SafeSigns: Enabling Community Resilience Communication for the Deaf and Hard of Hearing

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ABSTRACT

Emergency Management (EM) strategies often overlook the communication challenges faced by the Deaf and Hard of Hearing (DHH) community, limiting their involvement in disaster preparedness and response. This paper introduces *SafeSigns*, a geospatially enabled toolkit designed to bridge this gap by facilitating hazard reporting and communication by and for DHH individuals. By integrating Geographic Information Systems (GIS) with user-centered design, *SafeSigns* empowers users to report incidents, identify hazards, and coordinate with Public Safety (PS) officials. Unlike traditional EM technologies, which rarely prioritize accessibility, *SafeSigns* leverages ArcGIS Pro, React Vite, and TypeScript to ensure usability, efficiency, and accessibility. This research represents one of the first ISCRAM-related efforts to explicitly include DHH communities in EM. Findings support a more inclusive and participatory approach, demonstrating the significance of geospatial solutions in enhancing community resilience. Future work will refine *SafeSigns* through real-world testing and explore applicability to other vulnerable populations in disaster response.

Keywords

Deaf and Hard of Hearing Community, Community Resilience, Geospatial technology, IT Solutions, Emergency Management

INTRODUCTION

DHH and Emergencies

In the United States (US), the Deaf and Hard of Hearing (DHH) community is estimated to include over 11 million people (NDC, 2024). The DHH community has a range of complex identities, sociocultural norms, lack of English fluency, and communication preferences including those who use sign language (e.g. American Sign Language (ASL) or Signed Exact English (SEE)), a mix of visual/audio communication methods (e.g. ASL and spoken language), or spoken language and lip reading. In the US, most DHH signers use ASL as their primary language, which has a unique grammar and syntax different from English (Richardson, 2014). The DHH community represents an important yet often overlooked segment of the population when it comes to Emergency Management (EM) (Agrawal et al., 2008; Engelman et al., 2013). There are still critical gaps in the availability and accessibility of essential emergency resources for the DHH community, even though there have been major advancements in emergency response and prevention strategies. Understanding the challenges faced by the DHH community during emergencies is the most important step toward providing effective EM for this community (Hall et al., 2015). One of the most fundamental challenges with the DHH communities and EM is communication. Addressing this issue requires innovative solutions that empower the DHH community to participate in emergency preparedness and hazard reporting (Engelberg et al., 2019).

This paper presents *SafeSigns*, a geospatially enabled toolkit designed to facilitate communication and hazard reporting with a primary focus on the DHH community. While the platform is built using inclusive design principles to allow broader use by hearing users and Public Safety (PS) officials, *SafeSigns* centers DHH individuals as its core audience and co-designers. The toolkit is intended to empower DHH users to report community hazards, particularly those that may disproportionately affect them, while fostering a more inclusive emergency communication ecosystem. *SafeSigns* aims to provide DHH individuals with a grassroots voice in community resilience efforts by leveraging geospatial technology. The paper begins with a review of existing literature on emergency communication for DHH individuals and the role of geospatial technologies in disaster response. It then introduces *SafeSigns*, detailing its design, user insights, and its technical implementation. Finally, it discusses the implications of this work and outlines future directions for evaluation and improvement. To the best of our knowledge, this represents some of the first ISCRAM-related research to focus on enabling the DHH community to have a voice in community resilience efforts let alone any ISCRAM-related research related to the DHH.

LITERATURE REVIEW

Emergency Communication Challenges for the DHH Community

Several studies highlight gaps in emergency preparedness and response for the DHH community. Engelman et al. (2013) highlight critical gaps in emergency preparedness for the DHH community, revealing that both state-level EM agencies and Community-Based Organizations (CBOs) lack sufficient training and resources to effectively serve DHH individuals during emergencies. Research by Neuhauser et al. (2013) confirms these findings, showing that most existing emergency preparedness materials are not suitable for the DHH community.

Limited availability and poor readability of these resources add to the communication barriers already faced by DHH individuals in crisis situations. Similarly, Calgaro et al. (2021) explores the challenges that the DHH community faces in Disaster Risk Reduction (DRR) and identify the factors that increase their vulnerability in disaster scenarios. Their research shows that lack of accessible information and limitations in effective disaster response are some of the main causes for this group's vulnerability. The study also presents community-driven resilience-building solutions and tracks the outcomes of these solutions over six years, offering valuable insights into the long-term challenges and successes of implementing inclusive DRR practices.

Communication problems, combined with a general lack of awareness among PS professionals about the specific needs of DHH individuals, are a key factor that underlies gaps in emergency services for DHH communities (Neuhauser et al., 2013). Communication barriers often stem from language discordance between DHH ASL users and English-speaking emergency first responders. These barriers are often compounded by inadequate training for emergency first responders, discomfort in caring for DHH, delayed dispatching of emergency providers, and incomplete knowledge of disaster preparedness or recovery tools by DHH community members (Rotoli et al., 2021; Takayama et al., 2022). For example, delayed deployment and lack of ASL interpreters negatively impacted bi-directional communication and information exchange between emergency first responders and DHH communities during hurricane Katrina (White, 2006) and after the 2024 mass shootings in Maine (Karimi, 2023).

Community Resilience and the Role of Geospatial Technology

Community resilience has been defined as "the ability of a community to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions" (FEMA, 2020). Effective communication of risk has been found to be a critical element of community resilience (Houston, 2018; Houston et al., 2015). One particular communication issue critical to community resilience absent in the literature is ensuring that the DHH community has a voice in community resilience activities. This gap is not only a communication challenge but also a fundamental equity issue. Meaningful participation in resilience planning requires accessible channels for engagement, yet DHH individuals often face barriers to inclusion due to inadequate accommodations, such as a lack of qualified interpreters, captioning, or accessible emergency alerts. Also importantly, community resilience is often fundamentally geographic in nature, involving complex interactions between people, places, and the environments in which they live. Community resilience efforts that originate from the bottom up, "grassroots"-level are essential for ensuring that individuals at risk, such as those in DHH communities, can participate in identifying and addressing local hazards.

