evaluation)	*"In the operational crisis management team, information in the LCMS was not always timely validated. As a result, the use of the wrong substance name was not timely noticed and corrected later."* *"In addition, many things were coordinated via mobile telephony, which meant that not everything could always be logged and / or included in the LCMS."*
2015	Scholtens et al. (2015) (external evaluation)	*"The examination of LCMS shows that information is usually inconsistent, multi-interpretable and not always correct. This means that the sharing of crucial information within the crisis organization should not be done electronically. Crucial information must be transferred from person to person."*
2019	Witteveen & Bos (2019) (external evaluation)	*"During the preparation of this evaluation, it appeared that the LCMS repeatedly contained incorrect data and was therefore not always a reliable source for drawing up the facts afterwards.* *"In the initial phase of the calamity, the LCMS was partly fed with opinions, facts and decisions. It was soon established that the category of opinions does not belong in the LCMS and can be disruptive"*
2012	Veiligheidsregio Utrecht (2012) (internal evaluation)	*"For all teams, the information from LCMS has not always been validated and analyzed for its significance for the team in question. The participants were not comfortable with the information in LCMS. Due to the large amount of (sometimes brief) information, the relevance of the teams involved was difficult to assess."*
2015	Inspectie Openbare Orde en Veiligheid (2016) (external evaluation)	*"The national crisis management center creates a national incident in LCMS, which contains general information (e.g. contact details). However, an unambiguous (national) picture of the nature, extent, effects and possible duration of the power failure has not been established."*
2012	Veiligheidsregio Groningen (2012) (internal evaluation)	*"De period of high water showed that during long lasting incidents too much information is added to LCMS. This makes it very difficult to keep pace with the actual information. This did not help in the decision making process."*
2017	Van Zanten et al. (2017) (external evaluation)	*"Interviewees from the operational crisis management team indicate that they have the impression that their information was insufficiently visible at the tactical crisis management team. In addition, the interviewees indicated that the speed in meetings and the amount of information made it difficult to fill LCMS properly and at the same time look at the additions of others."*

Table 2: Examples of evaluations addressing principle 2.

Principle #3: Technology should support crisis managers distributed way of decision making

A common assumption within crisis management is that it is possible to provide crisis managers at different levels (operational, tactical and strategic) within and between organizations with a common operational picture of the scene of the event. Technology is increasingly used to facilitate the development of a shared understanding of the situation at the scene of the event. LCMS is one example but there are more. Comfort et al. (2002) for instance report on the use of an university-wide information and collaboration system in the USA for emergencies and crises. According to the authors, this tool is aimed at increasing both the technical and organizational capacity to manage timely, accurate information exchange within and among organizations.

However, research has questioned the assumption underlying these tools and consequently the need to develop technologies that facilitate the development of a common operational picture (Scholtens, 2008; Helsloot, 2008; Groenendaal et al. 2013). First and most importantly, Scholtens (2008) points out on the basis of numerous evaluations of large emergencies and crises that crisis managers work well together in the majority of cases, even if coordination and a common operational picture are lacking.

Second, Helsloot (2008) and Scholtens et al. (2014) emphasize that in the first chaotic phase of the crisis, crisis managers often do not have much time to share information with others within and outside their organization, as this is often at the expense of the already scarce time available to fulfill the primary tasks such as extinguishing the fire, providing emergency care to casualties or restoring the public order.

Third, the presence of a common operational picture does not necessarily result in or improve collaboration at the front line. Groenendaal et al. (2013) note that the extent to which crisis managers can be controlled by front line commanders is structurally overestimated by both practitioners and scholars. Even if front line commanders would have an actual common operational picture they often lack the ability to hierarchically direct the response efforts accordingly (Groenendaal et al. 2013; Groenendaal & Helsloot, 2016; Groenendaal & Helsloot, 2018).

