Review

Social Networks in Crisis Management: a Concise Literature Review

Bashar Abboodi *, Salvatore Flavio Pileggi *, Gnana Bharathy *

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Review

Social Networks in Crisis Management: A Concise Literature Review

Bashar Abboodi [1,*], Salvatore Flavio Pileggi [1] and Gnana Bharathy [1]

School of Computer Science, Faculty of Information Technology and Engineering, University of Technology Sydney (Australia)

* Correspondence: bashar.abboodi@student.uts.edu.au

Abstract: This paper proposes a concise literature review aimed at identifying the current body of knowledge on the adoption of Social Networks in Crisis Management. The major input is a structured research question based on the initial reading around the topic. Before the recent pandemic, most literature has focused on local crises, with a relatively low number of exceptions. Additionally, self-organizing system are spontaneous established between people who are affected by a crisis. Among the identified challenges, there is the need to integrate official communication by emergency agencies with citizen-generated contents in a contest of credibility and trustworthiness. In certain cases, it has been reported a lack of specific competence, knowledge, and expertise, as well as a lack of sufficient policies and guidelines in the use of Social Networks. Those challenges need to be framed by considering the classic difficulties to provide timely and accurate information, to deal with fake news, unverified or misleading information, and information overload. Bridging major gaps though advanced analytics and AI-based technology is expected to provide a key contribution to establish and safely enable in practice an effective and efficient communication, to contrast dissonant mental models, which are often fostered by Social Networks, and to enable a shared situational awareness.

Keywords: social media; social networks; crisis management; mental model; situational awareness; disinformation; misinformation and fake news; infodemic; COVID-19

1. Introduction

Despite several different definitions, currently, there is no unique universally accepted definition for crisis, which may refer, among others, to disaster, emergency, and catastrophe [1]. [2] has defined crisis as an event which is been observed in time and space, where societies/communities face physical losses/damages/disruption of their functioning routine. [3] has classified crisis into natural and human made crises.

Crisis management is commonly understood as the process in which an organization and/or a government deals with an emergency [4] [5]. Crisis management is typically approached considering four different phases: mitigation, preparedness (prior to a crisis event), response, and recovery [4,5]. The mitigation phase aims to prevent the occurrence of a crisis event, as well as to mitigate known vulnerabilities inherent within the socio-economic systems. The preparedness phase explicitly targets enabling crisis managers and responders to act effectively [6]. In the response phase, responders act to prevent any further damage for ongoing issues, while during recovery, the focus is on restoring the pre-crisis state [6].

There is a tangible and increasing adoption of Social Media within the specific context of crisis management [7,8]. Indeed, Social Media have become an integral part of communication during crisis events, enabling effective real-time dissemination of relevant information [9,10].

Social Media has become an important communication channel for emergency agencies [11][12] to manage crisis [13]. Social Networks are used during crisis for information gathering [14], situation awareness [15][16], maintaining relationships [17], emotional support [18], volunteer coordination [19][20] and disseminating relevant information and providing advice and guidance [21]. For instance, Social Media were widely beneficial during the flood crisis in Queensland 2011 [22].

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In this research Social Media is defined within the specific context of crisis management as a socio-technical system that provides real-time information on the crisis and assists in protecting lives and properties [23]. Situation awareness is defined as being aware of what events unfolding around people and gaining an understanding of potential relevant information means to people in that specific moment and in the future [24]. A significant aspect of situation awareness is the gathering of data from a wide number of sources by crisis managers [25].

A mental model is defined as a cognitive model that people use to understand the world [26]. A mental model is shaped by various factors, including cultural, environmental, and social as well as people's experiences [27][28]. For instance, people use their personal experiences to develop their own models of understanding of the World and this influences their responses [29]. A shared mental model is useful in a multi-stakeholder context [30]. Shared mental models are about sharing information, knowledge, concepts, and word usage among individuals to achieve sufficient agreement among stakeholders [31].

In a complex environment, mental models are related to a systematic understanding and normally affect decision making as are a determinant on situational awareness [24]. Situation awareness is described as goal-oriented, and a goal-task analysis which was used to decide which data the users need to beware of, how the data needs are understood in relation to the goal, and what projections need to be established to reach these goals [24]. Further, situation awareness contributed to 88% of human error as people misunderstood the situation, and to avoid these errors, there is a need to develop a higher level of situation awareness [24].

