Crowdsourcing for collaborative crisis communication: a systematic review

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Abstract. *Efficient crisis response and support during emergency scenarios rely on collaborative communication channels. Effective communication between operational centers, civilian responders, and public institutions is vital. Crowdsourcing fosters communication and collaboration among a diverse public. The primary objective is to explore the state-of-the-art in crowdsourcing for collaborative crisis communication guided by a systematic literature review. The study selected 20 relevant papers published in the last decade. The findings highlight solutions to facilitate rapid emergency responses, promote seamless coordination between stakeholders and the general public, and ensure data credibility through a rigorous validation process.*

1. Introduction

The concept of crowdsourcing (CS) was initially defined by Howe [Howe et al. 2006] as a means to solve problems by leveraging the collective wisdom of the crowd. Social media platforms have emerged as a robust CS mechanism, enabling the collaborative input of users to share information and populate these platforms with data. The evolution of communication technologies has further enhanced the potential of CS, making the process more cost-effective and efficient.

As a result, society has discovered new ways to engage in collaborative projects and achieve greater efficiency. This study seeks to introduce CS solutions rooted in collaboration rather than competition. This occurs when the crowd willingly embraces collaborative approaches through the utilization of tools in system devices, for example: communicating with each other and coordinating their operational activities to accomplish complex tasks.

In contemporary times, establishing efficient crisis communication has proven to be a challenging endeavor. Issues can encompass delayed responses, inconsistent information dissemination, varying public opinions, suboptimal resource allocation, and geographical mapping complexities. However, it is notable that there is a scarcity of research in this domain.

In emergency situations, the collaborative efforts of individuals can play a pivotal role in providing essential support to organizations and professionals. This research paper delves into the utilization of CS, as documented in the literature, to enhance collaborative approaches in the realm of crisis communication. To achieve this, a systematic review methodology has been applied.

The systematic review method was employed to address the following query: How and why does CS offer valuable contributions to collaborative crisis communication? This inquiry is addressed through an analysis of the existing literature, focusing on CS solutions that employ collaborative practices to support crisis communication.

The structure of this paper is as follows: Section 2 elucidates the fundamental concepts essential for a comprehensive understanding of the core topics. Section 3 outlines the systematic review methodology adopted. Section 4 describes the data analysis process. Section 5 presents the results. Section 6 delves into a detailed discussion of these outcomes. Section 7 focuses on describing the Collaborative Crisis Communication. Section 8 provides the conclusion, and Section 9 is dedicated to acknowledgments.

2. Fundamental Concepts

In accordance with [Quarantelli and Dynes 1977], emergencies encompass critical situations that can either be of a natural or human-induced nature. These emergent situations often escalate into full-blown crises. According to the Global Humanitarian Overview, there was a significant surge of over 20% in the count of children requiring humanitarian aid in 2022 in contrast to 2021, totaling 149 million. This escalation has been attributed to emerging and prolonged conflicts, exacerbated hunger, and the climate crisis. According to the Global Emergency Event Database (EM-DAT)[CRED 2022], in 2022, there were 387 occurrences of natural hazards and disasters, leading to the death of 30,704 individuals and impacting the lives of 185 million people. According to the United Nations (ONU)[1], Brazil ranks among the top 10 countries worldwide with the highest number of individuals affected by disasters over the past two decades.

An integral objective in crisis management is the establishment of an effective communication strategy among the various stakeholders characterized by collaboration. These stakeholders encompass a broad spectrum, including witnesses, operational personnel, rescue teams, command centers, affected communities, authorities, the press, volunteers, and individuals in the vicinity. Emergency response operations necessitate the involvement of rescue personnel who are equipped to take swift and coordinated actions in the aftermath of a crisis [Quarantelli and Dynes 1977]. These response efforts primarily focus on saving lives, mitigating suffering, ensuring the protection of affected populations, and providing vital services such as medical care, food, water, and shelter [Quarantelli and Dynes 1977].

