Stakeholder Perceptions in the Context of Community Risk Reduction (CRR): Self-reported Hazards as Two-Way Communication Between First Responders and the Communities They Serve

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Abstract. Due to rapid advances in technology, particularly location-based services, there has been an increase in the availability of self-reporting hazard tools and mobile applications. However, many challenges remain in understanding stakeholders' perceptions of community risk reduction (CRR) information systems and the impact these self-reports have on emergency response. This paper addresses the gap in the existing literature by combining theories and data from multiple disciplines. Existing research has traditionally focused on Wildland-Urban Interface (WUI), citizen science for Geographic Information Systems (GIS), and participatory mapping. Still, the extant literature does not comprehensively evaluate community stakeholders' perceptions and engagement in emergency preparedness efforts, particularly for applications intending to engage both civilians and first responders. More importantly, there is little existing research to better understand the relationships that exist between the first responders, technology, and residents they serve in their first-due areas. Consequently, this paper aims to provide an overview on how to best support multiple stakeholders and to foster more constructive communication between first responders and the communities they serve through technology mediated self-reporting tools.

Keywords: Community risk reduction · Emergency communications · User experience · Emergency response · Community engagement

1 Introduction

Due to recent advances in technology, people are connected now more than ever to their emergency services. The popularity of mobile applications has made community risk reduction (CRR) efforts further reaching. Recent developments in the area of mobile applications empower civilians to aid before emergency responders arrive on scene by

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encouraging those certified in rendering cardiopulmonary resuscitation (CPR) to intervene [1, 2]. Additionally, some mobile applications create the opportunity for individuals to self-report medical data, similar to a digital medical alert bracelet, in case of emergencies. Seminal work in this area has summarized the impact of mobile applications in emergency response more broadly [3]. While the extant literature demonstrates the utility of applications for specific purposes, such as CPR interventions, most of this research takes the form of market research in industry, rather than a formal academic evaluation or approach. The goal of this paper is to outline some of the more important sociotechnical dimensions that can be conceptualized as an integrated framework for understanding how to support mobile and technology-mediated two-way communication between first responders and the community they serve.

2 Related Work

Trends in fire data indicate that the majority of fire-related deaths of both civilians and firefighters occur at the scene of residential structure fires [4]. As a result, there is a movement to increase the amount of data made available to first responders [5]. This additional information is not only to augment their understanding of residential structures in their first-due areas, but also as a way to engage citizens in hazard mitigation efforts. However, this movement is relatively understudied and presents new opportunities and challenges for all stakeholders involved in the collection, management, retrieval, storage, and security of this residential data.

To situate this paper in the extant literature, we will explore the existing models for CRR efforts. In particular, we examine how the Wildland-Urban Interface (WUI) community has successfully engaged citizens in risk reduction efforts to save lives and property. This paper will demonstrate the importance of understanding citizens and business owners' perceptions of the fire service. Specifically, we will examine the impact of the availability of residential structure data on first responders. One of the implications of these trends is that citizens may be reluctant to provide information if they do understand how and when it will be utilized. We also explore the impact of several sociotechnical dimensions (e.g., privacy, transparency, trust) on citizen engagement in CRR efforts.

It is important to operationalize the constructs and dimensions identified in this work. Although there is some debate depending upon the disciplinary lens through which these dimensions are evaluated, we leverage the existing definitions to further define this work. In this paper, community is defined as

2.1 Community Involvement: Current Domains and Directions

Citizen participation in risk-reduction activities has traditionally been shaped in two major ways. First and foremost, in terms of disaster and crisis response, citizens have been involved in the process to create more resilient communities through a focus on preparedness efforts [6]. We elaborate on this concept in further detail below. We begin with a broad discussion of public participation and then we move to other domains of public interest that have successfully implemented community involvement.

Emergency Preparedness. Across the literature, emergency preparedness is a common theme in the context of community participation in risk reduction efforts. For example, a large study in Atlanta focused on identifying and prioritizing fire inspections to reduce the risk of fire loss [7]. This approach leveraged machine learning techniques to better support fire agencies in identifying buildings at risk, consequently improving preparedness and mitigation efforts.

