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Using Social Media Data in Emergency Management: A Proposal for a Socio-Technical Framework and a Systematic Literature Review

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ABSTRACT

Data represents an essential resource to the management of emergencies: organizations have been growingly investing in technologies and resources to lever data as an asset before, during, and after disasters and emergencies. However, research on data usage in emergency management remains fragmented, preventing practitioners and scholars from approaching data comprehensively. To address this gap, this research in progress consists of a systematic review of the literature in a two-steps approach: we first propose a socio-technical framework and use it in an exploratory mapping of the main topics covered by the literature. Our preliminary findings suggest that research on data usage primarily focuses on technological opportunities and affordances and, hence, lacks practical implementation aspects in organizations. The expected contribution is double. First, we contribute to a more comprehensive understanding of data usage in emergency management. Second, we propose future avenues for research on data and resilience.

Keywords

data eco-system, data processing, social media, information management, information technology, emergency organization

INTRODUCTION

The latest decades saw the emergence of data extraction, selection, processing, and manipulation before, during, or after critical emergency events. Coming from authorities to non-profit organizations or even emergent communities, a large spectrum of organizations has approached these techniques as relevant opportunities to better manage emergencies (Stieglitz et al., 2018, Saroj and Pal, 2020). For some years already, data usage for crisis management has been discussed significantly in crisis-related communities of scholars and practitioners (Tapia &

Moore, 2014). Accordingly, data-related technologies – including data mining, data visualization, machine learning, and artificial intelligence – have been presented as strategic assets for resilience (Meier, 2015).

The combined rise of social media and machine learning accounts for scholars' and practitioners' embracing of data. In the emergency sector, some organizations have been exploring methods and algorithms involving artificial intelligence, machine learning, and data mining to explore social media as data sources (Alam et al., 2020). Also, early adopters have started to recruit data analysts dedicated to social media. Concurrently, they are reorganizing their processes to better benefit from the insights obtained from the data collected. Social media data radically transform operations, poses new challenges (Duffield, 2015), and induces new practices and capabilities in the emergency sector (Elbanna et al., 2019; Karanasios et al., 2019).

In particular, social media platforms have been providing raw data streams directly to emergency responders. Ideally, these streams could help organizations generate new insights. However, they can also create tensions in organizations due to the need for additional competencies and efforts to integrate data into emergency management. As such, the usage and integration of social media data into emergency management is not a purely technological matter (Davenport & Kirby, 2016; Lyytinen et al., 2021).. Rather, it depends on the imbrication of technological, organizational and environmental elements.

Better understanding the major features of this imbrication and its role in emergency management has become crucial. Still, the combination of the technical and organizational aspects of social media usage in emergency management has not been examined thoroughly and systematically (Calic & Resnyansky, 2015, Roja and Pal, 2020). Rather, an important part of the research has been approaching the processing of social media data as a technical challenge (Reuter et al., 2018). Our research aims to address the following gaps. First, review previous works on the human-technological capacity of data extraction and processing in emergency management, labeled in this paper as data usage. Second, address the lack of a comprehensive conceptualization of data usage to help define and practically support it within emergency and disaster organizations.

That is why this paper presents a work in progress that addresses the following research question: What are significant avenues of research on social media data usage in emergency management?

To address the question, we propose a new theoretical framework of social media data usage in emergency management. This framework draws on existing ones, as well as socio-technical thinking. This paper is structured as follows. First, major threads of research on data and emergency response are documented. Then, a version of a socio-technical framework for data usage in emergency management is presented. This framework considers the strong ties between the technical and technological implementation process and its surrounding organizational ins and outs. Then, based on this framework, a preliminary exploration of the literature is provided to draw potentially necessary research avenues on this question. Section three details the adopted methodology, and section four explores the first results of the literature analysis, as well as the expected contribution of this work.

THEORETICAL BACKGROUND: FROM DATA EXTRACTION TO DECISION MAKING

The backdrop for our study comprises three fields, namely i) computer science, ii) information systems, and iii) emergency and crisis management. Studies from these three fields reveal growing but fragmented interest in data concerning emergency response. This first section explains how the lack of a comprehensive view of data in emergency management can affect practices and knowledge. Second, we propose a socio-technical framework of data usage in emergency management as a basis for proposing a socio-technical process and its ins and outs that support the data usage lifecycle and enable the mapping of new avenues for research based on the corresponding topics already covered by the literature.