[Quarantelli and Dynes 1977] also underscores the significance of addressing communication between diverse organizational systems. These specialized organizations are structured to fulfill distinct roles in disaster-related scenarios. For instance, there exist medical systems responsible for emergency healthcare services and military systems tasked with maintaining security. Communication among these participating organizations is not unidirectional; it involves numerous bidirectional and sequential exchanges amongst various multi-tiered groups [Quarantelli and Dynes 1977]. This might encompass facets like aid stations within a medical system, ambulance or transportation units, public and private hospitals, as well as various authorities operating within

[1]ONU; Accessed on 18 of August of 2023; https://brasil.un.org/pt-br/71500-onu-brasil-est%C3%A1-entre-os-10-pa%C3%ADses-com-maior-n%C3%BAmero-de-afetados-por-desastres-nos-%C3%BAltimos-20

specific jurisdictions. Consequently, the complexity and challenges of communication intensify during community disasters. Swift and precise communication serves as a vital component in ensuring effective and efficient organizational responses to disasters [Quarantelli and Dynes 1977].

All emergency events should be promptly communicated to the population residing in the affected area. Benali et al. [Benali and Ghomari 2017] highlight the importance of effective communication and collaboration between organizations and crisis response teams. However, the conventional media channels often prove insufficient for adequately coordinating crisis management efforts.

Given the hurdles encountered in the implementation of crisis communication support, CS techniques emerge as a viable means to extend the reach of messages. Benali et al. [Benali and Ghomari 2017] highlight the importance of sharing information, citizen participation in crisis management, and the pressure to make quick decisions. The approach proposed by Benali et al. uses CS to involve citizens in collecting opinions and evaluations about crisis response actions. The case study presented by Mohammed et al. [Benali et al. 2018] demonstrates how a CS platform plays a key role in the early detection of locust pests. It collects data from social networks and direct contributions from citizens, providing near real-time spatial information on the status of locusts.

This present study is a systematic review designed to explore how CS solutions bolster communication between the general public and the myriad actors involved in crisis scenarios. The following questions guide our investigation: How does CS contribute to crisis communication? How have CS solutions been evaluated? Who are the target users of the examined CS solutions? What categories of crises are addressed by CS solutions? Which stakeholders in crisis communication are referenced in the literature? Lastly, what channels of crisis communication are employed in CS solutions?

3. Systematic Review Method

This work is conducted by a systematic review focused on CS and Crisis Communication, shaped by the central subjects: collaboration, user acceptance, and human communication. The goal of the review is to find an existing CS solution that applies collaborative practices for crisis communication support.

This present literature review is conducted based on the guide defined by [Kitchenham 2004]. Firstly, the search was conducted by using the search string. We formulated the string based on the central problem studied to find papers presenting solutions. Secondly, we searched the scientific libraries. Finally, the results are refined by the inclusion and exclusion criteria. Ethical issues that applied to this research have been followed.

3.1. Digital Libraries

The scientific libraries used in the search process are described in Table 1. The choice of libraries took into account the relevance of the papers indexed in these engines for the academic community.

3.2. Search String

The search string was composed of four dimensions as described in Table 2: (i) crowdsourcing and similar; (ii) acceptance and collaboration; (iii) communication; (iv) crisis

Table 1. Scientific Basis for the Literature Systematic Review.

Scientific Library	Portal
Scopus (Elsevier)	https://www.scopus.com/search/form.uri
Science Direct (Elsevier)	https://www.sciencedirect.com/
IEEE Xplore	https://ieeexplore.ieee.org/Xplore/home.jsp

and similar. Each dimension is connected with the "AND" operator. At least one term of each dimension should be present in the paper's title, abstract, or author keyword.

Table 2. The search string for the literature review.

Dimensions	String
1	"Crowdsourcing" OR "Collective Intelligence" OR "Crowd Comput*"
2	"Collab*" OR "Accept*"
3	"Communicat*"
4	"Crisis" OR "Disaster" OR "Emergency" OR "Emergencies"

The first dimension is one of the main topics of the study: crowdsourcing and similarities words such as collective intelligence and crowd computing, or crowd plus derived words from "comp". The second dimension is regarding the specific part of crowdsourcing that we want to look at, such as collaboration (or words derived from "collab") or acceptance (or words derived from "accept"). These words bring to the returned works the themes related to collaboration and acceptance which mean users who are open to contributing (accept to execute tasks or collaborate in the presenting tasks). The third dimension: communication (or words derived from the radix "communicat"). The area of communication is associated with giving a message, notifying, or alerting a certain public. The last dimension is the keyword "crisis" and similar words such as "disaster", "emergency" or "emergencies". These keywords are related to the context in which the selected works should be inserted.