The majority of the studies focused on the use of Social Media in crisis management in the United States [32], while there is a relatively limited number of studies in other countries or with a more generic focus.

Many organizations have invested in incorporating social media into their crisis response strategy [33]. It is important to observe how crisis management agencies currently leverage Social Networks to enhance both situational awareness and decision-making. Furthermore, Social Networks are a critical component of any emergency response and preparedness [34]. Government officials have turned to Social Media for various purposes, including information sharing and direct connection with citizens [34].

The Virtual Social Media Working Group (VSMWG) has been established by the US Department of Homeland Security Science and Technology Directorate [34], which focuses on providing guidance to emergency agencies on safe practices in using Social Media technologies [34]. There is a generic interest in understanding the relationship between Social Media and situational awareness in public safety [34]. Many authors emphasize that several organizations have not yet fully understood how to use Social Media to effectively communicate during a crisis [35] [36] [37] [38] [39].

Crisis Management is a relevant topic, which is often the object of review as well as of holistic and more specific discussion. This paper aims to provide a concise literature review on the adoption of Social Networks in the specific field of crisis management. In this context Social Networks and Social Media are used indistinctly.

Structure of the paper. The paper follows a classic structure including a discussion of methodological aspects (Section 2), an overview of the review conducted (Section 3) and a discussion of major findings (Section 4).

2. Methodology and Approach

This section outlines the methodological approach that has been adopted to provide a concise overview of the impact of Social Media on Crisis Management. This review has been conducted by following the typical methodological guidelines for performing a systematic literature review in Software Engineering [40].

The topic of the review is summarised by the Concept Map [41] [42] [43] depicted in Figure 1. Such a conceptualization is further developed and discussed in context as an outcome of the study conducted.

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That's a conceptualization of the initial research question: *how can a better situational awareness be achieved in a crisis management context?*

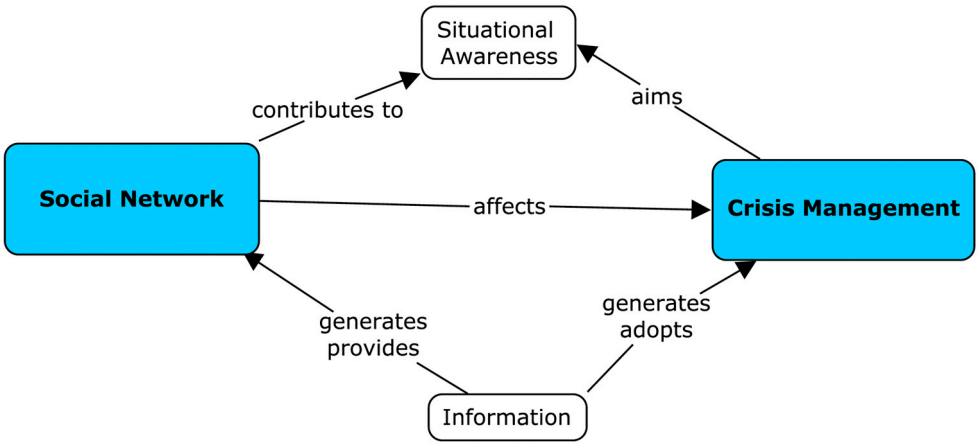

Figure 1. Initial Conceptual Map of the review topic.

According to the methodology adopted by [40], there is a need to define formal search criteria. This study is mainly based on peer reviewed papers, as well some relevant reports are referenced. They have been retrieved by performing multiple queries based on the combination of significant keywords in the field in the most popular databases and repositories. Finally, 100+ documents have been selected to be discussed in this concise review as a result of a critical assessment of the relevance in the context for the target research question.

3. Crisis Management & Social Network

By definition, emergency agencies play an influential and central role during emergency events [53]. The study conducted by [21] has explicitly focused on emergency agencies adopting Social Media, which are extensively used to push critical information, normally according to a one-way channel that does not include any feedback loop [54] [55]. Moreover, emergency management agencies have to enable effective and timely decisions to minimize damages [11] [56] [57].