Social media data and emergency management

Scholar focus on data usage

In the latest years, scholar examination of social media and emergency management has covered a growing spectrum of topics (Elbanna et al., 2019; Martínez-Rojas et al., 2018; Reuter et al., 2018). In order to better understand the diversity of topics, Reuter et al. provide an insightful and comprehensive overview of the four major threads of research on social media and emergency management (2018).

An initial thread acknowledged and analyzed the role of social media in emergency communication. This thread depicts how organizations involved in emergencies formally rely on social media to provide updates to their stakeholders. Likewise, it explores communities' reliance on social media as a technological opportunity for ad hoc mobilization of its members (Palen & Hughes, 2018). A second thread examines the impact of social media

on information practices in the mid and long term in the emergency sector. Studies from this thread outline that social media data can deeply shape decision processes (Elbanna et al., 2019) change how organizations communicate and make sense of an emergency (Bubendorff et al., 2021). Furthermore, access to data through social media can disturb coordination patterns and push new logics (Karanasios et al., 2019). The third thread studies how to co-construct tools and solutions to make social media data more beneficial to responders. Finally, a fourth thread examines how to collect and process data from social media to generate original insights.

This thread had been attracting growing attention and corresponds to the scope of this paper. The development of social media platforms - resulting from Web 2.0 - has come with the generation of massive amounts of data (O'Reilly, 2007). As **Error! Reference source not found.** illustrates, scholar studies on data extraction and use from social media multiplied by eight since 2013.

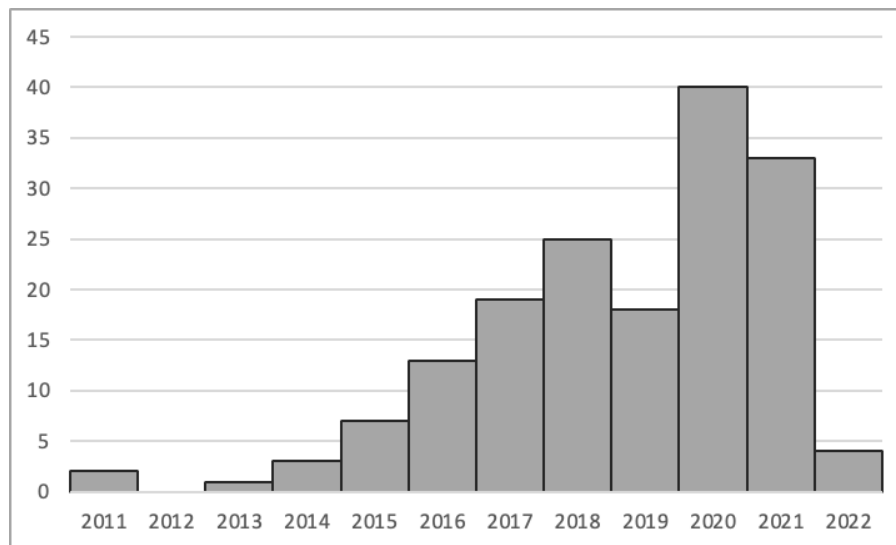


Figure 1. Distribution of articles per year, resulting from the search string in Table 1 executed on Web of Science, on the 1st of February 2022

Social media data usage in emergency organization

Social media generates massive amounts of heterogeneous: GPS coordinates, text, event date and time, like, tags, videos, pictures, meta data etc.

Emergency organizations have been growingly using social media analytics (Stieglitz et al., 2018). Social media data can potentially generate very diverse insights on emergencies. The literature has mentioned a large spectrum of cases where organizations practically use social media data to manage emergencies. In a systematic review, Saroj et Pal (2016) reported the topics which social media data can inform in emergency organizations, including emotions, ties between organizations, and events. Existing research has extensively mapped the techniques to produce insights out of social media.

However, studies on information production from social media data usage in emergency organizations remain specialized (Saroj, Pal, 2020). In other domains than emergency management, some authors put into perspective the technological and organizational dimensions of social media data usage. For instance, public management scholars conceptualized data lifecycles to better understand its usage (Attard et al., 2015). Likewise, studies on transportation agencies outline the need to invest and manage infrastructure to fully exploit social media data. In emergency management, attempts to put into perspective technological and organizational dimensions of data usage were rarer. McCormick (2016) alerts on the lack of knowledge from emergency organizations on how to deal with social media data.