There is currently a dearth of Information Technology (IT) mechanisms that provide the DHH community opportunities to have a grassroots voice about hazards in their community. For example, during focus groups discussion we undertook with DHH community members as a precursor to the work presented here, community resilience and emergency communication were highlighted as an area of concern. Specifically, when testing geospatial mapping tools - precursors to *SafeSigns* - designed to help DHH community members to map hazards within their neighborhoods, participants expressed that having the ability to map hazards in their communities gave them a "voice" in community engagement, as they often feel unheard.

Geospatial technology has a wellknown precedent in the literature for use in community resilience mapping efforts, including Volunteer Geographic Information (VGI) and crisis mapping (Tomaszewski, 2021). Geospatial technology such as Geographic Information Systems (GIS), remote sensing, and Unmanned Aerial Vehicles (UAVs) have become well-established in EM practice around the world (Horiike et al., 2019). Bhanumurthy et al. (2015) studied the deployment of GIS methods during Hurricane Sandy in New York City, demonstrating the potential of GIS to identify vulnerable populations and aid resource management (Bhanumurthy et al., 2015). Similarly, Manfré et al. (2012) investigated the use of remote sensing, GIS, and Global Navigation Satellite Systems (GNSS) in managing various aspects of disaster scenarios, from damage mitigation to recovery (Manfré et al., 2012). By providing a means for DHH individuals to crowdsource hazard information, these geospatial tools can help strengthen the "information chain" between the community and PS officials. Research also shows that geospatial technology and mapping tools can be used by emergency managers to improve local disaster responses for people with disabilities (Enders & Brandt, 2007).

RESEARCH QUESTION AND SAFESIGNS TOOLKIT

With this background, in this pilot work, we investigated how geospatial technology can be leveraged as an IT solution to enhance community resilience by providing DHH individuals with a stronger grassroots voice in community resilience activities. To address this question, we present *SafeSigns*, a geospatially enabled toolkit specifically designed to enable DHH community members to identify, map, and communicate hazards within their communities with an information flow to PS officials (Figure 1).
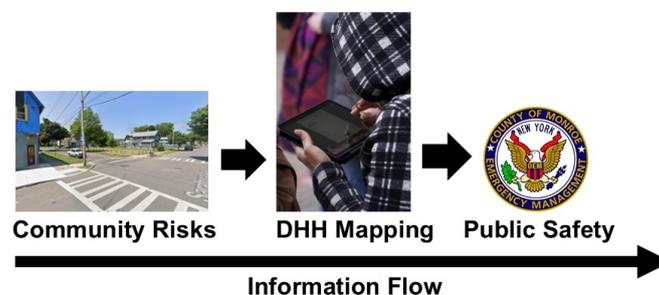

Figure 1. *SafeSigns* conceptual model. *SafeSigns* is envisioned to allow the DHH community members to map hazards in their community with an information flow up to PS officials.

SafeSigns is envisioned to play an important role within the broader framework of enpowering the DHH community to independently assess and communicate hazards in their environment.

SAFESIGNS DESIGN AND DEVELOPMENT

User-Centered Design and Community Collaboration

SafeSigns has been envisioned to enable DHH community members to pinpoint hazards using an accessible application, while PS teams and other stakeholders can receive this crowdsourced data, enabling rapid and informed responses, like seen in Figure 1. The outcomes and tools developed through this research are intended to be scalable, ultimately enhancing the resilience of DHH communities in the face of emergencies. *SafeSigns* aims to demonstrate how DHH community members can be involved throughout the development process, ensuring that solutions are practical and user-friendly, making EM more inclusive. Another goal of *SafeSigns* is to raise and enhance situational awareness among PS officials, ensuring better responsiveness to DHH individuals' unique needs during emergencies. The toolkit contributes to emergency responsiveness by empowering the DHH community and facilitating more inclusive emergency response practices (Calgaro et al., 2021). *SafeSigns* is also envisioned to play a crucial role in bridging gaps in EM services for DHH individuals.

Designing Interfaces for the DHH Community

Existing Human-Computer Interaction (HCI) research on interface design for DHH users has revealed common patterns in DHH behavior, which researchers have translated into sets of heuristics. Some of these heuristics build upon Jakob Nielsen's ten heuristics (Aristizábal et al., 2019; Nielsen, 1994) for interface design, adapting them to better meet the needs of DHH users. Several studies have reached conclusions similar to Nielsen's heuristics through research involving DHH participants, including those by Dingman et al. (2021), Hutter and Lawrence (2018), Liu et al. (2022), Mack et al. (2020), Nathan et al. (2018), and Schefer et al. (2018). While it is debatable whether these findings represent a form of theoretical convergence or implicit bias in usability research, their alignment with Nielsen's heuristics suggests the broad applicability of these principles to DHH user experiences. This recurring emphasis on Nielsen's heuristics in accessibility research highlights their continued relevance in shaping usability frameworks and design guidelines for DHH users.

Nielsen's heuristics are based on observations of cognitive behavior, but they do not mention accessibility (Nielsen, 1994). HCI researchers such as Schefer et al. (2018), Nathan et al. (2018), and Mack et al. (2020) address this gap by examining accessibility challenges for DHH users. Many of these studies highlight observable communication challenges, aligning them with Nielsen's second heuristic, "match between system and the real world," by emphasizing the need to "speak the user's language" (Nielsen, 1994). HCI researchers are not alone in recognizing the communication gap (W3C, 2019, 2024); the World Wide Web Consortium's (W3C) guidelines also address alternative forms of communication for audio content (W3C, 2024). Yet focusing narrowly on translating audio content risks solutions that may exhibit cultural appropriation, audism, or technological paternalism.

Another approach to accessibility research within HCI that is gaining traction is value-based design (Boeijen & Zijlstra, 2020; Hutter & Lawrence, 2018; Mack et al., 2020). Value-based design acknowledges individual abilities but focuses much more on the collective values of the cultural groups individuals are associated with (Boeijen & Zijlstra, 2020). Hutter and Lawrence (2018) and Mack et al. (2020) both reference the values of the DHH community that play additional roles in communication. Hutter and Lawrence's research (2018) focused on in-person usability testing with DHH participants, where they found that interpreting for DHH individuals influences trust, and that proper communication requires special preparations. Mack et al. (2020) recognize the physical limitations of one-handed signing on the phone, the desire to educate others about DHH culture, and many other DHH values. The findings of these researchers suggest that working with DHH communities could benefit from a more culturally nuanced approach (Hutter & Lawrence, 2018; Mack et al., 2020).