Emergency agencies find out that the re-sharing feature on Twitter is the key mechanism to expanding the agency's visibility during the crisis [22] within a given community. Therefore, it is necessary for emergency agencies to push re-sharing more during a crisis [21]. Clear sentences with a specific focus have shown to be especially impactful on the public in terms of dissemination and influence [58].

Online Social Networks have become a significant channel in the context of crisis management, as they have played an important role to assist people during crises. For instance, Facebook has provided the "*I am safe*" functionality that allows individuals to inform their connections that they are safe in a given critical situation [59]. Safety check during crisis resulted to be an effective mechanism to enable Facebook users to notify their contacts list that they are safe [60].

Another clear example in literature is the early detection of bushfires in Australia that provides a holistic understanding of the problems facing emergency agencies during bushfires [61]. The data collected from IoT-based forest monitoring sensors [61] combined with data gathered from social media is able to provide emergency agencies with a complete picture of the crisis and enhance their knowledge-sharing processes [62] and decision-making mechanisms.

Social Networks are recognized to enhance situational awareness [45]. Recent studies [45] have contribute to consolidate a theoretical link between Social Media and situational awareness. The same study identified Twitter as the most popular platform used during the crisis [63].

However, there is a need for further research on the use of Social Media in crisis management to better develop situational awareness [64]. Indeed, in some cases, crisis managers are unable to coordinate crisis management strategies, due to the lack of situational awareness, which leads to poor decision-making [64]. The time and resources constraints push response agencies to make decisions

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in a continuously changing environment. It requires constant collection, analysis, and sharing of actionable information among the different agencies [65].

3.1. Information, Misinformation/Dis-Information and Fake News

While many studies have focused on the role of Social Media to improve the dissemination of critical information during crises (e.g. [66]), several contributions [67] [68] [69] [66] address the need for further research on di-information and mis-information, pointing out a relatively limited number of studies on the topic. Indeed, exactly like in everyday life scenarios, Social Media has contributed to create and disseminate false or misleading information [83] [84]. That is of course reason of increasing concern [74][83][75][84], as such phenomena may become especially critical during a crisis [76]. There are many socio-economic factors that could hinder the communication among social media users or generate unwanted patterns [85]. Among others, language barriers [86], lack of trust [87] and different cultural backgrounds [88][11] normally play a relevant role.

[67] examined the fast diffusion of rumours among the public and its consequent impact on the decision-making. For instance, it is the case of the earthquake in Ecuador in 2016 [74] [75].

In [67] and [70], the authors have focused on the need for early detection of rumours spread through Social Network and on the consequent need for a quick response based on verified updated information. However, it is evidently challenging and expensive, as it requires a highly active presence of emergency agencies on Social Media sites [71] [72] [69] [73].

According to [76], information exchanged via Social Media channels during the crisis, and also post-crisis, present a generic challenge in terms of trustworthiness and reliability, noted as the most complex challenge yet to face. Consequently, emergency agencies must disseminate trustworthy and accurate information as early as possible to address the uncertainty [76]. Such an activity needs to involve experts, government officials and emergency agency representatives. Overall, this is perceived as a challenge [14][15][77] and contributes to uncertainty and the enormous pressure the decision-makers in crisis face under time constraints [14]. It contributes to perceive Social Media channels as a treat inhibiting de facto to gain benefit [60].

Among the very many, [79] has suggested AI-based mechanisms to detect, verify and control rumours on online platforms to prevent the spread of fake news and unverified information [80][81], for instance trough prediction and verification [82].

The work in [89] reported a lack of credibility and trustworthiness in citizen-generated contents as the main barrier to use Social Media for emergency organisations. Additional possible barriers are lack of competence, including knowledge and expertise [89], as well as certain internal limitations within organisations, such as appropriate policies and guidelines on the use of Social Media in situations of crisis and a lack of awareness of potential benefits [89]. Emergency agencies normally base their decisions on information that is originated from trusted sources and vetted as credible according to the organisation standards and procedures [23]. That doesn't normally include 'The Wisdom of Crowds' [90].

3.2. Managing Information from Social Media

According to a study conducted by [93], the provision of real-time information via Social Media to emergency agencies provides an invaluable opportunity to enhance their overall performance in managing the crisis. In addition, the analysis of Social Media information is used to improve decision-making outcomes [15].