We posit in this work the need to further relate the techniques of social media data usage to their implementation in organizations. Our rationale is that data usage embeds in complex cognitive and interactional activities in organizations, such as sensemaking, decision making (Wolbers et al., 2021). Hence, data usage, far from being neutral, is socially constructed (Mulder et al., 2016).

To address this lack of comprehensive understanding of social media data usage, we propose a socio-technical framework. We then to map existing research and upcoming avenues based on this framework.

A proposal for a socio-technical framework of data usage in emergency management

Data usage frameworks

To the best of our knowledge, there is no comprehensive framework of data usage in emergency management. We detail the two frameworks that we draw on i) the CRISP-DM and i) TOE frameworks. However, some frameworks detail the major processes underlying data analysis in organizations – labeled as data mining. Shearer (2000) presents the Cross-Industry Standard Process for Data Mining (CRISP-DM). This framework has standardized in multiple industries, gained momentum, and supported a holistic view on information production out of raw and unstructured data in organizations (Huber et al., 2019). The presents six major phases:

1. Business Understanding: identification of the relevant business issues or goals.
2. Data Understanding: data collection and inventory.
3. Data preparation: data cleaning and feature augmentation.
4. Modeling: identify the correct modeling method, build the model, and assess the model quality.
5. Evaluation: evaluate the performance of the model with respect to the originating business needs.
6. Deployment: deployment and monitoring planning, review.

Multiple frameworks inspired on CRISP-DM. For instance, the Machine Learning Operations methodology (MLOps) (Treveil et al., 2020) describes the lifecycle of machine learning models. As training machine learning models requires data, MLOps reuse the data management part of CRISP-DM and add additional components reflecting the deployment of the trained models. Data usage is impacted by the practices and processes of the organization in which it develops. The Technology Organizational Environment (TOE) framework aligns with this view and was used to study technology adoption. Previous works investigated the adoption of social media analytics in organizations from this perspective (Stiegler et al., 2018). However, this framework focuses on the adoption of social media analytics and does not consider social media data usage in the long run. by the practices and processes of the organization in which they are deployed. However, existing frameworks primarily target engineering goals. The rest of this section presents the socio-technical framework proposed to identify the different areas of interest in data usage in emergency organizations.

Socio-technical thinking applied to data

For multiple decades, the human and the technological have been approached as mingled (Latour, 2007; Leonardi, 2011; Orlikowski, 1992; Ropohl, 1999; Suchman & Suchman, 2007). According to socio-technical thought, technology and human beings mutually interact, especially in organizations that tackle complex problems (Ropohl, 1999). For instance, a specific technology offers possibilities of action that its users cease, thereby generating new activities or adapting processes. Reciprocally, users design technology or adapt its features depending on a large spectrum of organizational variables: operational needs, processes, organizational culture, etc. Hence, an underlying tenet of socio-technical thinking is the need to examine the mutual interdependencies between technology and human (organized) action. First, how technology can influence processes and activities in an organization. Second, how human activity shapes, defines, selects designs, and implements technology.

Until recently, human, and technological dimensions of work used to rely on distinctive capabilities. While humans and technology mutually shape each other, their own features remain distinct. However, the increasing sophistication of technology - such as the rise of machine learning – based on growing access to data – blurred the distinction between human and algorithm capabilities (Lyytinen et al., 2021). Given the foregoing, we propose a new framework that draws CRISP-DM, TOE, and outlines the interactions between the i) technological, ii) organizational and iii) environmental components of social media data usage.

Proposal for a framework of data usage

Error! Reference source not found. provides a visual summary of the framework and its different components. Each component reflects where data is involved in the organization. In the framework, Environment refers to both external and internal environment. In emergency settings, the external Environment concerns the context in which organizations operate: the command chains, institutional logic, professional values, interdependencies with other organizations, etc. The internal Environment includes hardly visible phenomena that deeply influence the functioning of the organization in the long term: organizational culture, routine, hierarchy, etc. What we label ‘Data processing activities’ concern the very extraction and manipulation of social media data. Data processing activities appear as a lifecycle or process as the one presented through the CRISP-DM framework. They combine

technological (such as algorithms and programs) and human capabilities (such as the labeling of the data to train the machine learning models and the supervision of the overall process). Organizational activities comprise operations, planning, and backup activities.