Context of Technology During Emergencies for the DHH Community

One of the most important factors in all aspects of EM that HCI researchers agree on is communication. DHH communities usually experience feelings of isolation that have roots in audism (Hutter & Lawrence, 2018), even outside of emergency situations (Mack et al., 2020). There are multiple barriers for communication for DHH individuals when an emergency situation like a natural disaster or medical emergencies occur. These barriers are related to trust, English language proficiency, and autonomy (Calgaro et al., 2021; Liu et al., 2022; Simko et al., 2023). Technology is used in different ways to try and overcome these barriers, but there are limitations (Liu et al., 2022; Simko et al., 2023) and designing communication solutions for DHH communication is a complex social and technological task (Calgaro et al., 2021; Liu et al., 2022).

Trust has a significant influence on a DHH individual's willingness to communicate during emergencies (Calgaro et al., 2021; Liu et al., 2022). Outside of the US, Calgaro et al. (2021) describe a complex "trust network" involving DHH individuals, their peers, close hearing friends and family, and Emergency Medical Services (EMS) personnel.

The study found that DHH individuals trust information from close hearing contacts more than from DHH peers. Difficult experiences with EMS personnel who are unfamiliar with DHH communication can have a negative impact on trust (Liu et al., 2022).

Liu et al. (2022) tackle this problem by defining a utility-cost model which suggests that reporting an emergency is a rational choice. Kahneman and Klein (2009) indicate through extensive research that human decision-making often relies on heuristics and biases rather than just rationality. Liu et al. (2022) also show in their studies that emotional support during real-time text-based communication could determine how much critical information the reporters might be willing to share, but EMS personnel may not offer such support in certain emergency categories or when the reporter remains anonymous. This invisible bias makes it harder and more complicated to build trust with DHH communities (Calgaro et al., 2021; Kahneman & Klein, 2009; Liu et al., 2022).

Mutual understanding has a significant effect on trust building and it can not happen as long as there is no shared language (Calgaro et al., 2021; Liu et al., 2022). Since 90% of DHH people are born to hearing parents (Mitchell & Karchmer, 2004), and only a small percentage of these parents learn ASL, some DHH individuals have limited exposure to early language (including ASL) and have limited access to education in written language leading to low English literacy rates. Given the range of communication needs and abilities, building trust and effective communication generally requires multiple modalities rather than a single universal solution.

Simko et al. (2023) showed that most technologies are designed without taking emergency situations into consideration. Video relay systems which are crucial to DHH users during emergencies are extremely vulnerable if there are infrastructure failures. In their study of technology usage during hurricanes, Simko et al. (2023) observed that people ration resources, turn off devices, or attempt to adopt new tools when connectivity is compromised. They suggested adaptive features for emergency contexts, such as selectively compressing certain parts of video calls to conserve bandwidth.

Although texting (including text-to-911 services) is available in parts of the US, both texting and calling 911 can become unreliable during major disasters (FCC, 2020). Moreover, the Federal Communication Commission (FCC) still advises making a voice call to 911 "whenever possible", implying voice calls offer superior service which risks promoting audism (FCC, 2020; Hutter & Lawrence, 2018). All of this shows how difficult and challenging it can be for DHH individuals to reach even the baseline communication standard available to hearing peers in emergencies.

There is not much research addressing GIS and interactive maps for DHH individuals, and GIS practitioners have to rely on cartography and visual design principles (e.g. Gestalt principles (IxDF, 2016), color theory). While some HCI studies, such as those by Kuparinen et al. (2013) and Liu et al. (2022) explore how people interact with mapping technologies, the broader User Experience (UX) design of geospatial User Interfaces (UIs) remains under-examined. Kuparinen et al. (2013) proposed heuristics for interactive mobile maps, closely aligning with Nielsen's ten heuristics. Liu et al. (2022) investigated conversational interfaces for wayfinding. However, new types of UIs, especially those used in emergencies, require unique spatial thinking and behavioral changes that are not fully covered by existing HCI or Geographic Information Science (GIScience) research. This further indicates the need for more specialized studies that consider both cultural and accessibility-related nuances for DHH communities.

DHH User Insights and Prototype Design

Guided by the aforementioned discussed user-centered design ideas, the technical implementation of the *SafeSigns* platform presented here was designed and developed primarily based on information and comments obtained from focus groups with members of the DHH community based in Monroe County, NY, in 2024. Two focus group sessions with a total of 11 participants were conducted to evaluate the usability and effectiveness of *SafeSigns*. Informed consent was obtained before the sessions began. The first group consisted of five DHH students from the National Technical Institute for the Deaf (NTID), ranging in age from approximately 18 to 25, while the second group included six DHH community members from the Rochester Recreation Club for the Deaf (RRCD), with ages ranging from approximately 50 to 70. Focus group sessions were led by a hearing facilitator. An ASL translator was present in each session to ensure that DHH participants could understand the questions being asked (Figure 2).

Figure 2. A focus group discussion to review prototypes of *SafeSigns* with Science, Technology, Engineering and Mathematics (STEM) students at the NTID.

During the sessions, participants were guided through a structured evaluation process in which they interacted with paper prototype screens and key features of *SafeSigns*. They were asked to complete tasks that evaluated the accessibility, ease of navigation, and overall usability of the tool. Throughout the discussions, participants were encouraged to ask questions and provide feedback, including any concerns or suggestions for improvement, with a focus on how well the tool met their needs for emergency preparedness and community hazard reporting. These sessions generated valuable insights that informed refinements to enhance *SafeSigns'* effectiveness for the DHH community. Based on DHH focus group sessions, several high-priority features and recommendations were put into practice as the fundamental components that make up the *SafeSigns* platform.

