Enablers in Crisis Information Management: A Literature Review

No-San Lee
University of Cologne
lee@wim.uni-koeln.de

Stefan Hirschmeier
University of Cologne
hirschmeier@wim.uni-koeln.de

Sven Müller
University of Cologne
mueller@wim.uni-koeln.de

Lars Jürgen Luz
University of Cologne
luzl@smail.uni-koeln.de

Abstract

Social media often plays a central role in crisis informatics as it is an important source for assessing, understanding, and locating crises quickly and accurately. In addition, social media enables actors to react more effectively and efficiently when managing crises. However, enablers of crisis information management have not been carved out explicitly in a systematic view. Therefore, we perform a literature review to synthesize the existing literature on crisis information management with a focus on technical enablers and their classification into the crisis-management phases. As our results show, searching for crisis informatics mostly results in social media-related publications. We found that Twitter is one of the most important technical enablers but that research on other social media platforms is underrepresented. Also, most publications center on the post-crisis phases of crisis management, leaving out the pre-crisis phases.

1. Introduction

Crisis informatics has made significant advancements over the last few years, emerging as a major topic in information systems (IS) research. Our research shows that a main reason for this increased scholarly attention is that social media has produced numerous enablers for managing information during crises. Numerous studies have been published in dedicated conferences and journals over the last several years, and major IS conferences have recently designed specific tracks on crisis informatics. The multifaceted nature of this particular literature stream has recently brought some literature reviews to the scene focusing on different aspects of crisis informatics, such as communication barriers [22], collective behavior [21], etc.

With respect to technical enablers, social media often plays a central role in crisis informatics as it has become be an important source for assessing, understanding, and locating crises quickly and accurately. More than that, it enables actors to react more effectively and more efficiently when managing crises. While this enabling function is the underlying reason for the majority of papers in this area, it is almost never stated explicitly. Therefore, we see technical enablers (e.g., social media), used alone or in combination with associated technologies and methods, as a catalyzer to improve or increase the performance and capabilities of users, applications, and processes in crisis information management.

However, enablers of crisis information management have not been carved out explicitly in a systematic view. To address this issue, we perform a literature review to synthesize the existing literature on crisis information management with a focus on technical enablers. Our review can be understood as a complement to Fischer et al.'s [22] review, which focuses on communication barriers. In our review, we intend to find clusters of publications and elicit key findings about enablers for every one of them. Hence, we formulate the following research question:

RQ: Which technical enablers can be found in crisis information management, and which crisis-management phases they relate to?

The remainder of this paper is structured as follows: In the next section, we construct a theoretical framework for our analysis. Therein, we address three parts of the framework as a theoretical background – namely, crisis-management phases, crisis responders, and crisis information enablers. On this basis, we perform our literature analysis, the method for which we explain in Section 3. In Section 4, we present our findings and the aggregated clusters of relevant literature. In the last section, we discuss our results and the limitations of the work.

2. Theoretical background and framework

The aim of this section is to develop an analysis framework that we use to conduct our literature review. We base our framework on a theoretical background similar to Fischer et al. [22]. We first characterize a theoretical foundation of crisis-management phases and then describe the actors

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involved. In the last part of our framework, we develop a structure for the technical enablers we want to examine.

2.1. Disaster informatics and crisis informatics

Many synonyms have been used in the literature for crises, among them disaster, emergency, and catastrophe. In IS research, not only one but two terms – crisis informatics and disaster informatics – emerged over the last decade and were used interchangeably. A clear distinction between crisis informatics and disaster informatics has not been drawn yet as in most contexts, there has been no need to do so. In this review, we treat crisis informatics and disaster informatics as synonyms. Still, we will perform initially separate searches on crisis informatics and disaster informatics in order to state the popularity of the terms.