Based on a socio-technical approach to data usage, this framework represents how data processing activities embed into organizational activities and Environment. In addition, we used this comprehensive to map aspects of data usage that were already investigated in the literature. For this reason, the different elements of the figure are explained below. In the methodology section, we detail how we rely on this framework to classify the articles considered for the review.

- **1. User Needs:** Organizational analysis of the needs and of the problems encountered in the organization, which call for data usage
 - o 1-2. Setting up of a collection method in response to informational needs of the organization.
- **2. Data Collection:** Available data sources state of the art and collection implementation.
 - o 2-1. Interactions from user needs to data collection are relative to the selection of data from the identified problems and needs.
 - o 2-3. Interactions from data treatment to data collection refer to a technical or expert retroaction in which the data collection can be refined to improve the treatment.
- **3. Data Treatment:** Processing of the data flows. This is a step where limitations of the data itself are questioned and methods are built to circumvent them.
 - o 3-4. Creation of information on the basis of targeted methods for data processing.
- **4. Information Production:** Information production (e.g., application of an algorithm, training of a model to recognize information, etc.) for decision-making from processed data.
 - o 4-3. Retrospective analysis of the information produced in relation to the processing method initially used
 - o 4-5. Influence of decision making, based on how the information is produced.
- **5. Decision-making:** Decision-making of the actors in relation to the information produced by a system (e.g., a decision in front of a dashboard presented to a user), how it is done and what its impact is etc.
 - o 5-6. Impact of the influence of decision-making through data use on the organization, in the long term.
- **6. Long-term Impact:** Long-term consequences of data extraction, processing, and interpretation within the organization.
- **7. Environment:** Impact of data usage on the organization's Environment, i.e., its command chain, institutional logic, professional values, interdependencies with other organizations, etc., or organizational culture, routine, hierarchy, etc.

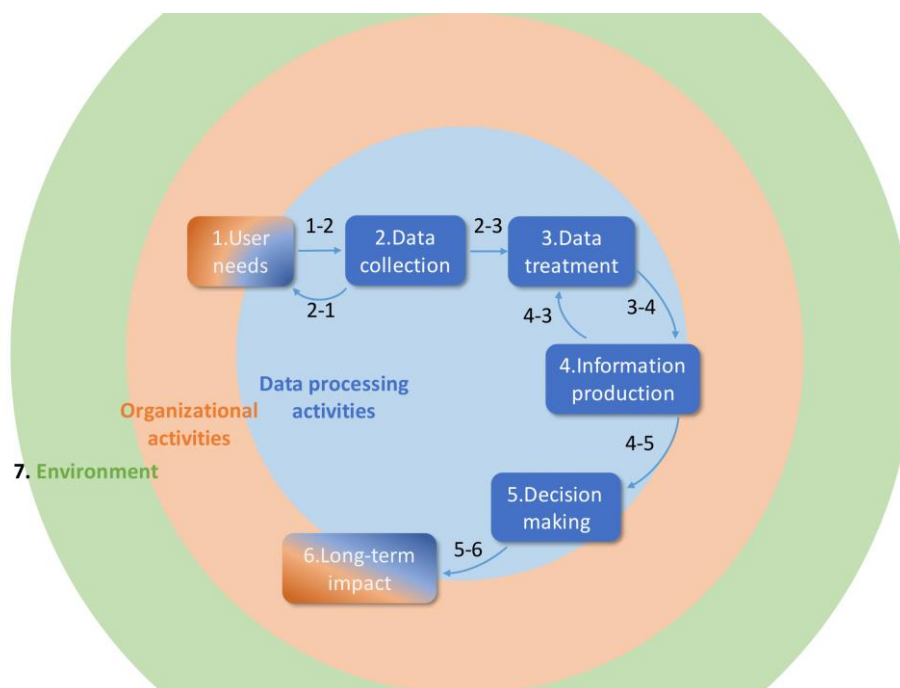


Figure 2. Socio-technical framework proposed for data usage in emergency management.

METHODOLOGY

To define the future avenues related to supporting the data usage lifecycle in the emergency and disaster management field, a systematic literature review is conducted. The framework previously proposed is used as a base for exploring the state of the art and eventually detecting unexplored areas. A set of keywords and topics was first set and transformed into a query string executed on the scientific databases Web of Science. The following details the methodology applied before drawing the first results of a preliminary sorting of the literature.