One of the most important recommendations of the DHH personnel from these sessions was to have clear instructions and training for DHH users to be able to easily navigate the platform and report hazards without causing confusion or frustration. This, in turn, would foster greater confidence and trust in the platform from the DHH community. Another major question was what types of hazardous events the platform would be able to cover. Participants requested a broad set of hazard categories, including ones that are more relevant and have a higher chance of occurrence for the DHH community such as power outages and medical emergencies. They also encouraged close collaboration with DHH groups to ensure responsiveness to DHH perspectives. Some other noteworthy features were the addition of a login system and user profiles for different groups of individuals, such as the DHH community and PS officials which allows the platform to customize the experience based on their specific needs and implement relevant communication strategies. The addition of a notification system was also mentioned not only for PS officials to be immediately notified of new hazard reports, but also for users to be notified when there is an emergency in their proximity.

Although core functionalities and concerns were the main focus of the discussions, other ideas that could help improve the platform were considered as well. Some participants proposed that the platform dynamically adjust the visibility of a reported hazard based on how many users either confirm or disconfirm its validity. In addition, there were some concerns regarding the frequent lack of real-time information on radio and television broadcasts; a proposed solution involved adding ASL videos with a Certified Deaf Interpreter (CDI) to convey critical updates. Others mentioned the possibility of adding social networking capabilities or other interactive elements to further engage the community. While many of these recommendations may play a role in future development, the community resilience communication aspects of *SafeSigns* were deemed a priority for the first iteration of *SafeSigns*.

In summary, the focus group discussion provided a framework for both the design and technical implementation of the *SafeSigns* platform based on (a) the need for clear guidance, (b) accessible notifications, (c) expanded hazard categories, and (d) robust communication features that align with DHH cultural and linguistic preferences as per the discussion in the previous section.

SafeSigns was designed specifically with DHH users in mind by incorporating insights from accessibility-focused HCI research and continuous feedback from DHH focus group participants. Unlike generic hazard reporting tools, *SafeSigns* will emphasize non-verbal communication, customizable notification systems, simplified navigation patterns, and future integration of ASL-based guidance. The platform will also be culturally responsive, incorporating DHH communication preferences and user testing to reduce barriers created by low English literacy or lack of auditory alerts. These design decisions are embedded throughout the interface to ensure the platform is not just accessible, but meaningfully usable by DHH individuals.

SAFESIGNS TECHNICAL IMPLEMENTATION

In the first phase of the *SafeSigns* technical implementation, the main goal was to create the core platform for deployment of all the aforementioned features. Because of the geographic focus of community resilience, a geographic base map was created in ArcGIS Pro by implementing census tracts and other demographic data to highlight DHH population distributions and potential hazards. This base map was created due to communications with our PS officials where they indicated having very limited to no knowledge of where DHH community members are located. Thus, although we recognize that this is not ideal in terms of data resolution, the census track-level data provides a baseline for understanding of the locations of special needs populations. *SafeSigns* can also utilize different GIS tools and services such as query features by taking advantage of Esri's strong infrastructure and frameworks. The created base map will serve as the core underlying data infastructure for building all the subsequent features and functionalities.

ArcGIS Pro was selected for this phase of development due to its advanced geospatial capabilities and institutional availability, which allowed rapid prototyping of *SafeSigns'* core functionalities. However, this reliance may limit long-term accessibility. Should SafeSigns transition into a fully open-source deployment model, the plan is to migrate its geospatial components to widely adopted alternatives such as QGIS for analysis and Leaflet for web-based mapping.

SafeSigns is implemented as a browser-based Progressive Web App (PWA), ensuring that users can access the platform using standard web browsers on any device without requiring installation. Optional install features (e.g., 'Add to Home Screen') are available to enhance accessibility but are not mandatory for full functionality. This decision was made to minimize access barriers for users with varying digital proficiency. React Vite (Vite, 2025) and TypeScript (TS, 2025) were implemented to ensure a responsive accessible user interface. React's compatibility with Esri's mapping libraries enables embedding of interactive maps into the PWA (Esri, 2025). Using TypeScript with React enables type checking and code maintainability, reducing the likelihood of runtime errors and making the development process more efficient.

This integration also ensures real-time user interaction and reporting hazards with minimal latency - thus ensuring communication performance and accessibility. In this context, 'real-time' refers to dynamic interactions within the platform, such as role-based view changes, hazard status updates, and visual feedback occuring without requiring page reloads. While periodic refreshes could achieve similar functionality, this implementation offers smoother transitions and improved responsiveness, which are critical for usability, particularly for DHH users navigating under stressful emergency conditions. The choice of React also supports future expansions and enhancements of the platform without compromising performance which goes hand in hand with scalability in the future. In its current form, the platform supports hazard reporting process, which enables users to pinpoint hazard locations on the map, select relevant categories, and add descriptions or multimedia evidence. A review step prior to submission was also incorporated, giving users an opportunity to confirm or adjust their reports.

Four user roles were created to structure access and permissions (Table 1): Guest (view hazards without logging in), Registered (submit hazard reports), Special (PS officials who can confirm or resolve hazards), and Admin (full oversight of the platform). Google's Firebase (Firebase, 2025) is utilized for managing user authentication and permissions. Firebase offers a reliable and scalable solution for handling user data, ensuring secure login processes and efficient management of user roles. Integrating Firebase with React Vite helps to simplify user registration, login, and role assignment. Firebase was selected for the initial phase of development due to its ease of integration with React and its robust authentication features, allowing us to quickly prototype core functionality. However, there are risks to relying on third-party services. If *SafeSigns* evolves into a production-level or open-source tool, the plan

is to migrate user management to a self-hosted solution or an open-source identity provider to ensure long-term sustainability and autonomy.

User Role	Permissions and Features
Guest	View existing hazard reports
Registered User	Submit new hazard reports; view existing hazards
Special User (PS Official)	Confirm, resolve, or remove hazards; respond to reports
Admin	Full access: user management, hazard control, system oversight

Table 1. User roles and associated permissions on the SafeSigns platform.