Home Visits. In the extant literature, home visits represent a significant portion of effective CRR strategies, particularly in the case of residential emergency preparedness [8]. Home visits are defined as strategies that focus on public safety officials leveraging face-to-face methods to engage in discussion about risks with citizens. The literature points to the utility of home visits internationally, that is, even outside the United States, home visits account for higher levels of engagement with civilians in the community [8]. Along these lines, studies in rural communities indicate that exposure to emergency preparedness materials and campaigns led to greater awareness of hazards and enhanced preparedness practices [9].

Wildland Urban Interface (WUI). Perhaps one of the richest areas that focus on citizen and community involvement in risk reduction efforts in the area of wildland firefighting. This literature is often described in terms of community involvement due to the serious nature of risk assessment and its impact on individual stakeholders [10–13]. More importantly, the risk to the community more broadly emphasizes the importance of sharing information between the public and the agencies serving them in times of crisis.

For example, the design of applications such as Wildfire Analyst supports wildland fire operations by allowing firefighters to dynamically assess fire behavior using real-time 3D models [14]. The advent of such mobile applications supports fire operations but typically does not involve end-users other than experienced firefighters who need to build situation awareness of the environment around them. Therefore, the majority of research in this area focuses more on risk communication messages to engage the public and local community in mitigation and preparedness efforts.

Similar to WUI risk, public health is a domain that has received considerable attention in terms of addressing community-wide involvement and mitigating public health crises based on location, vulnerability, and risk assessment. We provide a brief overview of the literature in this space below.

Public Health. In addition to emergency preparedness and hazard mitigation efforts, community engagement may also take the form of public health initiatives. As outlined by Israel et al. [15], the importance of individual risk factors often minimizes some of the barriers to accessibility of treatment and related concerns in managing public health issues. This has led to an emphasis on the idea that individuals are entrenched in social, political, and economic systems that are directly linked to maintaining health. Meaning that obstacles or barriers to accessing resources can negatively influence health outcomes. Consequently, there have been movements to address these barriers through community-based health initiatives. These initiatives focus on engaging citizens to participate directly in partnerships that contribute to understanding these barriers in a way that addresses inequity [15]. For example, this has led to programs that focus not only on integrating citizens into public health initiatives, but also focus on how to self-evaluate

and measure the impact of these initiatives in terms that health organizations can leverage [16]. The design of such an assessment allows for organizations to monitor the efficacy in community involvement, ultimately leading to better outcomes for all stakeholders involved, including healthcare providers, patients, and communities.

Volunteered Geographic Information (VGI). The majority of research in stakeholder engagement beyond agency specific CRR efforts such as smoke detector initiatives, has focused on understanding the impact of involving citizens in the collection of GIS data, sometimes referred to as volunteered geographic information (VGI) [17]. This information is prevalent within the fields of GIS and geography and is gaining traction as a way for the government to gather large amounts of data. However, the quality and credibility of this information has been scrutinized for decades [18–20]. Due to the interdisciplinary nature of VGI and quality control challenges, **there currently is no existing integrative framework to interpret or apply stakeholder perceptions of security and privacy in the context of volunteered information for CRR efforts.** Moreover, there is little attention given to conceptualizing the structure of these information systems or mobile applications as *intentional communication, or dialogue,* between first responders and the citizens they serve.

We contend that these issues in crowdsourced information might hinder the creation of more comprehensive applications, as there is no current theoretical framework to paint a whole picture of how these findings fit together and how widely they can be applied. Consequently, it is critical to understand the ways to support both citizens and emergency responders in the context of these current and future data applications to better support all stakeholders involved in the process of managing hazard-related data. In subsequent sections of this paper, we draw from literature in multiple disciplines to better understand the impact of sociotechnical dimensions on community engagement in hazard mitigation.