Systematic literature review

A systematic literature review consists of a “systematic, explicit and reproducible method for identifying, evaluating, and synthesizing the existing body of completed work produced by researchers, scholars, and practitioners” (Fink, 2019). Reviewing is essential for scholars and systematic research projects, and empirical work. Another evidence of the importance of reviewing can be found in the large spectrum of journals and journal issues that focus on the topic.

The objective of reviewing the literature is to identify what has already been studied on the one side, and, on the other side, what requires further investigation (Cropanzano, 2009), what could be the object of new debates (Kunisch et al., 2018) or decision making (Briner et al., 2009). Hence, the review goes beyond mere classification and description of existing research but rather aims at addressing questions and limitations through analysis of previous work (Cropanzano, 2009). In line with this view, mapping reviews support theory development through the exploration of gaps across subgroups (Booth et al., 2021).

In this research, we aim at better understanding the state of the art on the socio-technical dimension of data usage in emergency management organizations. The mapping review technique consists of categorizing existing literature and identifying its major features, as well as avenues for future research (Booth et al., 2021).

Data collection

TABLE 1: EXECUTED SEARCH STRING.

Filtered by	Document Type: Article
Crisis Topic AND	(crisis OR crises OR emergencies OR emergency OR disaster*) NEAR/1 ("manage*" OR "detect*" OR "response")
Data Exploitation Topic AND	(exploitation OR Interpretation OR Analysis OR process*) NEAR/3 (data OR text OR image* OR tweet*)
Social Media Topic	"social media" OR "tweet*" OR "twitter" OR "facebook" OR "social network" OR ((media OR network) NEAR/1 social)

First, relevant keywords related to data extraction and processing in crisis response were identified and enriched with related terms. Thanks to this, we elaborated a broad search string at the intersection of the fields of crisis, data exploitation, and social media, as provided in Table 1. The request resulted from multiple tests across various databases.

We executed this search string on the scientific database Web of Science (WoS) which is a globally appraised database to collect articles and focuses on journal papers from a multidisciplinary perspective. The request was designed iteratively, with each iteration resulting in samples of various sizes, ranging from 280 papers to 1492 papers. We excluded conference papers to avoid any redundancies with journal papers. Then we achieved a first filter by scanning titles, abstracts, and findings of the papers to determine those retained in our sample. This initiated some discussion among the authors on the scope of the research. After discussion, we agreed to exclude the papers that fell short of details on data usage. For instance, some studies mentioned data material involved in the analysis of Twitter communication rather than analyzing how data was or could be extracted. This selection process led us to consider a sample of 233 articles (as of the 1st of February 2022).

Data Analysis

Once we had the sample, we selected keywords used more than five times referenced among the papers and used VOSviewer v.1.6.18, a source graph and network analysis software, to highlight the most recurring topics and

their interconnections to get a first global glance at our corpus. This analysis identified four clusters of keywords related to the organization of the response (blue), communication to the public (yellow), the joint opportunities of social media and technologies (green), and the data automated processing (red), illustrating the strong interaction existing among these research communities (Figure 3).