However, such an adoption implies several challenges. For instance, agencies are called to respond requests by highly heterogeneous communities [94]. Some studies [58] [22] have put emphasis on the difficulty to canalize the attention on information from authorities' sources, given a large volume of data generated by the public. It led to a need for a shift in thinking to develop experts system for crisis, which are expected to enable dialogical interaction to strengthen management capabilities [89].

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Finally, there is an intrinsic need to deal with information overload, understood as information produced and presented at rate too high to be correctly comprehended [91][92]. It sets a pressing need for an advanced computational support.

3.3. Situational Awareness

Various studies emphasise that organisations still do not fully understood how to communicate crisis information using social media [35] [36] [39]. This lack of understanding can lead to compromising the organisational competitive position and reputation [97]. The research conducted by [97] focuses on the increase in organisations' situational awareness to enable the organisation to gain better understanding of how organisation communicate crisis information to different stakeholders.

According to [89], Social Media contribute significantly to establish situational awareness, building social capital, and allow direct, rapid and wide communication with citizens and other agencies. [89] suggests that more research is needed to study the practices of dissemination of knowledge that contributes to situational awareness.

Crisis managers have often to deal with a high volume of information from different sources in order to maintain good situational awareness [99]. The study in [98] points out that decision-makers performance declines with the increase of the information load to be processed under time constraint.

Research clearly shows the role of Social Media that enable emergency responders, media outlets, and public health officials to communicate directly with the public [100] [101]. In case of acute public health crises, Social Media may play a central role to quickly disseminate information to the public on a large scale. For instance, in 2009 Alexandria Virginia health department effectively used Twitter to direct people to the vaccination sites during H1N1 outbreak [102]. Also, research shows the extensive use of Social Media during Ebola outbreak in West Africa [103].

Twitter is the most used platform [63], often adopted to detect and spread the most critical information in an efficient and accurate way to support situational awareness [63]. The public is often sharing useful real-time information in the affected areas, offering assistance to others, and requesting assistance from others [104]. More in general, Social Media enable 2-way provision of information [21].

In general terms, Social Media provide a solid support to communication [101][33] as shown in several situations. For instance during Hurricane Sandy period in 2012 [106] there were more than 20 million tweets sent[107][108]. During Thailand flood in 2011, information through traditional channels was slow and ambiguous, while Social Media established a more consistent and reliable two-way communication system [109].

[89] focuses on the potential of Social Media to facilitate citizen interactions, "help citizens to help others", with a potential to establish consistent self-organizing systems.

A consistent management of crisis is related to people mental models, that involve biases, experiences, beliefs and values of individuals [28,96]. Mental models are always subject to change in any dynamic environment [95] and play a critical role in decision-making.

3.4. Crisis Management, Decision Making and Technology

The main function of emergency agencies during a crisis is to enhance situational awareness and to inform the public to make the right informed decisions to increase the overall safety outcomes [111][112]. Normally, the decision-making processes occur within a multi-agency team in the crisis management context [113].

There is a relatively limited guidance in the literature to enable crisis mangers to select appropriate crisis response strategy [97] and crisis communication theories don't fully address Social Media [97]. A study reported in [97] adopted a qualitative approach to analyse multiple organisations in their use of Social Media in crisis. Situational crisis communication theory (SCCT) [114] has been used as a lens to analyse Facebook posts and Tweets [97]. Such generic-purpose platforms are also the most popular in situations of crisis in several countries, for instance Australia [114][115]. The

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study pointed out a potential [65] not fully exploited and a number of risks—i.e. for the reputation of a given organization for not being able to fully address issues on online platforms [97].

Social Networks are expected to play a relevant role in the current and next generation of systems for crisis management. However, at the best of our current knowledge, there is no exhaustive and well-defined analysis of the potential impact of cutting-edge technology, especially AI, to define the next generation of systems, which is expected to be extremely sophisticated. Such a potential is addressed in many different contributions but, overall, the big picture is still somehow missed. For instance, social bots have recently gained some popularity because of their potential to automatise alerts and messages by emergency agencies [116] [117] [118] [77]. Current research shows promising results when social bots are used retrospectively [77].

While it is implicitly assumed that most part of modern communication relies on Social Media, emergency agencies need to take specific steps to address rumours and non-accurate information. Advanced analytics [18] and AI-based technology [119] are expected to provide a key contribution to establish and safely enable in practice an effective and efficient communication.