SafeSigns employs a modular client-cloud architecture. The frontend is a React-based PWA, while authentication and user management are handled through Firebase. Spatial data and map services are served through Esri's ArcGIS online infrastructure, which allows cloud-hosted feature layers and geospatial services to be queried and updated directly by the client. This architecture minimizes the need for a self-managed backend server while supporting real-time interactivity and scalability as displayed in Figure 3.
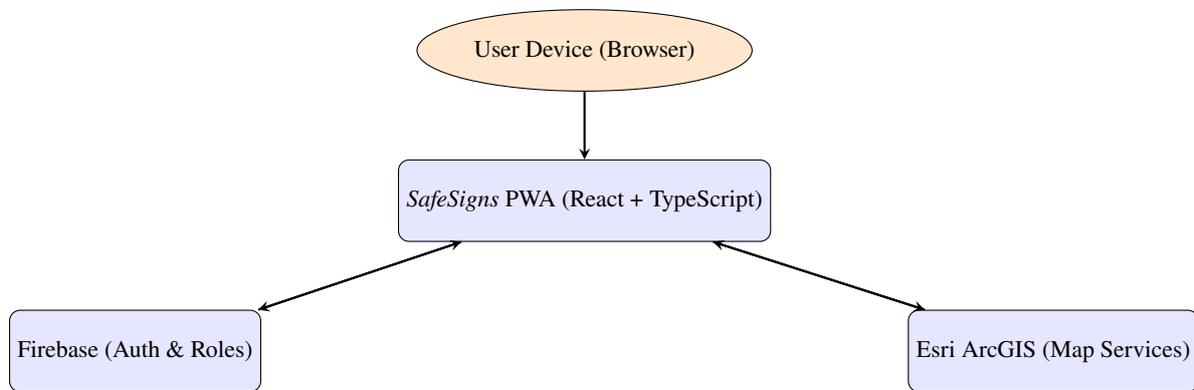
Figure 3. System architecture of *SafeSigns*, showing client-side interactions with Firebase and Esri cloud services via a browser-based PWA.

To reduce spam and ensure data quality, the initial version of *SafeSigns* requires users to register before submitting hazard reports. However, we recognize that registration can be a barrier for some users, particularly in emergency contexts or among those with limited digital proficiency. Future iterations of the platform will explore support for semi-anonymous submissions, where users can report hazards without full registration, but essential metadata is still preserved for moderation and trust management.

In recognition of the sensitivity of hazard data when submitted by or about vulnerable communities like the DHH, *SafeSigns* is planned to implement a tiered visibility model. Hazard reports will initially be marked as 'unconfirmed' or 'unverified' and only accessible to special users (e.g., PS officials) for review. Public display of reports may be delayed or restricted based on verification status or community reporting thresholds. This layered approach helps reduce misinformation risks while preserving users' ability to share concerns in real-time. The team is also exploring options for report anonymization and custom visibility settings to further support responsible data sharing and building trust within the community.

Throughout the design process of the *SafeSigns* platform, particular attention was paid to ensuring accessibility for DHH communities based on feedback from the aforementioned focus group discussions. Hazard categories and subcategories included with *SafeSigns* reflect the concerns expressed by these communities in the focus group. These inputs helped refine the interface to make it easy to navigate and inclusive for users with varied technical skill levels.

SafeSigns Walkthrough of Reporting a Utility Emergency Hazard

In this section, we provide a walkthrough of *SafeSigns* to demonstrate how users with different roles can utilize this platform during a utility-related emergency. We also evaluate the user experience of reporting a hazard and highlight the tailored features for each user role on *SafeSigns*.

In this scenario, a registered DHH individual encounters a dangerous situation involving a downed power line. The following procedure shows the steps taken by the user to report the hazard and notify PS officials as quickly as possible.

Registered User Walkthrough

Opening the Web Application

The user opens *SafeSigns* using a smartphone, tablet, or personal computer. The user also has the option to create a shortcut to the the *SafeSigns* website for faster access during emergencies. In the future, a cross-platform version of the application will be made available on different devices for easier access and navigation.

The user is then prompted to log in to their registered account using their credentials or to create an account if they have not already done so, as shown in Figures 4a and 4b. If the user has previously logged in to the platform, there is no need to go through the login process again.
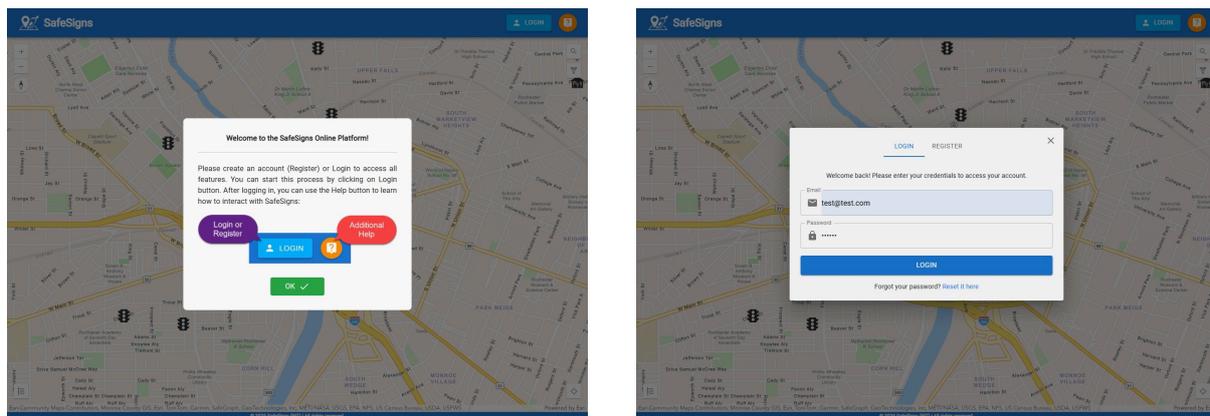
(a) The user being prompted to log in or register.   (b) The registered user logging in with their credentials.

Figure 4. Login and registration process.

Initiating a Report:

After successful login, the "Add Hazard" button becomes available in the interface. The user can click the "Add Hazard" button at the top right corner of the map and the platform opens the hazard reporting form as shown in Figure 5.