Fourth, researchers are skeptical about the extent to which remote tactical and strategic crisis management teams are able to make meaningful decisions based on the operational information provided by the crisis managers at the front line (Scholtens, 2008; Helsloot, 2008; Groenendaal et al. 2013). Treurniet & Wolbers (2020) for instance

emphasize that information acquired by crisis managers, as well as the uncertainty inherent in that information, cannot always be codified in time or in sufficient detail to provide the remote tactical strategic crisis management teams with input for decision making.

By referring to distributed decision-making theory (DDM), Scholtens (2008) therefore argues that information systems should exist not to develop common operational pictures or to keep central crisis management teams informed, but to help decentralized crisis managers carry out their tasks. Groenendaal et al. (2013) proposed to apply the concept of stigmergy to crisis management, which is a form of self-organizing, bottom-up coordination in which activities are neither centrally controlled nor locally supervised; it is generated by placing signs and modifying the environment. Both concepts – DDM and stigmergy – emphasize the importance of supporting local decision making rather than enhancing central coordination and hence the need for a common operational picture.

LCMS is not particularly aimed at supporting local decision making. Its objective is to facilitate the development of a common operational picture which can be used to centrally coordinate the response rather than enhance local decision making. As a consequence, it does not comply with principle 3.

Principle #4: New technology for crisis managers should reduce or keep cognitive task demands at the same level

Generally crisis managers do not benefit from new technologies that increase cognitive task demands during crisis (McLennen et al. 2007; Mosier, 2008; Mosier et al. 2012; Zsambok & Klein, 2014). Militello et al. (2015) point out that newly introduced technology should never distract crisis managers from the unfolding situation as this may disrupt their ability to build and maintain situational awareness. The authors stress that it is important to avoid developing software tools that engage and distract users from their task at hand or interfere with other tools already be used. Therefore, the fourth principle implies that new technology (or features of it) should integrate with or replace existing technologies as much as possible in order to reduce the chance that its use will increase cognitive task demands of crisis managers during crisis.

LCMS does not meet this principle as it is used in the Netherlands as an additional technology which only comes into play when multidisciplinary coordination is deemed necessary. LCMS is used on top of other technologies that are used on a daily basis by emergency response organizations to communicate and document information. Table 3 provides a few examples. Consequently, the use of LCMS by crisis managers is likely to increase the cognitive task demands which might negatively impact their ability to build and maintain a proper situational understanding.

Year	Evaluation	Example
2015	Scholtens et al. (2015) (external evaluation)	*"During the incident three different information systems have been used: LCMS, LiveJournaal and an internal chatbox."* *"Due to the chaos, the police was already completely occupied with filling its own internal systems, so that the multidisciplinary system LCMS was not adequately filled and used in this case either."*
2018	Van Zanten et al. (2019) (external evaluation)	*"The different participants in the crisis organization use different information systems. For example, several water managers used LCMS in addition to the sitrap module for net-centric work. Because these two information systems were used side by side, information was not always updated synchronously and sometimes archived twice. In addition to the use of the sitrap module and LCMS, a lot of information was also received by telephone and email."*
2013	Veiligheidsregio Twente (2013) (internal evaluation)	*"Users indicate that they have little capabilities to use LCMS effectively. In addition, questions are being raised regarding the added value of LCMS. To fill the system with data, to read everything and to use it seems to be an aim in itself."*

Table 3: Examples of evaluations addressing principle 4.

Principle #5: Technology should consider and preferably enhance self-reliant behavior of citizens

That ordinary citizens are self-reliant and also assist others during crisis is generally accepted within the disaster and crisis management community (Quarantelli, 1997; Perry & Lindell, 2013; Helsloot & Ruitenberg, 2014). In fact, the literature even shows that the effectiveness of the crisis response depends to a large extent on self-reliance and the assistance provided by ordinary citizens (Scholtens & Groenendaal, 2011; Helsloot et al. 2014; Scanlon et al. 2014). Jurgens & Helsloot (2018) provide several examples of how citizens themselves use technology to foster community resilience before, during and after crisis. Scanlon et al. (2014) even go a step further and emphasize that helping citizens should be able to be connected to the response network and thus be given a formal

position. As a consequence, we argue that crisis response technology should take into account the fact that citizens are highly self-reliant and tend to provide assistance to response organizations or other fellow citizens if needed.

