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Digital Solutions for Disaster Management: Analyzing the Impact of the February 2023 Earthquake in Türkiye

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Abstract

This research investigates the involvement of information technologies, including communication platforms and social media solutions, in managing earthquake disasters, specifically focusing on the February 2023 earthquake in Türkiye. In order to achieve this, a comparative framework is constructed, which incorporates four main categories, namely goal, providers, target phase, and platform. The data is gathered from diverse sources, and a total of 130 solutions are identified immediately following the February 2023 earthquake in Türkiye. After conducting a thorough examination of these solutions and removing any duplicates and irrelevant options, the final dataset comprises 89 unique solutions sourced from 82 providers. According to the study's findings, the solutions employed in mitigation and preparedness phases prioritize proactive measures and planning, while the ones in response phase witnesses a significant increase in activities related to aid campaigns, emergency response, information dissemination, and support services. The solutions in recovery phase further intensifies support services to aid affected communities. Web-based platforms are predominantly used during different phases of disaster management, with mobile platforms playing a crucial role in communication and on-the-ground activities. Private organizations exhibit strong involvement in developing IT platforms, while public entities and NGOs contribute to a lesser extent.

Keywords: Disaster Management Systems, Disaster Management Phases, Earthquake Digital Solutions

1. INTRODUCTION

The use of information technologies in disaster management has gained increasing importance alongside technological advancements. The development of communication technologies and the widespread adoption of social media applications have provided new avenues for individuals to communicate and share information during and immediately after disasters, including earthquakes. In fact, it is important to benefit from technological developments in order to increase the effectiveness of disaster management systems.

Various technology-based solutions and systems (mobile and web applications) are expected to provide support in diverse activities, dedicated to four phases of disaster management which is detailed in Section 1.1. These include (for response phase):

- Helping people and pets under debris

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- Systematic identification of those in need, recording these data in databases and sharing over the web
- Providing temporary accommodation for those whose houses are damaged
- Delivery of on-site health services to injured citizens
- Supply of medical supplies such as medicine, blood, oxygen for first aid and delivery to the earthquake area
- Registration of the deceased, reaching their relatives, and burial according to the rules of the country

Türkiye experienced two terrible earthquakes, one in August 17, 1999 and the second on February 6, 2023. The last earthquake affected 11 provinces and over 50,000 lives were lost according to official figures. In the first, fixed-line phones were the only means of communication that people could use, while in the second, the communication needs of people were supported by service providers such as Vodafone Türkiye, Turkcell, and Türk Telekom via portable phones. The energy problems experienced right after the earthquake, and the inability of mobile power stations, unfortunately, caused the region to be without electricity for a long time. As a result, adequate and urgent communication could not be achieved between people and institutions. After the second earthquake, many software companies, students studying in the field of informatics, and public institutions put their existing web pages and applications into use to provide support for activities listed above.

From the academic side, a multitude of studies have been conducted, proposing innovative systems for managing and constructing organizational networks and frameworks. For instance, Xiangnan et al (2021) delves into earthquake-specific disaster management approaches, exploring policy changes and inter-organizational cooperation networks. Zhang and Yin (2022) put forth a mobile earthquake collection system, while Lin and Lee (2023) examines various types of disaster organizations and assesses a community-based earthquake management framework. Kaya (2023) employed ArcGIS software and web services to establish a database facilitating the swift assessment of post-earthquake urban building stock in the city of Elazığ, located in the eastern region of Türkiye. The primary objective of this study was to furnish digitized information aimed at mitigating the impacts of forthcoming earthquakes. Additionally, tsunamis are among the secondary consequences of earthquakes in coastal areas. Necmioğlu (2022) investigated challenges and prerequisites concerning the early detection of earthquake-induced tsunamis in Turkey, conducting an analysis that led to proposed solutions.

Given the emphasis in the existing literature on technology-driven solutions for earthquake disaster management, this study aims to address the research questions outlined in Section 1.2 to evaluate the utilization of technological solutions in the recent earthquake in Türkiye.

The organization of the paper is as follows: Section 1 introduces the importance of digital solutions in disaster management, explains the phases of disaster management and lists research questions. Section 2 discusses existing solutions and related work. In Section 3 a comparison framework is introduced along with data collection process. Section 4 provides answers to research questions and discusses findings. Conclusion is given in Section 5.