3.5. Datasets

As part of the analysis conducted, we provide an overview of available resources in terms of datasets. Such an overview is not expected to be exhaustive but it rather aims to explicit ongoing efforts to establish a solid ground in the field.

Among the many available datasets on the occurrence, impact and management of natural disaster or related crises, we mention:

- *Global Disaster Alert and Coordination System* (GDACS), containing real-time information about natural disasters, including earthquakes, hurricanes, and floods.
- *National Oceanic and Atmospheric Administration* (NOAA) on severe weather events, such as tornadoes, thunderstorms, and hailstorms.
- *Emergency Events Database* (EM-DAT) on mass disasters.
- *US Federal Emergency Management Agency* (FEMA) on federal disaster declarations in the United States.
- *Global Historical Climatology Network* (GHCN) on historical weather data , which can be used to study trends in temperature, precipitation, and other climate variables.
- *Sentinel-1 Radar Imagery*, which provides radar imagery of the Earth's surface.
- *Global Forest Watch Fires* on wildfires worldwide.

In addition, the following datasets are tailored for Social Media related to natural disasters:

- *CrisisLex* (https://crisislex.org/data-collections.html) includes social media data related to natural disasters, such as tweets, images, and videos, as well as annotations related to the type of crisis and the type of information shared.
- *CrisisNLP* (https://crisisnlp.qcri.org/) includes social media data related to natural disasters, enriched by annotations and metadata.
- *Twitter Crisis Response Data* (https://crisislex.org/data-collections.html) includes tweets related to natural disasters, enriched by annotations and metadata.
- *Social Media and Emergency Management Data Toolkit* (https://tools.emergencymanagement.columbia.edu/) includes multiple datasets that contain data from Social Media related to natural disasters, including tweets and Facebook posts, as well as annotations and metadata.

Advanced technological approaches, such as Machine Learning and Social Network Analysis, become vital to enforce a sustainable crisis management [121].

4. Results

The analysis conducted has been elaborate and consolidated to (i) conceptualise the state of the art and outline possible future research, (ii) identify related gaps and major challenges, and (iii) extend the initial research question to establish a more structured approach. Those outcomes are presented separately in the following sib-sections.

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4.1. Conceptualisation of the Literature Review

A conceptualization of the analysis conducted is proposed in Figure 2. As extensively discussed, the generic potential role of Social Networks in a context of Crisis Management is well established and largely accepted.