2.2. Crisis-management lifecycle

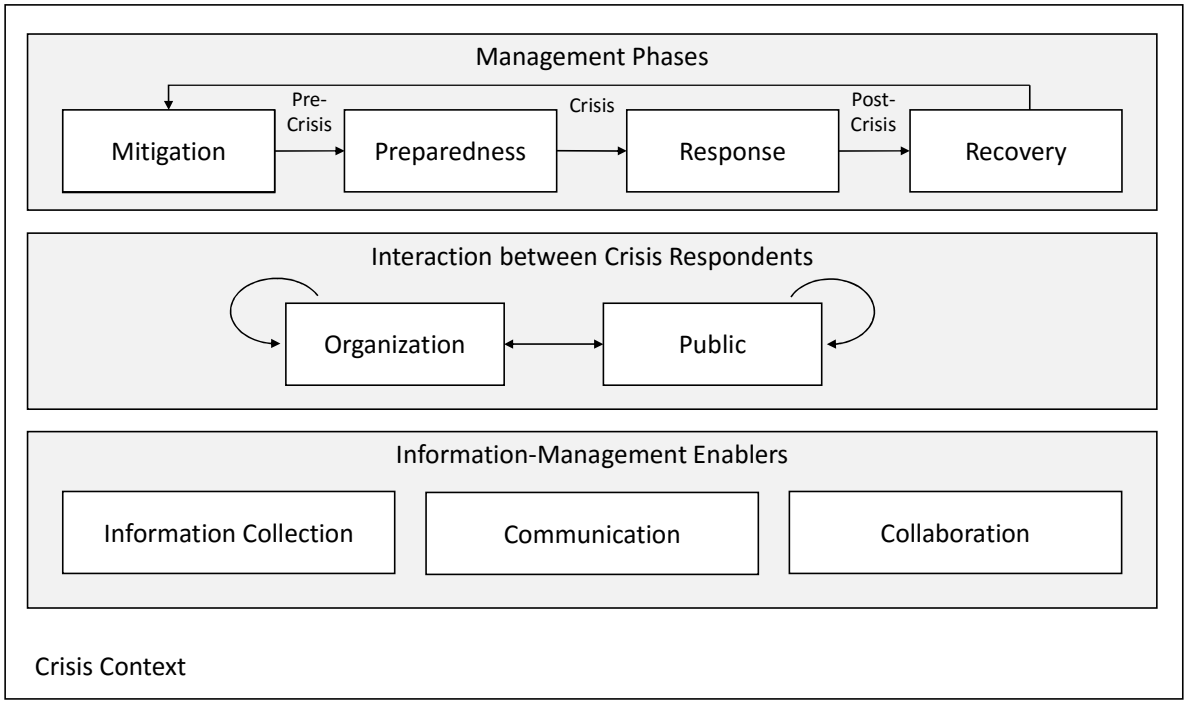
The research on crisis management has brought up several approaches for dividing and breaking down a catastrophe into several phases (e.g., the eight socio-temporal stages of disaster [67, 71, 87]). In addition to this breakdown of a crisis into phases, crisis management has also been modeled into phases. In the literature, we find a consensus on four time-oriented phases for crisis management [36, 45, 51, 54]: mitigation, preparedness, response, and recovery. In this time-oriented view, mitigation and preparedness are pre-crisis phases, and response and recovery are post-crisis phases.

Mitigation is a preventive phase and "consists of the efforts/actions aimed to minimize the degree of risk, to prevent disasters and to reduce the vulnerability of both the ecosystem and social system" [45] (see also [2, 14, 51]). Its objective is to develop "sustained measures to reduce or eliminate risks and impacts associated with natural and human-induced disasters" [36].

As the second phase, preparedness "involves actions to prepare responders and common people to post-disaster activities" [45]. Its objective is the "development of effective policies, procedures and capacities to plans [*sic*] for how best [to] manage an emergency" [36].

The response phase "consists of actions to manage and control the various effects of disaster (also the ripple effects) and minimize human and property losses" [45]. Examples for actions during the response phase [43, 72] are evacuation [98], sheltering [73], medical care, search and rescue, and damage control.

Figure 1. Literature Review Framework



The last phase, recovery, "consists of those actions that bring the disrupted area back to an often improved normal condition" [45] (see also [55]). According to Hawacha, it covers the "efforts taken to repair and restore a community following an emergency" [36].