1.1 Disaster Management Phases

The process of disaster management is structured into four distinct phases (McLoughlin, 1985; URL 1), namely mitigation, preparedness, response, and recovery, as illustrated in Figure 1. In the subsequent paragraphs, we delve into the specific characteristics of each phase. It is upon these characteristics that our study is founded.

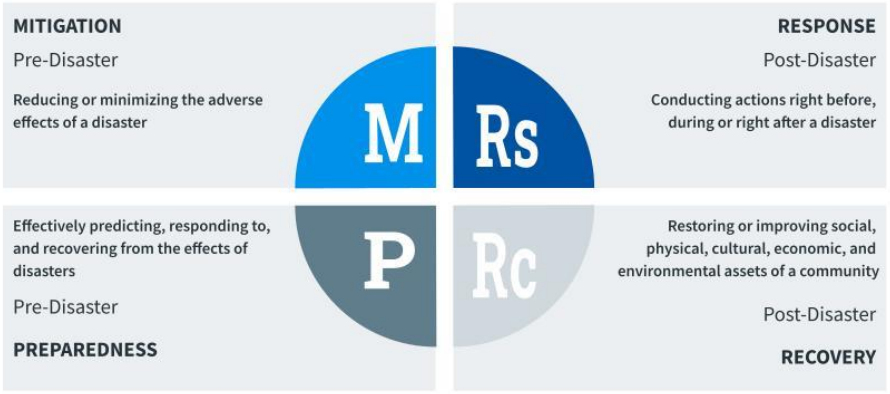

Figure 1. Phases of Disaster Management

Mitigation: This phase aims to reduce or minimize the adverse effects of a disaster. While it may not be possible to completely avoid the adverse effects of natural hazards, there are various strategies and actions that can significantly reduce their scale or severity.

Preparedness: This phase refers to the ability to effectively predict, respond to, and recover from the effects of potential, imminent, or existing disasters. Preparedness is driven by disaster risk management and focuses on building the necessary capacities to handle emergencies efficiently and facilitate orderly transitions from response to sustained recovery.

Response: This phase encompasses actions conducted right before, during, or right after a disaster to save lives, lessen health impacts, ensure public safety, and provide for the fundamental necessities of the people who have been impacted. Disaster response focuses mostly on short-term and emergency needs.

Recovery: This phase involves the restoration or improvement of the social, physical, cultural, economic, and environmental assets, systems, and activities of a community in order to prevent or lower the risk of future disasters.

The implementation of the management model mentioned above, which illustrates the fundamental phases in disaster management, requires collaboration among experts from various fields such as civil engineering, software engineering, psychology, sociology, and other related disciplines. Varol and Kaya (2018) emphasize the necessity of an interdisciplinary approach to disaster risk management, indicating that disaster risk management processes lacking in a multidisciplinary approach and neglecting the social dimension cannot be successful. Erkal and Değerliyurt (2018) have provided comparisons between emergency planning in developed countries, offering examples, and conducted assessments related to emergency and disaster management. They have also made recommendations specifically aimed at disaster management in Türkiye.

1.2 Motivation and Research Questions

With the advancements in technology, various disaster management solutions are developed and tailored for earthquake scenarios. The solutions aim to enhance efforts in preparedness, response and recovery by providing timely information, and facilitating communication and coordination.

However, it becomes important to evaluate and compare these solutions to identify their characteristics and effectiveness in addressing challenges of each phase. This study seeks to investigate and answer the following research questions.

RQ1. *How does the distribution of aid campaigns, emergency response, information dissemination, and support services vary across the different phases of earthquake disaster management, namely mitigation, response, recovery, and preparedness?*

RQ2. *What are the primary objectives of solutions used before and after the recent earthquake in Türkiye?*

RQ3. *What are the most commonly used IT platforms during different disaster phases (preparation, response, recovery) of earthquakes in Türkiye, and how do they contribute to each phase?*

RQ4. *What impact did social media solutions have during and after the recent earthquake in Türkiye?*

By addressing these questions, we aim to provide valuable insights for residents, and the participants involved in earthquake disaster management, namely emergency responders, decision makers, and technology developers.