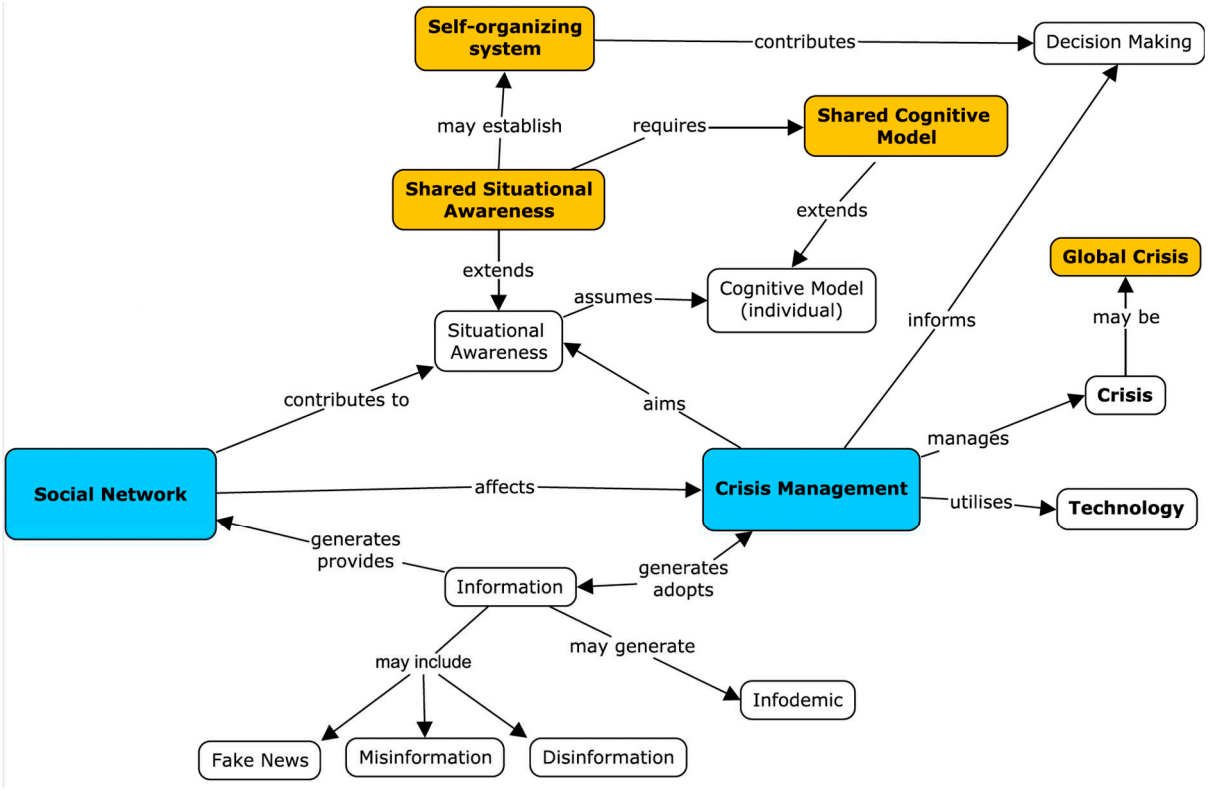

Figure 2. Conceptualization of the literature review.

There is an increase in the use of Social Network in such a context, mostly aimed at situational awareness [44]. At the same time, many studies noted that organisations are not always able to exploit the potentiality of Social Media [35][36][39].

While Social Media are recognised to contribute to situational awareness enhancement during crisis [45][63], they may also contribute to generate and propagate fake news, as well as, more in general, misleading information [15]. In this context, the relationship between cognitive load theory and misinformation [51] may play a key role, as people need to understand new information in a very short period of time and eventually take decisions and act accordingly. The key issue is the establishment of shared situational awareness to enable self-organising systems, to further enhance decision making [124][14].

Overall, the evolution of Crisis Management largely depends on the effective adoption of technology [115]. Cutting edge solutions based on IoT [61] and AI [47], both with the capability to manage large amount of heterogeneous data (e.g. from Social Media, geospatial, crowdsourcing, and sensors), are progressively enabling more capable strategies that assume a more and more consistent technological support (e.g. social bots [77][117,118]).

4.3. Gap Identification and Challenges

Many challenges have been identified. They are mostly related to:

- large volume of information exchanged via Social Media [76]
- uncertainty caused by the lack of reliable and trustworthy information [76]
- user-generated contents that don't meet the trust standards of the emergency agencies [15]
- lack of credibility and trustworthiness in the citizen-generated contents [89]

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- lack of competence and knowledge expertise [89]
- lack of sufficient policies and guidelines to use social media [89]
- fake news and unreliable information [80][83][84]
- information overload [92]
- lack of ability to provide timely and accurate information [105]
- lack of expertise to build self-organising systems using social media [89]
- fast diffusion of rumours among the public and its negative impact on the decision-making of the public [67][70]

These challenges need to be considered in context looking at potential mitigator factors, such as the "crowd wisdom" and self-organized groups [90]. A proper effective use of Social Media is expected to enhance the system in that direction. On the other side, exactly like in common everyday life scenarios, Social Media contribute to create and disseminate false or misleading information [83][84]. That is of course reason of increasing concern [74][83][75][84][125][126], as such phenomena may become especially critical during a crisis [76].

At the best of our current knowledge, there is no exhaustive and well-defined analysis of the potential impact of cutting-edge technology, especially AI, to define the next generation of systems which is expected to be extremely sophisticated. Such a potential is addressed in many different contributions but, overall, the big picture is still somehow missed. For instance, social bots have recently gained some popularity because of their potential to automatise alerts and messages by emergency agencies [77]. Current research shows promising results when social bots are used retrospectively [77].

The Covid 19 pandemic has shown additional concerning patterns as disinformation and misinformation switched from a local to a global context, generating an "infodemic" [128].

Consolidated research gaps and associated concepts are reported in Table 2.

Table 2. Research Gaps.