3.3. Inclusion and Exclusion Criteria

The inclusion criteria included papers that are: (i) scientific works; (ii) primary works; (iii) published in a conference, book, or magazine; (iv) presented as a CS solution that allows collaboration for crisis communication. The exclusion criteria removed papers that are: (i) no-scientific work; (ii) secondary works; (iii) thesis and dissertations; (iv) duplicated.

3.4. Selection Procedure

Initially, the total number of papers returned in the searches was 58 papers. After exclusion/inclusion by title reading, 38 papers have been excluded. In the end, the total of selected papers is 20. During the data extraction, we updated the exclusion criteria to exclude papers that did not mention humans in their communication solutions. After abstract reading, the other 24 papers have been excluded. In the abstract reading phase, we removed papers that only presented communication solutions by machines and included only solutions involving human communication.

Table 3 shows the remaining papers in each base, after the selection. The basis of IEEE Xplore and Scopus grouped all the remaining papers. The other basis had their paper removed by some criteria or by duplication. The Scopus library has the majority of paper results.

Table 3. Papers remaining in each scientific base after selection.

Library	Paper Returned	Total After Selection
Scopus	32	13
Science Direct	2	0
IEEE Xplore	24	7
All Libraries	58	20

3.5. Data Extraction

This work aimed to answer the following questions during data extraction:

1. How does CS support crisis communication?
2. How was the CS solution evaluated?
3. Who are the target users of the studied CS solutions?
4. What are the categories of crisis supported by CS solutions?
5. Who are the crisis communication actors mentioned in the works?
6. What are the crisis communication via applied in CS solutions?

4. Data Analysis

Figure 1 describes how the selected papers were analyzed. We first classified the papers by analyzing their metadata. We classified metadata according to year, publication venue, and keywords. After that, we categorized the papers by their content, such as experimentation, target users, crisis, crisis communication actors, and communication.

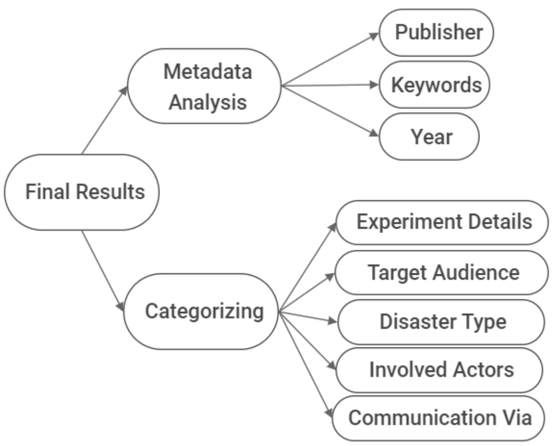

Figure 1. Diagram of the selected papers analysis process presenting final results classified according to metadata analysis (publisher, keyword, and year) and by paper categorization (experiment details, target users, disaster type, involved actors, and communication via).

The metadata analysis is focused on the year of publication, the venue of publication, and the author's keywords.

Figure 2 describes the number of selected papers published by year. In the years 2016, 2017, and 2019, there were 4 papers published per year. From 2011 to 2015, there were two works per year. In 2016, the quantity increased to 4 papers per year (except for 2018 had just 1 paper). We notice that there was no publication in 2020 and 2021. In 2022, after the pandemic scenario, the number of papers turned back increased with 2 papers published.

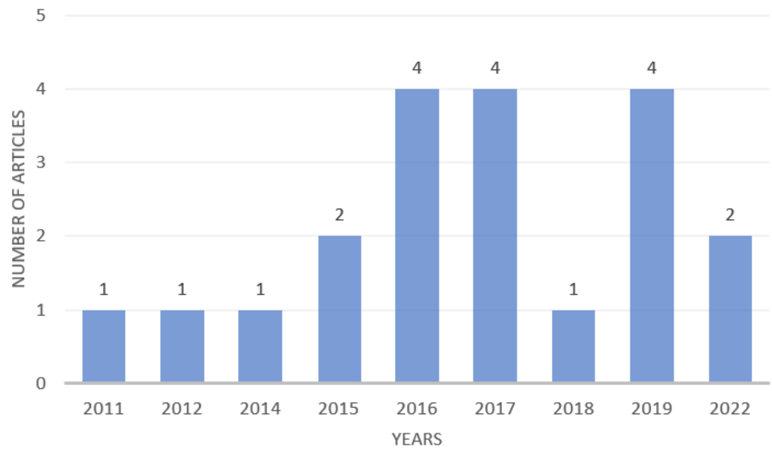

Figure 2. Bar chart describing the number of selected papers by year of publication. Since 2017, the average of selected papers has increased in contrast to the past years.