LCMS does not cater for ordinary citizens and organizations that provide spontaneous support during large-scale emergencies, disasters and crises. This was also recognized by the state appointed committee that evaluated the Dutch law on safety regions (see table 5). The committee emphasized that information management should take into account actors who fall outside the official authority structures and suggested that LCMS should facilitate this.

Year	Evaluation	Example
2020	Evaluatiecommissie Wet veiligheidsregio's (2020) (external evaluation)	*"Although information management is a constant point of attention in many evaluations of crisis and disasters, organizations and institutions involved in the provision of care are increasingly sharing information. However, current practices do not provide for identifying and bringing together actors who fall outside the authority structures.*

Table 4: Examples of evaluations addressing principle 5

DISCUSSION AND CONCLUSION

Technology such as information and crisis management systems can provide ample opportunities to support crisis managers and teams in their crisis response efforts. However, technology is not a panacea that can solve all issues in crisis management. As Klein (2009) notes, the use of technology during crisis helps us to pass some barriers but introduces others. Technology is not an end it itself – it must be a solution to a problem since every piece of new technology also introduces new challenges and issues that need to be overcome.

In this paper we presented 5 principles derived from the scientific crisis literature and used them to explain why LCMS according to numerous evaluations does not add much value to crisis managers. First, LCMS is not used on a day to day basis and therefore it can be no surprise that it is not used (properly) during crisis. Second, evaluations show that crisis managers are often constrained by the information provided by LCMS as it is outdated, not correct or open to multiple interpretations. Consequently, LCMS does not help crisis managers to make better sense of the information that is already available. Third, LCMS is based on the wrong assumption that it is possible to develop and maintain a common operational picture during crisis and that crisis managers need this understanding to work effectively (together). Fourth, as LCMS is an technology on top of already existing technologies, it is likely to increases task work load instead of reducing it. This makes it more difficult for crisis managers to maintain their understanding of the situation. Fifth and finally, LCMS does not facilitate the adoption of self-reliant behavior of citizens and organizations while there is much evidence that they should get a position in the crisis response effort.

As the principles identified in this research are based on existing research and hence not new, the question can be raised why they are not embedded in the design of information and crisis management systems such as LCMS. We think that there are several reasons for this. It could well be that designers of information systems are mainly focused on designing systems that meet the needs of certain targets group (e.g. information managers) without looking into whether the underlying goal (i.e. better crisis response) is also achieved. Another reason may be that information systems are initially designed in accordance with the five principles, but that concessions have been made during implementation and rollout or the system is not used as designed so that much of its effectiveness is lost. Finally, we know that it takes a while before scientific knowledge about crisis management is adopted in practice. Exemplary is the scientific knowledge base about citizen response during crisis which is still not always reflected in the plans of professional emergency organizations (Scanlon et al. 2014).

The practical implications of our findings are twofold. First, the principles identified in this research can be used (together with other and more generic user interface and usability principles) by developers of crisis information systems and other technology to design tools that actually facilitate and improve crisis management decision making by crisis managers and teams. Second, developers and users of the LCMS technology can use the principles to ensure that LCMS will contribute more to the effectiveness of crisis management. For instance, developers could think about ways to integrate LCMS in other tools that are used by crisis managers on a daily basis. Or invent new features that enable information managers to integrate emergent behavior of ordinary citizens.

Our research also provides starting points for further research. First, we encourage researchers to investigate more thoroughly how technology benefits the effectiveness of the crisis response. This means that researchers need to go further than just asking direct users of technology whether the tool has been helpful for doing their work. We recommend that scholars also consider the extent to which tooling leads to better decision making by crisis managers and ultimately better crisis management. For instance, this can be done by interviewing frontline personnel about the quality of orders they received from a crisis management team that used a crisis information

tooling. Second, we recommend researchers to aid the development of technology by following the principles identified in this paper. This implies for instance designing and testing technology that takes into account human factors (e.g. heuristics and biases related to information processing and decision making) and the distributed way of decision making during the first few hours of crisis.

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