The user can utilize the "Find Exact Location" option on the bottom right of the map to find the current location instantly. The "Search" option on the top right can also be utilized to find a desired location (Figure 5).
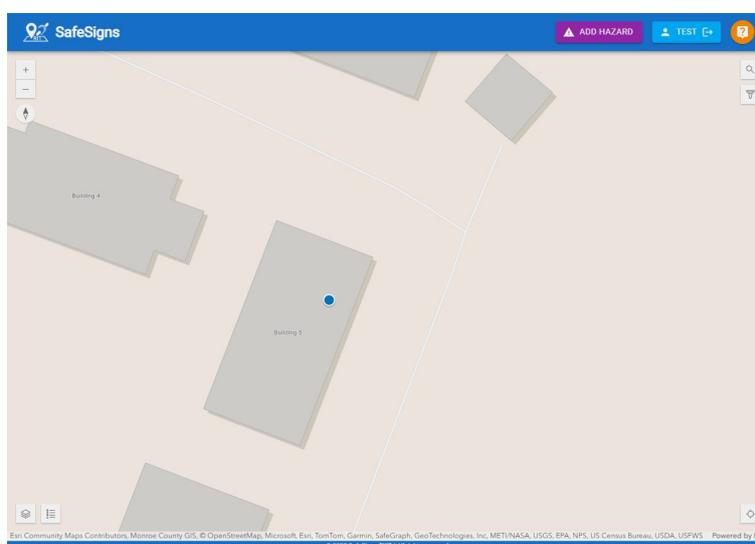

Figure 5. The "Add Hazard" button becomes available and the user locates their precise location.

If the user requires assistance with the hazard reporting process, there is a help button available on the top right corner of the map shown as a question mark which can be seen in Figure 6.
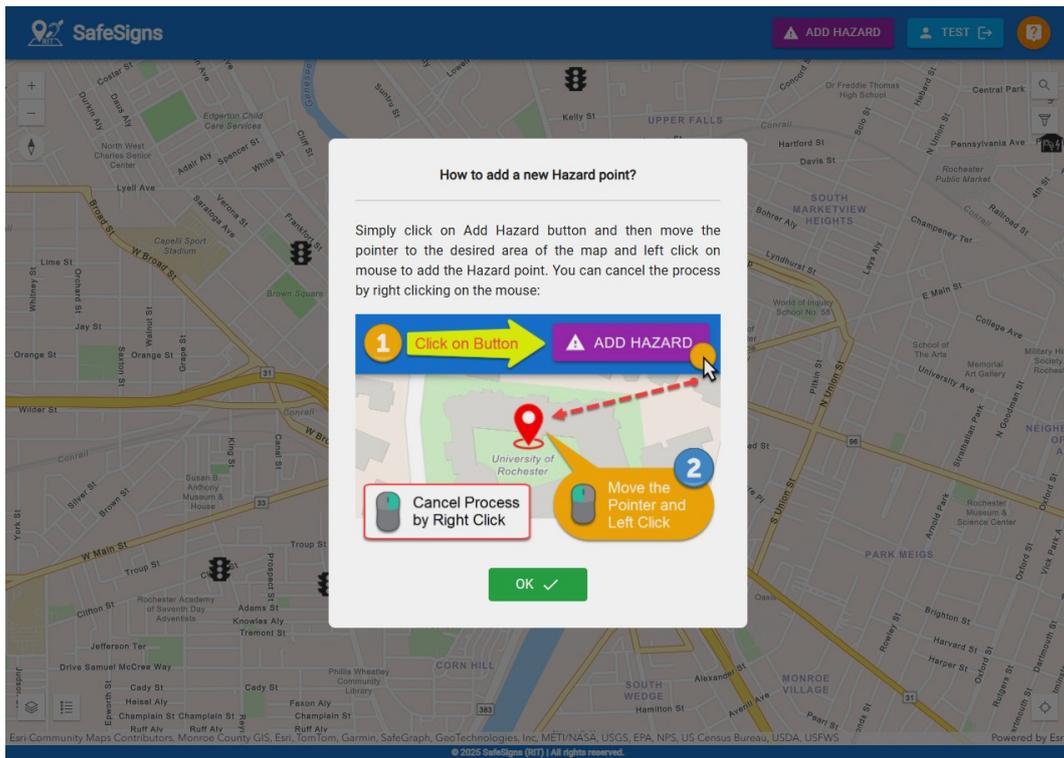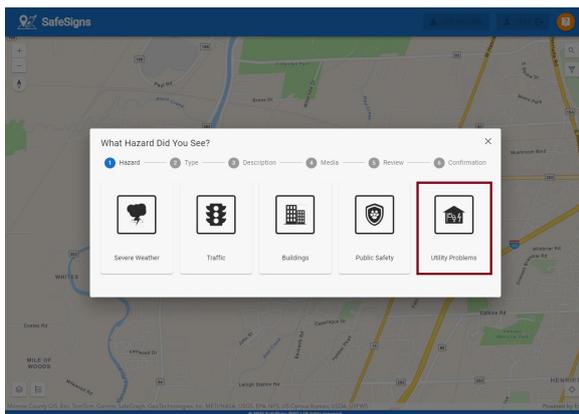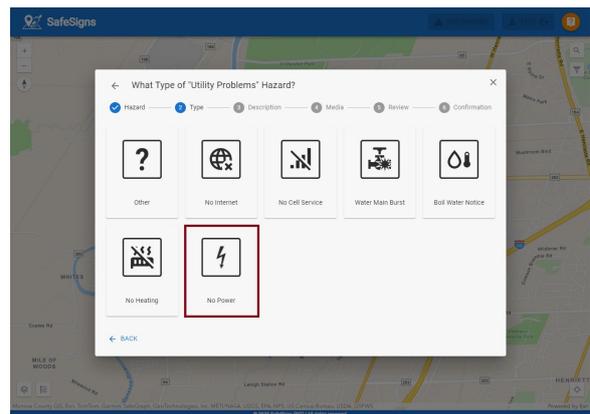

Figure 6. User requires assistance with the reporting process and clicks the help button.

Choosing Hazard Categories:

The system then prompts the user to select the type of hazard. The user chooses "Utility problems" as the main category (Figure 7a) and "No Power" as the sub-category (Figure 7b).