After the selection phase, the selected papers corresponded to a particular publisher venue. During the previous step of searching (before the selection phase), three venues demonstrated that have published more articles on related subjects, such as ISCRAM (International Conference on Information Systems for Crisis Response and Management), CSCW (ACM Conference On Computer-Supported Cooperative Work And Social Computing) and IDRC (International Development Research Centre).

Table 4 shows the most used keyword in the author's papers. These keywords represent the open research areas that can be explored in future research. The majority of keywords used by the authors are Disaster response, Emergency response, Volunteered geographic information, GIS (Georeferenced Information System), and Crisis management.

Table 4. keyword by the author's papers.

Keywords	Papers
Disaster response	3
Emergency response	2
Volunteered geographic information	2
GIS	2
Crisis management	2

For content analysis, we categorized the solutions described by the selected works. Table 5 shows the results of the categorization for each solution enumerate by decreasing order of publication year. The solution column contains a description of the author's work solution. The following are the solutions classified according to the experiment type, Target users, Crisis Type, Crisis Actors, and Communication Via.

5. Results

In 2022, Zhang et al. [Zhang et al. 2022] conducted an experiment focused on "Image classification accuracy" utilizing video content from social media platforms. Their tool primarily attends to social media users and emergency response agencies involved in disaster-related incidents. The crisis scenario in their study describes a disaster event, and communication between the public and agencies was facilitated through data transmission via social media streaming.

Another significant contribution comes from [Norris et al. 2022], who introduced a framework for temporal sensemaking. This approach provides collaborative insights aimed at resolving the challenging issue of time synchronization in crowd-sourced data. Their research involved interviews with humanitarian teams actively engaged in the collection of information during crises, such as hurricanes.

There are four solutions published in 2019. [Samir et al. 2019] proposed a blockchain framework and system, conducting simulated experiments. Their solution primarily targets affected communities and local assistance centers. The study investigated into disaster scenarios where community members, help requesters, and help providers were key actors. Communication in this context occurred through a mobile app.

The solution published by [Pezzica et al. 2019] presented an angular segment analysis workflow tailored for crisis managers involved in post-disaster planning decisions. The communication in their solution is facilitated through an urban grid.

[Cruz et al. 2019] introduced GALILEO, a geo-referenced system encompassing both web and mobile applications. GALILEO was designed to help individuals avoid overcrowded health services by directing them to less congested hospitals. Their user experience design evaluation involved users grappling with overpopulation crises in emergency services (hospitals). Users transmitted their data via the web or mobile app.

In [Dixon and Johns 2019], the authors introduced a smart city solution and a community resilience information system (CRIS). Their target audience comprises local communities and policymakers dealing with crises linked to natural disasters. Their work underscores the importance of providing the local community with access to pertinent information to actively engage residents in resilience planning and recovery efforts. By doing so, they establish a productive collaboration between government agencies and non-governmental organizations.

In 2018, [Fulco et al. 2018] introduced Crow4U, a cyber solution tailored for physical disaster evacuation drills. They evaluated their solution through simulations involving crowd workers addressing issues such as damaged areas. Key actors in this crisis included the community, rescuers, and local government entities. Crow4U served as a platform for crisis communication, and remote assistance from crowd workers played a pivotal role in assessing and providing crucial information to rescuers.

Between 2015 and 2017, we found ten works that employed various techniques for experimentation, including opinion questionnaires, simulations, brainstorming sessions, and workshops. These studies encompassed a wide range

Table 5. Categorizing the solution of each selected work by experiment, target users, crisis type, involved actors and communication via.