2.2 The Changing Landscape of Emergency Response

Increasingly, new demands have been placed on first responders. As fire-based emergency medical services (EMS) have expanded, the demands and needs of emergency medical providers have shifted [21]. These new demands require a more comprehensive analysis of the information systems EMS providers rely upon to gather information about their communities and related risks. Additionally, this changing landscape requires expansion of the data management frameworks and approaches leveraged by first responders. The introduction of mobile applications to self-report medical history affords an opportunity for emergency medical providers to treat patients more effectively, but this data comes with a cost.

Additionally, this changing dynamic is impacted by the availability of information. Pre-incident plans are documents, paper or electronic, that provide essential information about a facility and its associated hazards to first responders in the event of an emergency [22]. Typically, firefighters and other first responders do not have access to pre-incident planning information for single-family homes and other residential structures outside of apartment complexes or long-term care facilities [23]. Efforts have been made to make pre-planning residential structures a higher priority, but these efforts are largely unique

to each department and their responding areas [24]. Consequently, some departments do have the time or resources to manage residential structure data in addition to their existing pre-plan program. Recent studies have demonstrated the utility of such information in the context of residential fires [23, 24].

More importantly, firefighters also face hazard risks that they may not be adequately trained or equipped to understand, such as hoarding behaviors and vacant structures [25, 26]. These hazards increase the likelihood of injuries or fatalities on the fireground, which warrants closer consideration. The availability of data associated with these hazards could potentially reduce risk of injury or fatality, but this information is difficult to obtain, and civilians may be reluctant to report these types of hazards due to broader social and ethical barriers. Care must be taken when eliciting this information from socially vulnerable populations as well to ensure sound ethical guidelines are followed.

3 Method

We conducted a scoping review to map the landscape of the existing literature to better understand how different disciplines have addressed related concerns in CRR efforts. The purpose of this review was to identify work that has focused on stakeholder perceptions of self-reported hazards in the context of CRR efforts. More specifically, we were interested in examining the existing landscape with regard to the utility and availability of self-reported hazard data from the perspective of multiple stakeholders. These stakeholders would include the civilians uploading the information, the first responders leveraging the information on the scene of an emergency, and government agencies or other agencies that may play a role in emergency preparedness efforts or data management.

The process involved three iterations and was conducted between November 2020 and January 2021. We conducted our search via the ISI Web of Knowledge, EBSCO, and Science Direct. The search terms were derived from key words used in combination such as: "self-report and hazards," "self-reported hazards," "citizen engagement and risk reduction," "civic engagement and disaster response," "citizen involvement," "citizen participation," and "vulnerability assessment."

For the purposes of our literature review, articles must have met two criteria to warrant inclusion:

1. Peer reviewed and published work
2. Involved discussion of risk assessment or community risk reduction in the context of citizen participation or engagement

We excluded articles and works that covered topics outside the scope of citizen engagement, such as epidemiology. Our search terms identified over 500 papers that were initially reviewed for relevance based on the criteria above. Of the remaining articles, all were reviewed for relevancy and duplicates. A total of 37 papers were included in this review. We aggregated findings to communicate general trends related to sociotechnical dimensions of citizen engagement in CRR efforts to guide the broader discussion on how to enhance communication between the community and first responders in the context of self-reported hazards.

4 Results

This section outlines findings from our review of the literature. First, we provide a general overview of the articles. In the following sections, we identify the emergent themes gathered from the articles reviewed. We discuss some of the challenges and opportunities associated with maintaining citizen engagement and participation, as well as some of the more practical challenges associated with data management policies and processes. Then we leverage the framework initially proposed by Barnes [29] to map the existing landscape of participation and to provide guidance to agencies interested in exploring and evaluating dimensions of public participation in the context of self-reported hazards.

4.1 Thematic Analysis

Credibility. For the last decade, VGI credibility is often cited as a concern due to the crowdsourced nature of the information and the lack of experience on the part of involved citizens [18]. However, the increasing availability and involvement of multiple stakeholders is driving change in this area [20]. Although credibility is still a concern, VGI bridges a gap that otherwise may not be addressed due to the complexity and resource-heavy requirements of collecting large amounts of data.