2. RELATED WORK

Cities worldwide are severely affected by disasters. Urban disaster management must be handled seriously to prevent deaths, serious injuries, property damage, and economic loss caused by disasters. The objective should not only be to avert disasters but also to mitigate the potential vulnerabilities of individuals (Sim and He, 2023). A comprehensive analysis conducted by Lixin et al. (2012) reveals that while China possesses a disaster management system and a national emergency plan, it lacks integration. Similarly, Chun-Yuan et al. (2020) have examined China's disaster management system and concluded that it remains inadequate. The existing literature highlights the insufficiency of current disaster management systems. Hence, it is imperative to leverage technological advancements in order to enhance the effectiveness of these systems and minimize the impact of disasters.

In recent years, the rapid advancement of technology has emphasized the critical need to develop solutions that can effectively address disasters and enhance the quality of life for individuals affected by such events. These solutions, whether in the form of mobile or web-based platforms, can play a pivotal role in various stages of disaster management, including mitigation, preparedness, response, and recovery (Sakurai and Murayama, 2019; Abid et al., 2021).

A notable contribution in this domain is the work of Colajanni et al. (2023), who have introduced a three-stage stochastic network-based optimization model that integrates the power of 5G technology and Unmanned Aerial Vehicles (UAVs) for disaster management. Similarly, Alawad et al. (2023) have employed UAV systems to cater to different groups of victims identified during an investigation process in potential disaster zones within smart cities. In a systematic review by Junxiang and Peng (2022) they propose the integration of Building Information Modelling (BIM) and Geographic Information System (GIS) at both the data and solution levels. This integration allows for the combined benefits of BIM and GIS, optimizing their performance and enhancing their capacity to tackle urban-related challenges. Furthermore, Barth et al. (2023) have developed

a mobile and web-based communication system specifically designed for information exchange during all phases of emergency management. This system has proven to be an effective tool in facilitating effective communication.

The literature demonstrates a wealth of technology-based disaster management systems that have been summarized in recent years, highlighting the ongoing efforts to harness technological advancements for more efficient and effective disaster management. Earthquakes present a unique category of disasters, necessitating a tailored approach to earthquake disaster management studies. In a previous investigation, Ajami and Fattahi (2009) examined the efficacy of earthquake management information systems (EIMS) in mitigating destruction, drawing comparisons among Japan, Iran, and Turkiye. The study revealed that the EIMS in these nations operates in a decentralized manner, indicating a requirement for reformation and the development of a redesigned model. Xiangnan et al. (2021) conducted a comparative analysis of disaster policy changes and emergency management reforms in the context of two hazardous earthquakes in China. Notably, the second earthquake showcased enhanced coordination within the inter-organizational cooperation network at the local level.

Zhang and Yin (2022) devised a mobile earthquake collection system, enabling the real-time transmission of post-earthquake information from mobile terminals. This innovative approach allows for the acquisition of critical geographic data, including earthquake impact range and intensity.

Maki and Johnson (2016) undertook an extensive examination of three different types of disaster organizations across various countries. They further conducted a global comparison of recovery organizations to gain insights into their operations during large-scale disasters.

In their study, Lin and Lee (2023) discussed an assessment framework for community-based earthquake management combining the principles of community resilience and disaster management. This framework encompasses crucial aspects such as risk assessment, earthquake information gathering, imparting earthquake protection skills, and establishing a collaborative platform. The research findings demonstrate that communities with greater disaster management capacity are better equipped to collaborate with governmental and nonprofit entities in handling emergencies.

Due to the changing communication channels, the usage of communication methods facilitated by new technologies and the media tools that serve as intermediaries have once again come to the fore in Türkiye following the recent earthquakes. Usta and Yükseler (2021) conducted an analysis of posts and news circulated on social media platforms subsequent to the earthquake in İzmir Seferihisar on October 30, 2021, addressing both ethical and legal aspects. Their evaluation highlighted a frequent oversight of issues related to the Personal Data Protection Law (KVKK) within the shared content. The relevant organizations are recommended to conduct awareness campaigns regarding social media usage during disasters, develop principles and guidelines concerning communication, and establish a legislative framework to address these matters. Meanwhile, in a study by Bozkurt and Demir (2023), focusing on Kahramanmaraş city and its neighboring areas severely affected by the February 2023 earthquake, an evaluation was conducted regarding communication and media in disaster management, particularly from a technological perspective. Given the communication system's failure during this seismic event, the study reaffirmed that social media emerged as the most efficacious communication tool following disasters.