2.3. Information-management enablers

As a second layer of the framework, we focus on the interactions between crisis respondents – namely, organizations and the public. Organizations include relief organizations, government agencies, fire and rescue services, medical assistance, police, and all other crisis-response organizations. The public comprises witnesses, victims, volunteers, and other people affected by a crisis event [22]. In the third layer, we intend to structure the area of crisis informatics into subareas in order to follow a systematic approach to our literature review and classify enablers. A breakdown of crisis informatics into subareas has not emerged so far (at least we did not identify any structure of subareas that would be widely accepted in the community). As an ad hoc approach to divide crisis informatics into smaller areas, we propose to distinguish three areas of information management – 1) information collection, 2) communication, and 3) collaboration – and justify them as follows: 1) Information collection refers to one-way communication. The main purpose is not to communicate, but to gather information, for example, from social media, and to understand what is going on. In contrast, 2) considers two-way communication and 3) considers two-way collaboration between crisis responders, either within crisis-response organizations (intra- and inter-organizational); between organizations and the public; or between members of the public. To emphasize levels of communication, we separate communication from collaboration as this distinction is regularly done in computer-supported cooperative work, which leads to the justification of 2) and 3). Our triple may also be underpinned by major IS research areas as there is 1) information extraction (IE), 2) computer-mediated communication (CMC), and 3) computer-supported cooperative work (CSCW).

2.4. Framework construction

Based on the theoretical background, we construct our research framework in the style of Fischer et al. [22], who provided one of the most recent literature reviews in the field of crisis informatics. In Figure 1, the arrows between the management phases depict the lifecycle of crisis management. The middle layer shows that we limit our perspective to communication within organizations, across organizations, between organizations and public, and within the public. However, we do not classify the responders involved.

Table 1. Search Terms and Number of Hits

	Crisis Informatics	Disaster Informatics	Crisis Informatics or Disaster Informatics
Science Direct	16	13	24
ProQuest	92	61	141
ACM	68	29	75
Web of Science	99	175	253

3. Methodology

Many approaches can be found on how to obtain a relevant literature set for a review. A common way is to start an extensive search and then sort the literature using several screening steps, such as relevance screening, format screening, research design screening, and quality screening. Instead of narrowing down the literature set iteratively from a thousand publications, we chose a different approach. We first identified an initial literature set that exactly matched the search terms "crisis informatics" or "disaster informatics" in order to obtain papers that were part of the crisis informatics literature. Using this approach, we risk losing literature from the emerging years of crisis informatics, but we were willing to accept this as the term was coined 10 years ago [30], and we decided to include newer studies in favor of older work. On the other hand, we obtained an initial literature set of 1,046 publications referred to crisis informatics and disaster informatics (see Table 1). After a manual screening of the titles, keywords and abstracts of the papers we found, we obtained a core set of 104 papers.

Using this literature core, we performed a forward and backward search, as proposed by Webster and Watson [102]. To this extended literature set, we applied 1) a format screen, filtering out non-journal and non-conference works; 2) a research design screen, filtering out studies that do not refer to IS research; and 3) a quality screen, filtering out works that do not include the roles of organizations and the public. We ended up adding 158 papers through the backward search and 190 papers through he forward search, leading to a set of 452 papers.

In a third step, we narrowed the extended set down again by excluding papers written before 2006 that might have come into the set through the forward and backward searches and considering citations levels. We sorted the remaining publications by citation level and took the top 40 from the literature core, 30 from the backward search, and 30 from the forward search. We performed an in-depth analysis of the full-text on the remaining 100 publications and excluded 16 publications as a result. In consideration of the most recent literature reviews [21, 22], we added 5 publications which we identified as pertinent, ending up with 89 publications in our review.

4. Review results

Our aim was to identify clusters of publications, and, for each cluster, to generate a finding about enablers. To identify enablers or findings about enablers, we applied a qualitative content analysis based on deductive categories [53]. We manually identified 10 clusters, which we present in Table 2, and explain the findings afterwards. In some cases, we identified enablers directly; in other cases, we generated findings about the enablers. When enablers were relevant for several clusters, we associated and presented the enablers with the most relevant cluster in order to avoid multiple descriptions of the same thing and to emphasize primary associations.

Considering the crisis-management phases, in Table 2, multiple attributions were made when

Table 2. Crisis Informatics Literature Classification Framework

	Clusters of Publications	Mitigation	Preparedness	Response	Recovery
Information Collection	Social media data mining			[1, 9, 10, 60]	[1, 6, 10]
	Social media-based event and crisis recognition		[3, 11, 44, 80]	[3, 11, 38, 74]	[38]
	Social media-based location recognition			[24, 37, 48, 61, 86, 89]	[24, 61, 86, 89]
Communication	Detection of misinformation in social media			[28, 29, 56, 63, 69, 97]	
	Improved situational awareness through Twitter analysis		[5]	[5, 62, 99, 100, 105]	
	Crisis communication to and within the public		[57]	[4, 32, 34, 47, 49, 52, 65, 66, 67, 75, 87, 90, 92, 94, 96, 103]	[34, 47, 67, 85]
	Organizational use of communication systems		[39, 41]	[13, 15, 18, 23, 25, 33, 39, 40, 41, 79, 83, 84]	[17, 23, 35, 81, 88, 104]
Collaboration	Collaboration systems for volunteers and organizations		[82]	[8, 12, 16, 19, 26, 42, 50, 58, 59, 64, 76, 77, 91, 93, 95]	[59, 64, 91, 93, 95]
	Collective sensemaking			[31, 68, 70, 71, 101]	[31]
	Map mashup and crowdsourcing of volunteered geographic information			[27, 46, 78, 106]	[27, 46, 78, 106]