Authors	Solution	Experiment	Target users	Crisis Type	Crisis Actors	Communication Via
[Zhang et al. 2022]	Damage assessment (CD-NAS)	Image classification accuracy	Social media users and rescuer or recovery agencies	Disaster event	Emergency response agencies	social media streaming
[Norris et al. 2022]	Framework for temporal sensemaking approach	Interview	Distributed volunteer and crowdworkers	Hurricane	Distributed volunteer and organizations	CS system
[Samir et al. 2019]	Blockchain Framework and System	Simulated	Affected community and local help centers	Disastrous situation	Community, help requesters and help providers	Mobile app
[Pezzica et al. 2019]	Angular Segment Analysis workflow	Simulated	Disaster managers	Post-disaster planning decisions	Not applicable	Urban grid
[Cruz et al. 2019]	Georreferenced System (GALILEO)	User Experience Design	Population	Overpopulation in emergence service (hospital)	Citzens	Web/Mobile app.
[Fulco et al. 2018]	Cyber-Physical disaster evacuation drill	Simulated	Local residents and crowd workers	Natural disasters	Community, rescuers and local government	Crowd 4 U platform
[Dixon and Johns 2019]	Smart-city and community resilience information system (CRIS)	Not Applicable	Local community and policy makers	Climate change, natural disaster and extreme weather events.	Community and government	Interactive space in information system
[Hasse and De Rolt 2017]	Semantic Middleware (Co-SeMiWa)	Simulated	Community	Emergency situation	Emergency victim, victim's connections and professional team	Health knowledge system
[Freitas et al. 2017]	Collaborative Framework	Opinion questionnaire	Social media community and rescue teams	Emergency situation	Public, operations team, command and control and interation team	CS system
[Câmara et al. 2017]	ClickonMap Platform	Not Applicable	Disaster manager	Natural disasters	Citizen, volunteers and emergence manager	Web and mobile system
[Eldein et al. 2017]	Business Architecture	Not Applicable	Crowded large events and health organizations	Healthcare events	Patiente, physitian, ambulance professionals	Health care system in mobile device
[El Abdallaoui et al. 2016]	Lost Child Crowdsourcing Framework	Not Applicable	Community and government	Lost child	Parents/Family, authorities, crowd	Webpage (form and map)
[Middelhoff et al. 2016]	Lessons of experimentation	Simulated field experiment	Crisis professionals	Flooding	Crisis managers and citizens or volunteers	Not Applicable
[Ludwig et al. 2016]	crowdsourcing system (City-Share)	Brainstorming and workshop	Espontaneus volunteers	Not applicable	Citizen, volunteers and emergence manager	Crowdsourcing mobile app and public displays
[Brown et al. 2016]	metodology and toolsets (Safecast)	Not Applicable	citizen scientist	Nuclear disaster	Citizen, experts and volunteers	hardware and software system
[Dastjerdi et al. 2015]	consensus management approach	Performance	expert community	Not applicable	Experts and volunteers	Disaster Management System
[van den Homberg and Neef 2015]	COBACORE project	No results described	Affected community	Natural and man-made disaster	Responding professionals, affected and responding community	Gaming approach
[Calderon et al. 2014]	Communication tool (IntCris)	Simulated	official and non-official agents, and civilians	large-scale disaster	Not applicable	Website
[Kuehn et al. 2011]	Communication architecture	qualitative case study, workshop and comparative analysis	Safety agencies, organizations, affected public	Not applicable	Safety agencies, organizations, affected public	open communication system
[Farber et al. 2012]	Disaster service (Riskr)	Usability study	Riskr portal users, Twitter users	Fire and flood incident	Citizen	Portal and mobile app.

of disaster scenarios, including healthcare events, lost child incidents, flooding, and natural disasters. The actors involved in crisis communication varied, encompassing patients, ambulance professionals, family members, and volunteers [Hasse and De Rolt 2017, Freitas et al. 2017, Câmara et al. 2017, Eldein et al. 2017, El Abdallaoui et al. 2016, Middelhoff et al. 2016, Ludwig et al. 2016, Brown et al. 2016, Dastjerdi et al. 2015, van den Homberg and Neef 2015].

In particular, [Freitas et al. 2017] highlighted issues related to crisis communication, emphasizing the challenges of sending and receiving messages during moments of panic when the primary concern for all involved is personal safety. They also pointed out the challenge of managing a surge in interactions that occur instantly, leading to information overload and difficulties in selecting pertinent information. Additionally, they addressed issues related to credibility and the protection of individual freedoms. To mitigate these challenges, they proposed a collaborative framework for handling the influx of interactions on social media platforms.