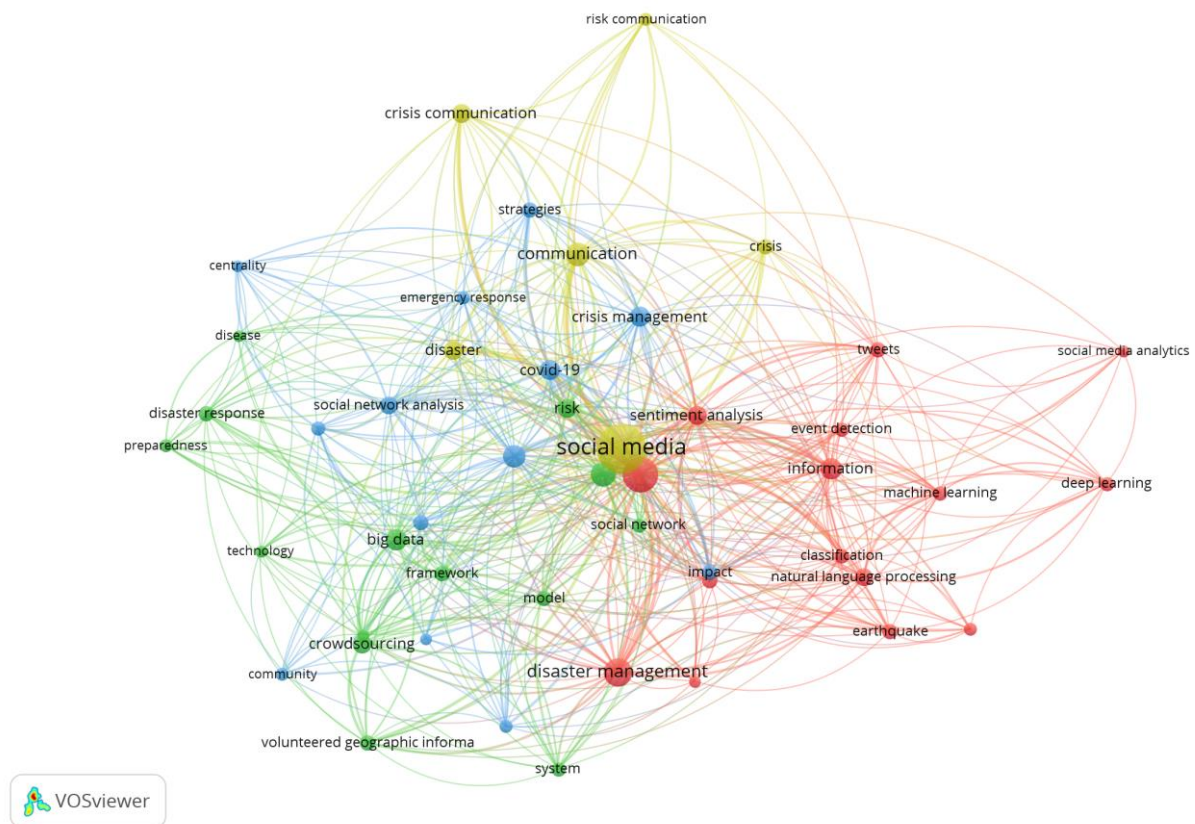


Figure 3. Network representation of keywords used more than five times in the retrieved articles and their co-occurrence. The different colors correspond to groups of similar keywords.

Once having obtained this relevant corpus of articles, a deeper analysis allows confronting the previously proposed socio-technical framework to the coverage of the literature on the subject.

We initially relied on the definition of each element composing the data usage framework to locate a randomly selected sub-sample of 50 articles within the data usage framework. We first made sure that each paper dealt with the topics within the scope of this research: techniques, methods, practices of data extraction processing, and use in crisis and emergency management, and discarded irrelevant articles. Then, in case an article dealt with a particular element of the framework, we assigned a boolean presence indicator for this element for this paper. Then, we computed the distribution of each article's related steps along with the data usage framework to get a preliminary representation of the different parts of the data usage framework in this sample.

PRELIMINARY FINDINGS

Of the 50 articles randomly sampled, 16 were identified as irrelevant. The 34 remaining articles were then analyzed to identify their contributions according to the classification guidelines presented in the socio-technical framework presented previously. Figure provides the resulting distribution of the paper per topic of the framework.

As illustrated by Figure 4, the various aspects of data usage in emergency management are very unequally investigated. The distribution shows that data processing and information production are investigated 10 to 20 times more frequently than the less investigated topics. This suggests - but still requires further investigation - a dramatic gap between four threads of research on data usage in emergency management. We first present each of these threads (that still require refinement in the coming lines)

1. Data treatment and information production focus

A first thread focuses on data treatment combined with information processing. It accounts for the most technical

aspects of data usage, and is largely investigated. For example, some works like Coche et al. (2021), Imran et al. (2014) propose algorithmic methods to extract information from social media data. Crossing multisource including social media data, Xu and Ma (2021) propose a method to assess the waterlogging probability. This thread shows to what extent the treatment and processing of data are researched together by researchers who have been very active in investigating data processing as a technological opportunity, searching for ways to propose new inputs from data.

2. Data sources selection

On the data sources selection thread, it is interesting to note that, out of the 34 relevant articles, only 6 of them questions the data sources themselves. Works such as Hao and Wang (2021) specifically raise the question by providing a data-driven platform named ADIR. In most research works based on social media, it has to be noted that Twitter is prevalent due to its data ease of access (Twitter API), often to the detriment of other social media.