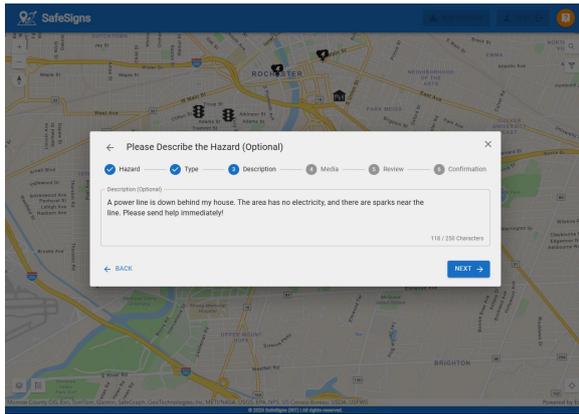

(a) Choosing "Utility Problems" as the main category.
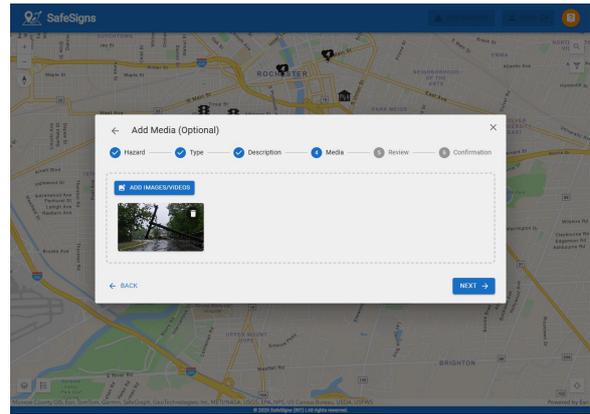
(b) Choosing "No Power" as the sub-category.

Figure 7. Choosing hazard categories.

Providing a Description and Media:

The user can add description to their report for additional clarity and upload a photo or a video for visual verification (Figures 8a and 8b).
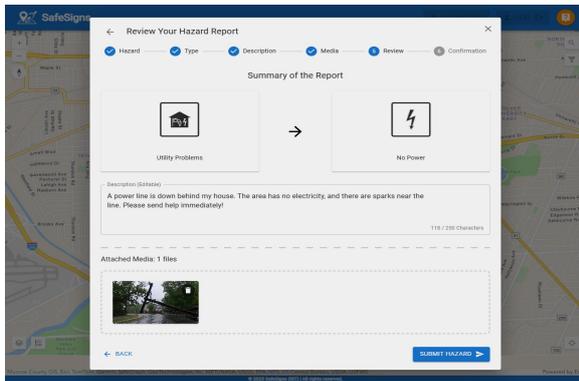
(a) Adding description to the report.   **(b) Adding images/videos to the report.**
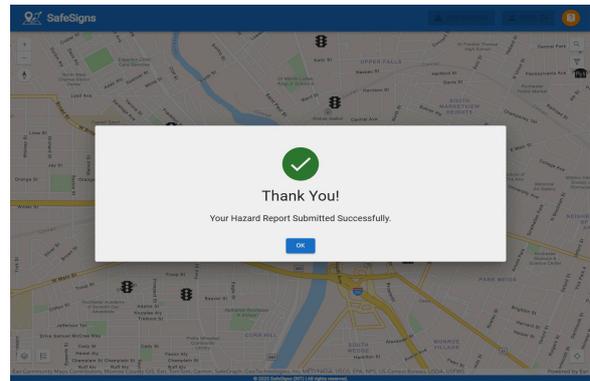
Figure 8. Providing description and media.

Reviewing and Submitting:

The user reviews all inputs and submits the report. A success message confirms the submission, and the hazard is now visible to other users on the map (Figures 9a and 9b).

(a) Reviewing the inputs before submission   **(b) Success message confirming the submission**

Figure 9. Review and submission process.

Special User Walkthrough

After the report is submitted, a special user such as a PS official, will be able to access the report and confirm the credibility and severity of the hazard. Special users have access to enhanced features like hazard status updates as shown in Figure 10.
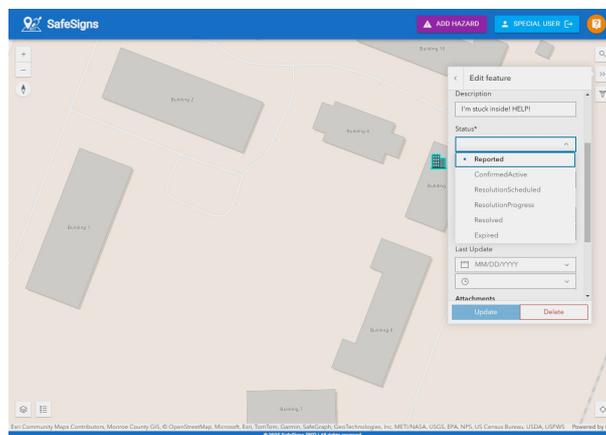

Figure 10. Enhanced features for special users.

Special users can also update hazard reports or remove them after they have been resolved. A notification system will also be implemented in future iterations to ensure efficiency and immediate access to user generated reports. This will help enhance responsiveness for PS officials.
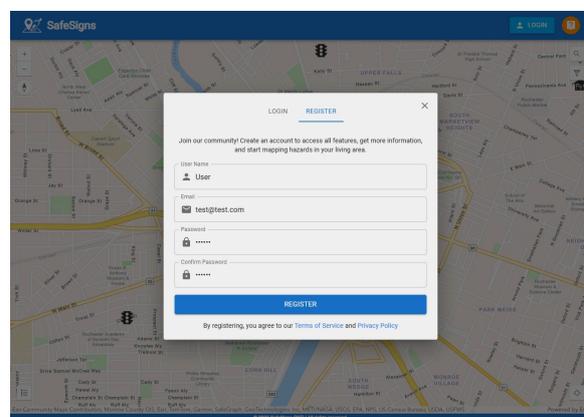
Admin and Guest Users

The admin user has full control over the platform; can manage user accounts, add or remove hazards, and oversee the overall operation of *SafeSigns*. At present, the *SafeSigns* platform and its underlying database are managed by the research team leading the project. However, we acknowledge the importance of transparency and user trust in administrative oversight. As part of the long-term deployment strategy, we plan to implement a formal governance framework with input from DHH community organizations and PS agencies. This model will define protocols for appointing admin users, outlining responsibilities, and ensuring that all administrative actions are subject to review and accountability.