Despite the increase in citizen participation, this still poses challenges due to the nature of the data. In the research context we have identified in this paper, we are examining the impact of self-reported hazards *on the success* of incident management, as represented by a first responder's ability to use this information. This has critical implications due to the dynamic nature of incident response and the importance of understanding how information is leveraged in crisis situations.

If citizens are not engaged in this kind of work, it is plausible that the information submitted may not be optimized for first responder use. In that case, either the agency collecting the information, or the first responder end-users must identify and refine the information for use on the scene of an emergency. This process is resource intensive and requires multiple quality control checks, which may not present a realistic solution for public safety agencies and departments that are already managing with less staff and resources.

Privacy. Dainty et al. [2] collected data on the perception of mobile applications that crowdsourced basic life support (BLS) from civilians for cardiac arrest incidents From their data, respondents indicated that legal and privacy concerns were an important issue. For example, location tracking and misuse of the data were brought up as potential data concerns. Additionally, further work in this space focused on stakeholder perceptions and end-user perceptions of the application [1]. We contend that this dimension of privacy and information security will impact the acceptance of these risk mitigation techniques within the community due to the nature of residential structure data. If participants have previously indicated that they are uncomfortable with the tracking and monitoring capabilities of a mobile application, it will be important to capture this information in order to strategize potential opportunities for technology adoption. Additionally, residential data would allow potential adversaries to gain critical information about community homes, that could lead to potential security breaches or dangerous outcomes. Therefore, data management and security will be of critical importance moving forward.

More specifically, from a first responder perspective, some of the challenge will come from interpreting the information submitted. However, the greater challenge will be maintaining this information and keeping it secure so only authorized personnel can access the data, as outlined in the current (2020) version of the NFPA 1620 standard [22].

Reliability. One of the more critical aspects to consider is the reliability of information provided to first responders. To determine the reliability of information, it would be necessary for civilians to upload multiple versions of their data and for responders to track changes from one version to another. This presents data management challenges as first responders must work quickly and have different needs than civilian users of such a system. According to recent statistics, the average home can become dangerous within five minutes [28, 29]. Therefore, one of the more critical challenges will be presenting and displaying changes in information to first responders in a way that is easily consumed within just a few seconds.

Transparency. Given the information exchange between civilians and responders during the event of an emergency, transparency plays a critical role. As illustrated in previous research, transparency plays a role in ensuring that civilians heed warnings, as well as in practices for sound governance [32].

Trust. Trust in the context of CRR focuses on the interrelationships and connections between civilians, responders, and the public safety agency or government agency involved in risk communication processes. One of the key aspects of trust is this idea that the government or agencies having authority should be able to demonstrate that they have more resources and capabilities for identifying threats than individuals [33]. This relates to the idea of transparency, but even extends beyond that. For individuals and community members to build relationships with public safety agencies, trust is a critical factor [34].

Vulnerability. Vulnerability encompasses assessments that focus not only on physical vulnerability of property, but some of the broader concerns surrounding social vulnerability. Based upon the WUI literature and the extant literature related to citizen risk assessment, vulnerability remains an area that requires further exploration. This is because certain groups or populations may be more vulnerable than others, leading to health disparities or an inability to participate in initiatives designed to engage citizens due to accessibility barriers [35].

We summarize the important dimensions outlined in the review of the literature in the Table 1 below.

Table 1. Thematic analysis of the literature: sociotechnical themes identified

Dimension	Definition
Credibility	The level to which information gathered about hazards is actually representative. This encompasses source, as well as information credibility as well
Privacy	Refers to the general concept that all stakeholders have a right to selectively choose how information is shared about them
Reliability	The extent to which users can rely on the information (e.g., First responders are confident the information is accurate)
Transparency	Availability of information about how and why decisions are made
Trust	Belief that the intentions and behaviors of an agency or individual are inherently in the best interest of involved stakeholders
Vulnerability	The extent to which there is a possibility for harm

4.2 Framework for Public Participation

Seminal work in defining public participation focused on adopting a framework that clearly identified the key dimensions to analyze public participation. Although this paper serves as a review of the literature, it is important to identify how and why participation is required. To better understand how this applies to our work, we leverage Barnes' model to identify the key aspects of participation and to scope the problem space in terms of risk reduction efforts [29].