The solution presented by [El Abdallaoui et al. 2016] proposes to assist parents in locating a lost child. Their work approached the technical aspects of addressing child disappearances efficiently. Their solution is designed to aid parents and government organizations in safely locating missing children. They introduced a framework that leverages human intervention based on the CS concept, fostering close collaboration between the public and government agencies by encouraging people to assist in the search process using mobile device features. However, a potential drawback of this solution is the possibility of diverse individuals providing less relevant results. Contributors may inadvertently provide inaccurate data, such as location and time, or become demotivated to contribute.

[Calderon et al. 2014] conducted a study known as IntCris, which is a communication tool that simulates experiments involving various stakeholders, including official and non-official agents, as well as civilians. Their study focuses on large-scale disaster scenarios, with communication primarily facilitated through a dedicated website.

In summary, these studies exemplify the diverse and innovative approaches within the realm of crisis management and communication, analyzing the critical role that technology and collaborative efforts play in addressing emergent challenges.

6. Discussion

In this section, we delve into the findings of our research, addressing the various aspects of crisis communication entities that emerged from our analysis.

1) How does CS support crisis communication?

CS solutions for crisis communication should prioritize safety and security to establish trust among users and organizations. Collaborative relationships between users play a vital role in this regard, with citizens placing trust in professionals and authorities participating in the system. In turn, authorities can rely on the data contributed by the community, which actively interacts with the CS system.

To ensure trustful communication, several techniques are utilized, including data validation processes such as blockchain [Samir et al. 2019] and data analysis techniques to eliminate false reports [Fulco et al. 2018]. Rapid response is an essential requirement for effective emergency solutions [Pezzica et al. 2019]; [Hasse and De Rolt 2017]. Effective coordination among the involved actors enhances communication and fosters collaboration in crisis relief [Freitas et al. 2017].

2) How was the CS solution evaluated?

Most works conducted their evaluations through either simulations or user-centered studies. For instance, [Samir et al. 2019], [Pezzica et al. 2019], [Fulco et al. 2018], [Hasse and De Rolt 2017], [Middelhoff et al. 2016], [Calderon et al. 2014], and [Kuehn et al. 2011] employed simulations in their studies. Meanwhile, [Cruz et al. 2019], [Freitas et al. 2017], [Kuehn et al. 2011], and [Farber et al. 2012] conducted user-centered studies.

Other approaches included the presentation of frameworks, as demonstrated by [El Abdallaoui et al. 2016] and [Norris et al. 2022], who offered collaborative tools for crisis management. In the former, the crowd contributes valuable reports to rescuers, while the latter showcases the crowd's role as official volunteers in gathering critical data from the web for crisis management.

3) Who are the target users of the studied CS solutions?

The target users encompass those who receive communication support through CS solutions. The collaboration process involves two sides, where one actively contributes to the other, thereby establishing an effective communication channel. On one end, the crowd contributes data to the system, while, on the other, formal organizations receive this data, facilitating crisis relief efforts.

The results indicate that the target users often include communities, volunteers, experts, and social media users [Freitas et al. 2017]. These groups collectively form the "crowd" due to their substantial numbers.

Apart from the crowd, formal organizations also participate in the collaborative process. These entities include local aid centers [Samir et al. 2019], rescuers [Fulco et al. 2018], professionals [Hasse and De Rolt 2017], rescue teams [Freitas et al. 2017], command and control centers [Freitas et al. 2017], emergency managers [Câmara et al. 2017], organizations [Kuehn et al. 2011], safety agencies [Kuehn et al. 2011], and government authorities [Fulco et al. 2018]; [Dixon and Johns 2019].

4) What are the categories of crisis supported by CS solutions?

The results indicate that the primary crisis categories supported by CS solutions encompass general disaster situations [Samir et al. 2019], [Pezzica et al. 2019], [Hasse and De Rolt 2017], [Freitas et al. 2017], [Calderon et al. 2014], natural disasters [Fulco et al. 2018], [Dixon and Johns 2019], [Câmara et al. 2017], [van den Homberg and Neef 2015], specifically floods and fires [Middelhoff et al. 2016]; [Farber et al. 2012], and health crises ([Cruz et al. 2019], [Eldein et al. 2017].

5) Who are the crisis communication actors mentioned in the works?