necessary. In Section 4.4, we present two further findings.

4.1. Information collection

Finding 1: ***Social media data mining*** serves as an enabler allowing people to react quickly to certain (usually predefined) conditions and recognize the needs of helpers and affected persons ideally in real-time [6]. Furthermore, the analysis of past content can be used to improve methods and serves as a research enabler [10]. The social media data mining enabler covers all methods that enable the analysis of certain content-based criteria and aspects. The methods comprise, among other things, keyword comparison [1, 9], text coding [6, 60], and sentiment analysis [9, 10]. Publications in this area also cover the necessary infrastructure for social media data mining [1].

Finding 2: ***Crisis and event recognition*** might be seen as part of social media data mining, but it deserves separate attention as a lot of publications explicitly focus on event recognition. This enabler covers both the recognition of an arising crisis and, if the crisis in already in place, the recognition of important events during the crisis. Social media is considered to be a good information source as individuals in the immediate vicinity of a crisis are the ones that notice the event first and post messages on several platforms like Twitter, Facebook, Instagram, Flikr, or YouTube [38]. Social media can complement other data sources to enhance situational awareness [11]. In terms of early warnings, social media-based recognition offers the chance to announce the crisis more quickly than traditional methods, forming an enabler for crisis information management. This area of investigation aims towards real-time recognition of events [80].

Finding 3: In addition to event recognition, ***location recognition*** is another enabler in social media analysis worth separate attention. In this area of investigation, the aim is to automatically extract and analyze location information in social media to create social media-enriched crisis maps to identify or predict location clusters [24], or to identify related messages by keyword comparison [37]. This covers unconscious behaviors, such as the attachment of geographical information (e.g., names of cities, street, places, or points of interest) within textual messages [24, 37, 48, 86]. This automated extraction, analysis and evaluation of relevant, credible, and actionable location data is a remarkable enabler [89].

4.2. Crisis communication

Finding 4: The ***identification of false information*** is a major enabler in crisis information management as, traditionally, it is almost impossible to get a grip on the dissemination of false information. Several approaches propose how to identify the believability of social media content [29, 97] in order to understand where and how to intervene and respond with correct information. Some publications also examine how the believability of social media content can be supported [69].

Finding 5: ***Situational awareness*** describes an idealized condition within a crisis event to recognize and understand relevant information and actors [100]. This idealized condition and its point of view "is helpful for anticipating how individuals, groups and communities can use information contributed by others in a social media context" [100].

Computer-supported decisions, which often have to be made regularly under time pressure, serve as an enabler to limit the impact of a crisis. Publications in this area focus on the observation and analysis of situational awareness of modern communications systems, especially social media, and also investigate the question of how to achieve and support situational awareness. Researchers in this cluster generally agree that (near real-time) analysis of Twitter information is the best enabler for improved situational awareness [5, 62, 99, 100, 105] as "sifting valuable information from social media provides useful insight into time-critical situations for emergency officers to understand the impact of hazards and act on emergency responses in a timely manner" [105].

Finding 6: ***Communication to and within the public*** is one of the most researched areas in crisis informatics. Many publications are case studies within the social media context [4, 32, 52, 65, 67, 75, 85, 87, 90, 92, 94, 96, 103]. Among the enablers mentioned, we found social media-related enablers like information and communication technology-enabled public self-organization through social media [66, 67] and social media as a "backchannel" [96] as well as media coverage [87] and information diffusion [92].

Finding 7: Within the publication cluster ***organizational use of communication systems***, availability of information is one of the main enablers. In classic communication channels, real-time information is generally neither available in real time nor provided by official personnel [41], but the usability of social media data is considered to be an enabler. However, the usability of data from the social media world has not been found to be sufficient [41] as of yet. We identified redundancy and system stability as a second enabler in this

cluster. As in the past, diverse cases about infrastructure failure were examined [15, 23, 25, 39, 40, 83, 84].