3. Information processing and decision making

A third thread investigates how information processing can affect decision-making: while they are not prominent in the studied literature, they provide very targeted studies. For example, Schemann et al. (2014) used quantitative and qualitative data and tried to find out what factors could be of influence for decision-makers during the 2007 equine influenza outbreak in Australia and pinpoint social aspects, especially monitoring social expectations and communicate in particular in case of false rumors.

4. The influence of social media usage in organizations

The last thread concerns the role played by data usage in the organizations in the long term. This topic remains rarely investigated in comparison with the others: the only article that emerged in the sample claims a strong criticism of digital humanitarianism on the long term (Duffield, 2015).

5. Focus disparities

Though, the studied literature seems to suggest that it has been less examined how organizations practically the organizations' needs that call for these opportunities. Besides, the literature hardly investigate the performativity of data processing, that is how reliance on data processing techniques can change the course of an emergency and transform organizations.

Relying on a socio-technical framework, this systematic review details the – already pointed at - specialization of the literature on social media data usage in emergency management. While the socio-technical dimension of data was already outlined, this review suggests that scholars have already explored the articulation between the social and technological dimensions of social media data usage. Here Figure 4 shows that some aspects of data usage in emergency management remain hardly articulated to the others. For instance, there is 0 or 1 article on 1-2, 2-1, 5-6 topics that concern organizational aspects of data usage.

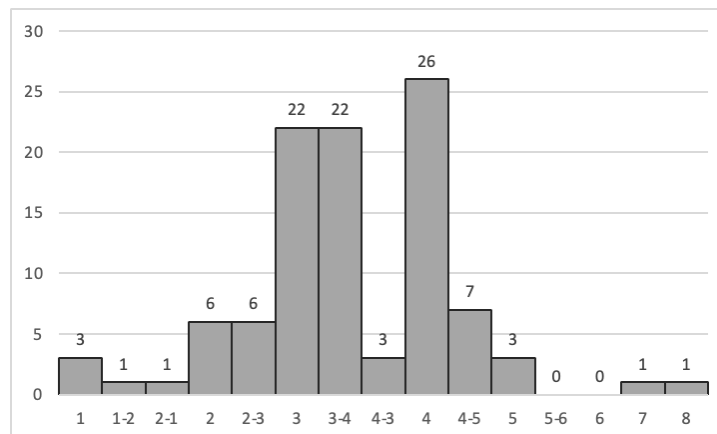


Figure 4. Distribution of the randomly sampled articles per proposed data usage steps.

EXPECTED CONTRIBUTION

This work proposes a framework that focuses to review research on social media data usage. Drawn on existing CRISP-DM, TOE and socio-technical theories, it underscores the technical and organizational aspects of social media data usage. This work relies on this framework as a lens to explore social media data usage in emergency

management. It outlines four threads of research that cover distinct areas of investigation.

Our analysis has just started and clearly needs refinement. The proposed framework, that we use as a mapping tool for existing research on data usage in emergency management, is likely to evolve through our analysis of the sampled articles. We expect to discover some topics uncovered by the current version of the framework. In addition, we classified the papers according to the topics of the framework that they address. In the future, two directions will be further explored. First, add deeper insights on the sociological and organizational perspectives by running a second query modified to focus on these aspects. Also, there is the need to sophisticate the classification grid, for instance by coding the research questions posed by the authors and that correspond to one or more topics of the framework.

However, this review – still in progress – still outlines important points to consider future research on social media data. First, existing works hardly explore the ties between social media data processing and other organizational activities. Without further insights on these topics, the field might become hyper specialized on technical topics, suffer from a lack of articulation of complementary stances and will lose its relevance. For this reason, our preliminary findings suggest the need for a more thorough examination of socio-technical aspects of data usage in emergency response. Second, the divergences between the four thread suggests the risk of fragmentation of research on data usage in emergency management. As Kuhn explains, knowledge building on a specific topic requires dialogue between the scholars who investigate this topic (Kuhn, 1962). The expected contribution of this work is double. First, the proposed framework can expand the scope of scholarly interest in data usage in emergency management. By approaching data extraction, processing, and interpretation as socio-technical, this work provides a conceptual grid that calls for further investigation of its socio-technical aspects. Second, by relying on a systematic mapping, this research will also help identify which aspects of data usage remain uncovered. More comprehensive research on data will benefit to practitioners and bolster research relevance.

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