Crisis communication actors encompass individuals affected by the crisis scenarios focused on in the studies. The results identified the following actors: communities (citizens, victims, patients, local residents), local government (authorities, organizations, managers), and, on occasion, professionals (operational teams or experts)

([Freitas et al. 2017]). The proposed solutions aim to support communication among these actors.

6) What are the communication avenues presented in the solutions?

Crisis communication leverages a variety of systems, including mobile apps ([Samir et al. 2019]; [Cruz et al. 2019]; [Eldein et al. 2017]), portals ([Kuehn et al. 2011]), and web services ([Cruz et al. 2019]; [Câmara et al. 2017]; [El Abdallaoui et al. 2016]). Data visualization techniques, such as maps ([Pezzica et al. 2019]; [Cruz et al. 2019]), and social media feeds ([Hasse and De Rolt 2017]; [Freitas et al. 2017]; [Farber et al. 2012]), further enhance crisis communication efforts.

7. Collaborative Crisis Communication through Crowdsourcing

The systematic review of the articles yielded solutions for crisis communication. These solutions were evaluated from the perspectives of CS and collaboration, and they have been organized into distinct entities shown in Figure 3. These entities are labeled as Crowd, Agents, Environment, Requirements, and Experiments.

CS enhances communication between various actors by enabling collective participation in various tasks. For effective crisis communication, CS solutions should consider the interactions between the involved parties, illustrate emergency scenarios, and employ collaborative practices. This helps in making tasks more acceptable and aids in devising strategies for seamless communication between professionals and the public.

In the analyzed solutions, the crowd can contribute by providing data through media production, data sensing, task completion, feedback, or information validation. The coordination of crowd-sourced data is essential and involves Crisis Agents, such as local aid centers, rescue teams, professionals, operational units, command and control centers, emergency managers, organizations, safety agencies, or government authorities.

Most CS and collaborative initiatives benefit from recent advancements in information technology. We examined the environments in which these solutions are applied and found that they are often deployed as mobile applications, web portals, web services, geographic mapping tools, or via social media platforms. These solutions come with certain requirements, including the ability to respond swiftly to emergencies, ensuring effective coordination between agents and the crowd.

Our research has identified specific requirements that emergency communication solutions should adhere to. It is crucial for these solutions to prioritize safety and security, instilling trust in both citizens relying on professionals and authorities relying on community-provided data. The data must undergo a rigorous validation process to ensure accuracy and reliability. Swift responsiveness is another critical requirement for effective emergency solutions, as it plays a pivotal role in preventing panic within the crowd.

The entities we have studied, including Crowd, Agents, Environment, and Requirements, can be further investigated through experiments. Our findings indicate that experimentation often took the form of simulations or user-centered studies, enabling researchers to assess and refine the proposed solutions.

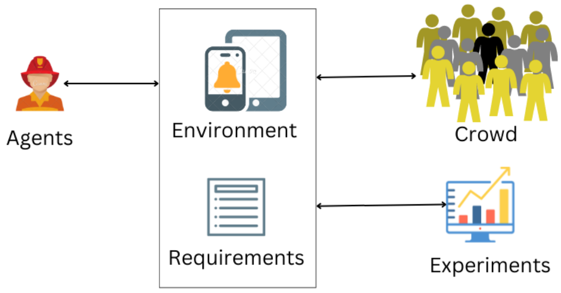

Figure 3. Diagram illustrating the entities involved in the process of crisis communication.

8. Conclusion

Efficient teamwork in CS tasks depends on various factors, like participants' expertise. In emergency situations, working together with the crowd can be crucial in supporting organizations and professionals. This paper explores how the literature discusses using CS to help collaboration in crisis communication. For this study, we used a method called a systematic review.

The study looked at the data from 20 chosen papers from four different scientific databases. We found that in the last ten years, 2017 had the most publications in this area. There has been an increase in publications in recent years. The main topics related to this area include teamwork, cooperation, location-based services, disaster response, blockchain, and trust. These topics provide opportunities for future research.

After studying and sorting the solutions in the selected papers, we got information about the audience, types of crises, people involved, and ways of communication. Most papers talk about the audience as the community or the general public. Many solutions are made for crises related to natural disasters. The people involved are usually regular citizens, government authorities, and professionals. Most communication solutions are based on websites or mobile apps.

This research has helped us understand how CS can be used for enhancing collaborative crisis communication. In future research, we will look at the works related to the selected papers.

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