3. COMPARISON OF DISASTER MANAGEMENT SOLUTIONS

In this section, a systematic and comprehensive process, Figure 2, is followed to explore, evaluate and contrast different approaches to answer the research questions explained in Section 1.2. This comparison will be meticulously structured into several tasks, each dedicated to a specific aspect of the research and analysis.

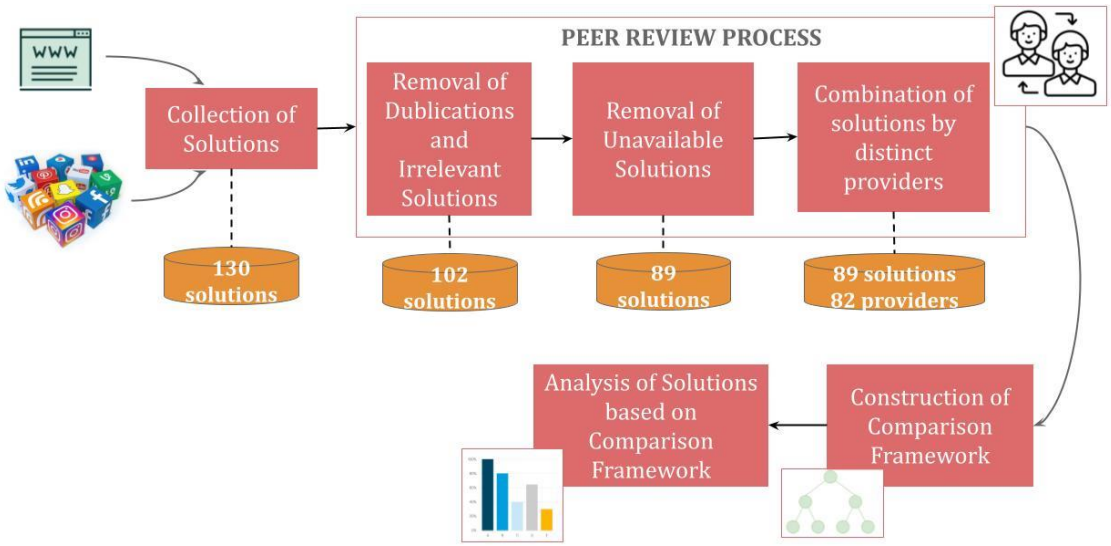

Figure 2. Comparison Process

3.1 Data Collection

The process of collecting data for comparing disaster management solutions involves comprehensive sourcing from various channels, including the web and social media. Initially, a total of 130 solutions were identified. However, through careful examination, the authors conducted a meticulous peer-review process to ensure the quality and relevance of the final selection.

In the first review, duplicates were removed, and irrelevant solutions were eliminated, resulting in a refined selection of 102 solutions. A subsequent review identified 13 solutions as unavailable and subsequently excluded from the analysis. Furthermore, during the third review, it was determined that ten solutions belonged to two institutions. To ensure a fair and unbiased comparison, these solutions were combined into one, considering the focus on unique providers.

As a result, the final dataset (URL 2) consisted of 89 distinct solutions from 82 providers, carefully curated to provide a comprehensive and reliable foundation for comparing disaster management solutions.

3.2. Comparison Framework

A comprehensive comparison framework was constructed to unveil trends, ascertain the primary objectives of the solutions, analyze their distribution across disaster management phases, identify any gaps or missing features, and provide insights for future research. The solutions are evaluated based on the following categories as shown in Figure 3.

Goal: Each solution serves one or more purposes; sustaining an aid campaign (e.g. donation), providing diverse forms of support (e.g. scholarship), assisting in emergency situations (e.g. SOS services), and facilitating information dissemination for the benefit of victims (e.g. earthquake-related data).

Providers: Several different organizations (e.g. public and private organizations) contribute to the creation, deployment, and maintenance of solutions tailored to distinct objectives within the realm of disaster management.