The guest user can navigate to the *SafeSigns* website. The platform displays an interactive map with visible layers, including current hazards (Figure 11a). The user can locate hazards on the map and check if an emergency has been reported. The guest user can view existing reports but cannot add new ones or edit data. The platform prompts the guest user to log in or register to report the hazard, guiding the individual through the necessary steps to become a registered user and get access to the report submission features as shown in Figure 11b.
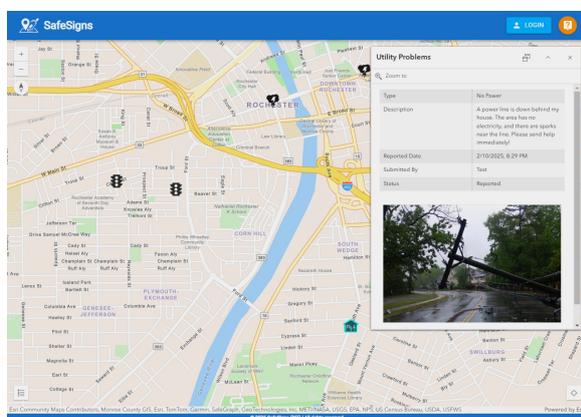
(a) Viewing the detailed information of a hazard on the map.   (b) Registration process for a new user.

Figure 11. Guest user overview.

ONGOING AND FUTURE WORK

The core functionalities of the *SafeSigns* platform are now operational and the next phase will be focused on equipping DHH community members with the knowledge and resources to take full advantage of *SafeSigns*. Training sessions and workshops will be conducted alongside the creation of video tutorials in ASL, written guidelines, and additional recommended formats. The plan is to introduce *SafeSigns* at DHH community events and gather hands-on feedback for ongoing improvements by collaborating with DHH organizations. Additional user interviews and experience testing will be conducted to ensure that the functionalities and features which are in development align with the goals and needs of the DHH community.

Other methods of communication, such as surveys and focus groups, will also be utilized throughout continuous feedback cycles. The first phase of user testing begins in Spring 2025 with semi-structured interviews designed to test the core technical functionalities of *SafeSigns*. Based on the results of user testing, adjustments to development plans will then be made as deemed necessary to make sure DHH users have a direct voice and impact in shaping the final iteration of the *SafeSigns* platform.

The final phase of the *SafeSigns* will involve shifting the focus to strengthening communications and bridging the existing gaps between PS officials and the DHH community. PS officials are currently able to access hazard reports in real time and respond using the platform. PS officials are the ones who can ensure the credibility of reports and inform the DHH community when an emergency is resolved. Training sessions for PS agencies will help them understand the unique needs of the DHH community and guide the development of protocols for the better utilization of *SafeSigns*. Feedback gathered from PS officials will then be combined with the collected data from the DHH community to refine and improve the platform, delivering more inclusive EM solutions.

To enhance data quality and trust in user-generated content, future versions of the platform will also incorporate an intelligent system to detect and filter spam or misleading hazard reports. This system will leverage rule-based logic and machine learning models trained on patterns of valid versus invalid submissions, aiming to maintain platform reliability while allowing more flexible forms of user participation, such as anonymous or semi-anonymous reporting.

The long-term plan for the *SafeSigns* platform is to evolve into an open-source geospatial toolkit which will be made available worldwide. Success of the project will be defined and measured by the continued collection of analytical data from the platform, demonstrating that *SafeSigns* is empowering the DHH community to map and communicate hazards effectively. There are also plans to integrate *SafeSigns* as a learning tool within GIS coursework for students to engage with the platform to develop their skills while contributing to its ongoing improvement. These efforts will result in the combination of academic collaboration with community engagement to achieve widespread adoption and create a lasting impact on disaster management practices for DHH individuals.

LIMITATIONS

One major limitation of the current iteration of *SafeSigns* is lack of availability and accuracy of demographic data on DHH individuals and other populations with disabilities. As discussed previously, census tracts and relevant datasets are not precise enough to provide accurate results on the geographical distribution of these communities. While more precise demographic data could support more targeted community resilience planning, the ethical and logistical challenges of collecting and maintaining such sensitive information need to be acknowledged. In future versions of *SafeSigns*, alternative approaches, such as opt-in user-reported data, anonymized usage patterns, or synthetic estimations, will be utilized to inform hazard mapping without placing individuals or communities at risk. These strategies will help balance data utility with privacy and equity considerations. Another limitation of *SafeSigns* is the risk that certain aspects of the platform might be difficult to learn and use for individuals with less digital proficiency. To identify learning gaps and areas of difficulty, multiple iterations of toolkit evaluations will be conducted. The results will inform targeted improvements to the platform's design and functionality.

SUMMARY AND CONCLUSIONS

The importance of inclusive EM approaches that prioritize accessibility and participation is critical for ensuring that all communities, especially vulnerable populations, are adequately supported during disasters. Geospatial technologies are often used in EM, but rarely used to facilitate communication for the DHH community. In this work, we have introduced *SafeSigns*, a geospatially enabled toolkit designed to enhance communication and hazard reporting for the DHH community within EM frameworks. Our study highlights the persistent challenges faced by the DHH community in accessing critical emergency resources, particularly the communication barriers that limit their participation in community resilience efforts. By leveraging geospatial technologies, *SafeSigns* can serve as a novel intervention tool to empower DHH individuals with a grassroots voice in community resilience, filling a critical gap in EM strategies.

The technical design and user insights presented in this study provide a foundation for future research and development in this area. To the best of our knowledge, this research represents one of the first ISCRAM-related efforts to focus explicitly on integrating DHH communities into EM and resilience-building initiatives via IT solutions. Future work will focus on evaluating *SafeSigns* in real-world scenarios, refining its features based on user feedback, and exploring broader applications of geospatial technologies to support other vulnerable populations in disaster response. By advancing inclusive and participatory approaches, we contribute to the ongoing effort to make EM more equitable and effective for all.

ACKNOWLEDGMENTS

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