Whose Participation Is Being Sought. In the context of this paper, we are seeking to understand how the community or stakeholders located in a specific region, municipality, or county engage with public safety agencies in terms of data management practices. As mentioned by Barnes, it is important to distinguish ***whether the public or the user*** is the sample of interest. However, we contend that in this particular case, the users are the community or public we are referring to. This is because there are multiple stakeholders using systems designed for sharing this information across and between agencies and individuals. Therefore, *we define the users as civilians, business owners, community officials, as well as the first responders, incident commanders, federal, state, and local agencies that have access to, collect, and manage such data sources.*

Type of Knowledge Accessed Through Participation.
Perhaps most important in this framework is the type of knowledge accessed through participation. In the case of submitting information about residential structures, the type of knowledge accessed during participation is both *explicit and tacit*. We define these types of knowledge in greater detail.

Explicit knowledge is shared through recorded mediums [36]. In the case of self-reported hazard data, this information would be shared through a database or mobile application. It is recorded in the form of images, blueprints, descriptive text, and data that can be captured as artifacts for later use.

Tacit knowledge is more abstract than explicit knowledge [36]. Tacit knowledge is accessed through the ability of community members to share their experiences and through the willingness of first responders to understand and derive meaning from community member experience. For instance, studies demonstrate that tacit knowledge sharing is more likely to develop from relationship building and affect-based trust [37]. A form of tacit knowledge could be an understanding that a particular building in an area represents a community hub or area of value to that community. This could mean that in efforts to save life and property, this property is valued as central and meaningful to the community members. The ability to recognize this building as a value of the local community represents one example of how tacit knowledge could be shared between community members and first responders. This contrasts with the idea that the use or willingness to leverage tacit knowledge is grounded in cognition-based trust.

Location of Participation
Community members participate in their respective locations. Typically, this would mean the community they reside in, but in the case of some stakeholders, such as business owners, this community may be different from their residential areas. The location of public safety agencies and their jurisdictions will drive participation of these groups.

Objective and Purposes of Participation
For the sake of simplifying the objectives and purpose of this data, participation is driven by a need for more effective emergency response operations [5]. This focuses on both the civilian and first responder sides of the coin. By providing more accurate and timely information, more lives and property can potentially be saved. Therefore, the goal of participation is to enhance the ability for community members to recognize the value of this information and for first responders to build relationships with their communities, to enhance trust and transparency, and to potentially increase the ability for tacit knowledge transfer.

The Degree of Power Sharing Implied
In the context of this research, we acknowledge that civilians must understand how and when their data is being used. More importantly, there is a dynamic of power between the individuals sharing information and the agencies entrusted to store this information for use in the event of an emergency. Therefore, it would be advantageous to map the extant landscape with regard to civilian perceptions. For example, as identified by Haworth, often in emergency management, the power is perceived to be conceptualized in terms of the agencies having jurisdiction or authority over communities due to their role in managing disaster scenarios [38]. To better support the public and the end-users of these systems, we must clearly research the methods for sharing power between civilians and the responding agencies.

The Scope of Participation and the Level at Which Change is Achieved.
In the context of this work, we propose the idea that the scope of participation is limited to the extent that the sociotechnical dimensions discussed in the above sections are factored into the conversation. Participation remains limited to the willingness of the community to volunteer information, and the willingness of agencies to demonstrate sound practices for obtaining, storing, and managing the data with an emphasis on privacy and security.