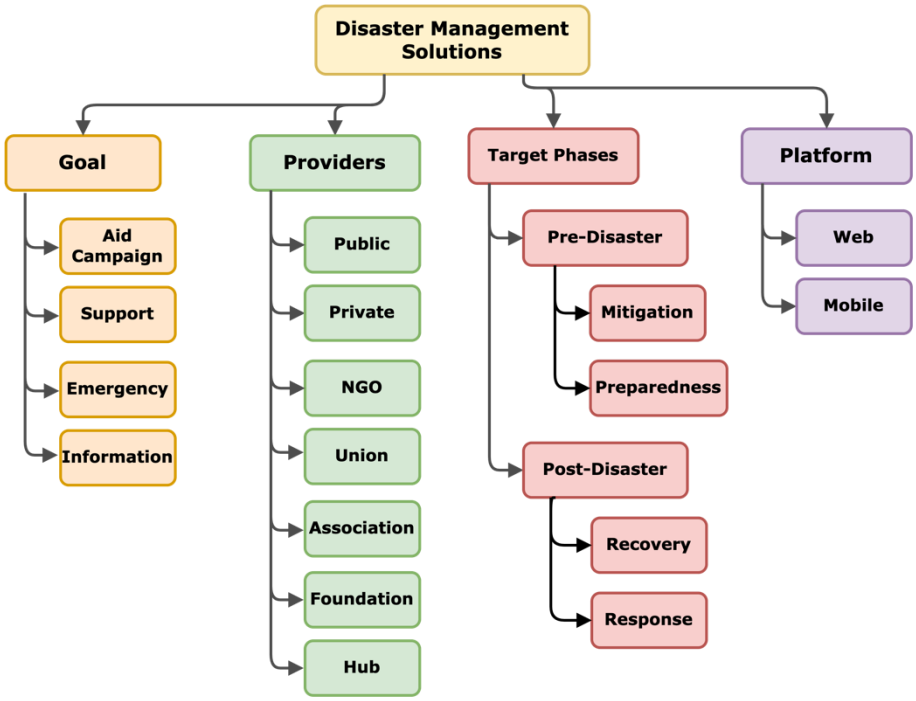

Figure 3. Comparison Framework

Target Phase: Solutions are designed to be utilized in one or more phases of disaster management, including mitigation, preparedness, recovery, and response. Each phase is further elaborated upon in Section 1.1.

Platform: Solutions are deployed in different platforms, including web-based and mobile-based platforms, catering to diverse user preferences and technological accessibility.

This comprehensive framework enables a detailed analysis of the solutions, shedding light on their objectives, the entities behind their development, their relevance to different disaster management phases, and the platforms on which they operate. By exploring these categories, valuable insights can be gained to inform future advancements and improvements in the field of disaster management solutions.

4. FINDINGS AND DISCUSSION

This section provides answers to research questions defined in Section 1.2

RQ1. *How do the distribution of aid campaigns, emergency response, information dissemination, and support services vary across the different phases of earthquake disaster management, namely mitigation, response, recovery, and preparedness?*

Based on the framework given in Section 3.2, we identified 21 solutions for Pre-Disaster (11 of them for Mitigation and 5 of them for Preparedness) and 77 solutions for Post-Disaster (34 of them for Response and 43 of them for Recovery). Figure 4 presents the distribution of aid campaigns, emergency response, information dissemination, and support services across the different phases of earthquake disaster management.

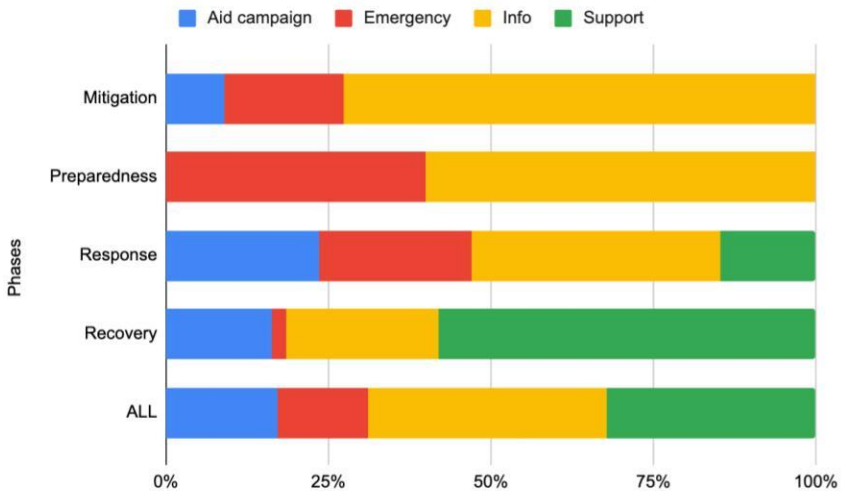

Figure 4. Goal Distribution across disaster management phases

The distribution in mitigation phase indicates a focus on proactive measures to reduce the impact of earthquakes and promote preparedness through information dissemination. For the preparedness phase, the emphasis is on preparing for potential earthquakes through emergency response planning and information sharing. The response phase demonstrates a higher number of solutions across all categories. This indicates a significant focus on immediate response efforts, such as raising awareness, providing aid, and effectively disseminating information to affected communities. The distribution in the recovery phase suggests that this phase places a strong emphasis on providing aid, supporting affected communities, and facilitating the dissemination of crucial information to aid the recovery process.