4.3. Crisis collaboration

Finding 8: ***Collaboration systems for volunteers and organizations*** cover a wide range of enablers. We found several systems with a different focus (e.g., systems for volunteers who are onsite [58] and systems for collaboration among individuals who are not locally involved [93]). We found the homogenization of mobile technology usage, data models, and infrastructure to be an enabler for collaboration [8, 12, 26]. Standalone systems, only addressing only part of the crisis and only usable by single responders, limit the ability to fully exploit the efficiencies of crisis management as a whole [19]. Because relief organizations often bring different technical resources to a crisis, covering software, data, or hardware that have been applied in conjunction beforehand, problems of interoperability can occur [16]. With respect to social media, we identified mobile collaboration to be the most important enabler [77].

Finding 9: ***Collective sensemaking*** is an often spontaneous, self-organized, collective process of analyzing the events within a crisis with the goal of understanding the situation or gathering information [101]. The main vehicle and enabler are infrastructural components, such as social media platforms, as they allow for information exchange and have a widespread smartphone infrastructure. We found numerous case studies, related to collective sensemaking that aim at describing collective behavior [68, 101].

Finding 10: ***Volunteered geographic information*** refers to the voluntary behavior of the public to use modern Web 2.0 technologies to create, collect assemble, and disseminate spatial data [46]. With ergonomic, simplified and user-friendly tools users are enabled to read and write maps [78, 106]. A *map mashup* is a possible result of this enabler, integrating several forms of information with spatial data in order to obtain insights about diverse relationships [46, 78]. In a crisis context, map mashups can be used to create valuable spatial data for organizations or the public that provides information about the place, local processes, or other important details [27, 78].

4.4 Macro-level findings

Finding 11: From Table 2, we see that most approaches and analyses refer to the ***response phase*** of the crisis-management lifecycle. Here, we concur with Dorasamy et al. [20] who state that most research explores the ***post-crisis phases***, especially the response phase.

Finding 12: The majority of our findings on enablers was related to the application, analysis, or use of ***social media***. In concrete examples, however, it was notable that most publications referred to ***Twitter***. In an analysis of average word frequency, we found Twitter in the first place (33) followed in great distance by Facebook (6), Flickr (3), and YouTube (1).

5. Summary, limitations, and implications for future research

In this paper, we identified 10 clusters of publications and contributed findings regarding enablers for crisis information management for every each. Most of the enablers we found were related to social media. Even though most publications discussed social media in a general way, a closer look reveals that the majority of papers focus on Twitter. Whereas the analysis of Twitter is promising as it provides easy access to data, ease of access should not be the primary motivation for choosing a research object. While most researchers identified Twitter as the most promising social media platform for crises, a clear imbalance in social media research can be seen. More research should also be done on other social media platforms and non-social media enablers. Likewise, most of the literature has focused on post-crisis phases. In order to identify enablers that are suitable for the pre-crisis phases, further research needs to be done. Promising contributions are likely to come from evaluating whether post-crisis enablers are found in pre-crisis phases as well and whether they have the same impact on crisis information management. For example, crisis communication to and within the public in the less-researched pre-crisis phases may benefit from post-crisis enablers like self-organization via social media, social media as a "backchannel," or media coverage.

Still, this review only focused on the enabling capabilities of social media, leaving out the flipside of social media. Therefore, it is important to note that the use of social media is controversially discussed in the literature as social media is not only seen as an opportunity but also a source of further problems. For example, social media infrastructure might be a catalyst for false information. In combination with source ambiguity and lack of transparency regarding who can and has posted what, social media may turn out to be dangerous, especially in the response phase [63]. Additionally, the integration and verification of

information generated in online forums is still a major challenge [7].

Our research methodology clearly has limitations. The chosen approach to filter out literature has drawbacks. In our format screen, we filtered out papers from less-important outlets, possibly ignoring expert communities. Also excluding publications under a certain citation threshold bears a similar risk. Still, our composition of papers from the original search and forward and backward searches of 30/40/30 can be called into question. Finally, as we only focused on the most prominent clusters, we also limited our view on the main topics from the past and possibly left out smaller or emerging topics. By making these choices, we accepted that we could have missed some papers that would have been relevant for this review.

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