5 Discussion

In this paper, we present an integrative framework that draws on previous research by classifying and synthesizing the opportunities and challenges associated with citizen engagement for self-reported residential hazards and information. We argue that such a framework is an organizing and unifying structure that accounts for enhanced communication and thus, better opportunities for more successful CRR efforts. Such an integrative framework is timely because, within the emergency response field, there exists no single theoretical perspective that can support a common communication platform. This platform would need to incentivize citizens to provide this information and would need to further evaluate the level to which law enforcement, firefighters, and emergency medical providers can rely upon this information. Initial analysis of the literature did not find evidence suggesting that a common set of terminology exists to describe community engagement. We hypothesize that a set of dimensions for classifying and understanding the user experience of multiple stakeholders could lay the groundwork for explicitly consolidating extant literature. Without further analysis it is difficult to understand what self-reporting implies for citizens, much less the challenges and opportunities for technology designers to assist in enhancing user experience. In contrast, with a framework to refer to, technology designers, engineers, citizens, and public safety agencies can easily understand how these components play a role in the success of these mobile applications and information systems.

5.1 Practical Implications

In terms of addressing some of the problems associated with collecting, managing, retrieving, and storing residential data, one of the major areas for concern that we identified was the credibility of the information. As previously outlined by Flanagin and Metzger [18], volunteered information presents challenges due to the nature of the work. The individuals volunteering the information typically do not receive adequate training and may not be interested in some of the more practical aspects of learning about the science of fire behavior. Consequently, some information may be misrepresented. Meldrum et al. [10] highlighted similar concerns in their study on assessing property risk. This was due to individual property owners' lack of understanding surrounding wildland fire behavior. Thus, this review demonstrates the importance of considering how training for civilians could and should be implemented to better support public safety agencies.

However, this also poses practical challenges for public safety agencies who need to secure funding for training, allocate staff to run the training, and find methods for providing the training across the community, to reach multiple groups of stakeholders. A seemingly straightforward concern can quickly morph into a barrier for some departments and agencies already struggling to obtain adequate funding and resources to develop more effective programs. Despite these challenges, there are also benefits and opportunities that we have captured in the section below to demonstrate the potential positive impact of these programs.

5.2 Theoretical Implications

Community building and relationship building remain important factors that drive the success of emergency response agencies [34]. By identifying the sociotechnical dimensions inherent in self-reported hazard communication, it is possible to enhance the channels through which emergency response operations are managed. Although we mentioned some of the more practical challenges in the above section, it is also valid that through this framework, there is a potential to change public perceptions of public safety agencies to facilitate more effective communication, particularly in the context of emergency preparedness and hazard mitigation efforts. However, this framework has not been experimentally tested and therefore, empirical analysis is necessary to validate this framework.

5.3 Conclusion

We emphasized aspects of sociotechnical systems that are important for identifying ways first responders and citizens can communicate with one another through self-reporting hazard applications. We identified some of the dimensions that would prevent citizen engagement in reporting self-hazards, and we described how these dimensions, if addressed in information systems, can facilitate two-way communication. We outlined the advantages of citizen engagement, with a focus on the contribution of such an approach to our understanding of risk reduction, grounded in two-way communication between first responders and the citizen they serve. Then, we presented a brief overview of the user experience framework and discuss its dimensions. These dimensions are described in terms that can be measured and evaluated in empirical studies. Thus, the combination of dimensions used to construct the framework provides movement towards a clearer definition for effective two-way communication, which in turn is expected to predict the actual degree of citizen engagement and emergency response agency engagement. More importantly, *this framework can be used to define the development of mobile applications, tools, and other related information systems in which multiple stakeholders are sharing information.* Without a detailed description of the constructs that underpin communication between civilians and first responders, it would be difficult to design systems that facilitate this relationship. On the other hand, with a set of definitions, more informed decisions and recommendations can easily be made during the creation of these tools, therefore enhancing the perception of the multiple stakeholders utilizing these tools for CRR. This paper presents a research plan with an overarching goal to help ensure that community risk reduction software and mobile applications for emergency response are developed systematically with scientific validation principles grounded in HCI best practices. The result of this plan and future work will be a set of best practices to improve communication between first responders and community stakeholders.

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