	Research Gap	Concept
G1	The capability to systematically retrieve information real-time as well as to generate effective analytics and predictive models is still a challenge [18].	*Information Retrieval/Analysis, Analytics, Predictive Models*
G2	There is no exhaustive and well-defined analysis of potential impact of cutting-edge technology, especially AI to define the next generation of systems [119].	*Cutting-edge technology, AI, next generation systems*
G3	Advanced Analytics and AI based technology are expected to provide a key contribution to establish and safely enable in practice an effective and efficient communication [18] [119].	*Advanced Analytics, AI*
G4	The well-known effect of Social Networks on dis-information, misinformation and fake news has an evident potentially higher impact on mental and cognitive models in exceptional situations such as crisis. Such aspects are currently object of study [130] [84].	*Mental model, cognitive model, mis-leading information, fake news*
G5	Dissonant mental models are often fostered by social networks at different levels (e.g. algorithms, influencers) which together undermine social cohesion and form barriers to shared situational awareness. To support effective crisis management there is a need to establish alignment of mental models and shared situational awareness, which is evidently a challenge [130] [131].	*Dissonant mental model, influencer, shared situational awareness*
G6	In general terms, there is an intrinsic need to early detect and properly deal with rumors and fake news. It becomes more and more critical and relevant in crisis management [79] [81]([82].	*Rumours*

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G7	There is a general lack of trust and effectiveness across mechanisms that strongly rely on social networks and the recent Covid-19 'infodemic' is a clear example [130].	*Trust, Infodemic, Global Crisis*
G8	The COVID 19 pandemic has unfortunately provided a kind of stress-test for our system. Lessons and, more in general, the experience and knowledge we are developing from the global crisis has not yet been fully translated into tangible general frameworks [130].	*Knowledge Management, Global Crisis*
G9	Managing a global crisis (e.g. a pandemic) is a complex process that involves many stakeholders to be effective. Shared situation awareness through some mental models alignment may play a critical role [130].	*Global Crisis, Shared Situation Awareness*
G10	There is a relatively limited knowledge about the public-to-public interaction during the crisis and on the impact of this self-organizing system [132] [76] [21].	*Self-organizing system*

4.4. Research Questions

A large number of research questions may be generated looking at the gaps and challenges previously discussed. Based on the conceptual analysis conducted, the initial research question has been elaborated and structured into two main generic research questions and a number of associated sub-questions. Main questions reflect research mainstreams according to a holistic perspective, while sub-questions define more specific research lines.

Table 1. Structured research questions resulting from the conceptual analysis conducted.

	Research Questions
RQ1	***How can a better shared situational awareness be achieved in a crisis management context?***
RQ1/a	*How can the use of social media and AI-based technology change cognitive models to develop a shared situational awareness during crisis?*
RQ1/b	*How can we establish alignment of individual cognitive models and shared situational awareness to support effective crisis management?*
RQ1/c	*What is the expected role of cutting-edge technology in the next generation of systems?*
RQ2/	***How can effective cognitive models be established during global crisis?***
RQ2/a	*What are the negative aspects of using social networks in a context of infodemic?*
RQ2/b	*How the public interact during the global crisis in term of information seeking and self-organizing?*
RQ2/c	*How can shared mental models be established in a global crisis?*

5. Conclusions

The purpose of this study is to identify the body of knowledge related to the nexus of Crisis Management and Social Networks by adopting a multi-perspective approach involving crisis managers, communication experts, and social network analysts.

The review indicates a potentially critical role of Social Networks in a context of crisis, as demonstrated by a tangible and measurable increase in the adoption in real-world situations, including local and global crisis. Crisis managers tend to incorporate Social Networks into situational awareness strategies, as they have been critical in assisting crisis agencies to formulate preparedness,

recovery, and response efforts. However, while the use of Social Media is assumed to be a consolidated practice, an effective and efficient use in the different crisis situations is still considered a challenge.

Situational awareness is a central concept that need to be understood in context, looking at a fluid and continuously changing environment in which information, mis-information and fake news are likely to co-exist. There is currently a relatively limited number of studies to assess the relationship between relevant situational awareness and cognitive models, as well as on the key factors to effectively establish a shared situational awareness.

Last but not least, the strong inequality still existing among the different countries [133] may be a serious discriminant in fact as real capabilities may significantly differ from country to country.

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