Overall, the results illustrate a shift in focus and distribution of efforts across the different phases of earthquake disaster management. While mitigation and preparedness phases primarily concentrate on proactive measures and planning, the response phase sees a significant increase in efforts related to aid campaigns, emergency response, information dissemination, and support services. The recovery phase further intensifies support services to assist affected communities in their recovery journey.

RQ2. *What are the primary objectives of solutions used before and after the recent earthquake in Türkiye?*

To explore this question, individual goals are broken down into sub-goals and elaborated upon. It is important to note that a solution can fulfill multiple objectives, and the number of solutions that cater to a particular objective is indicated in parentheses in Figure 5.

Aid Campaign: Out of 15 solutions, (i) 7 of them (housing) aim to assist victims in the listing, searching, and finding suitable housing, and (ii) 10 of them (donation) focus on collecting money, furniture, outfit, heaters, and/or utensils.

Support: Among 29 solutions, (i) 5 of them (recruitment) help establish connections between victims and companies to facilitate job hunting, (ii) 2 of them (psychical health) provide free treatment and prosthetics, (iii) 6 of them (mental health) offer free therapy sessions and the essential information to support the mental well-being of victims, (iv) one of them (legal) provides legal awareness regarding the aftermath of the disaster and potential legal actions, (v) 9 of them (scholarship) collect solutions from victims to support students in affected cities, (vi) 4 of them (education) offer free courses or cover stationery expenses, and (vii) one of them (data collection) creates a visual archive for the investigation and judicial process to gather evidence.

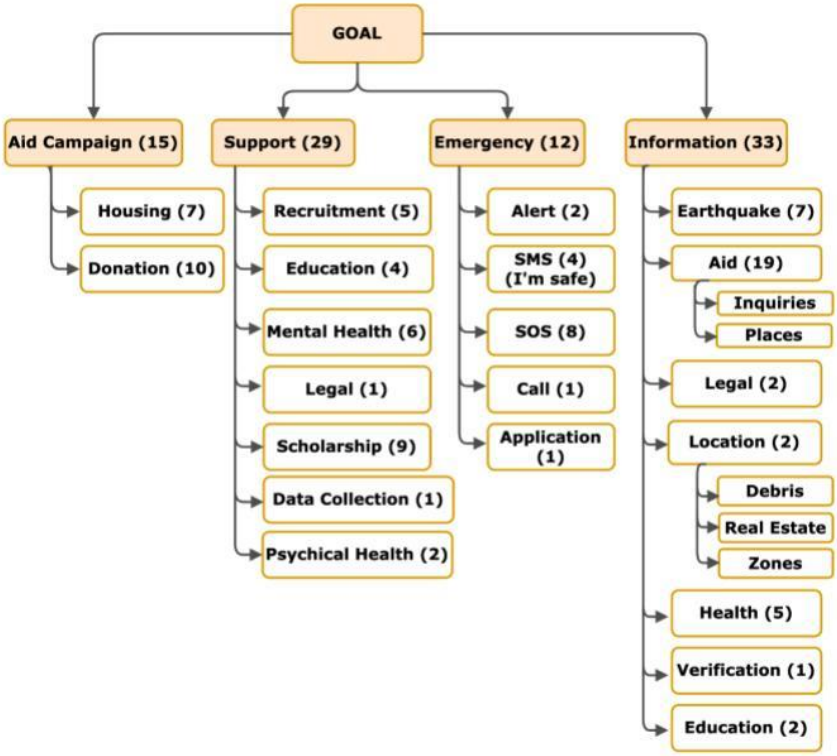

Figure 5. Sub-categories under *Goal* with number of solutions

Emergency: Out of 12 solutions, (i) 2 of them (alert) provide an early warning system to notify people in the event of potential earthquakes, (ii) 4 of them (SMS) enables users to send "I'm safe" messages to their friends and relatives, (iii) 8 of them (SOS) have a feature where users can send SOS messages with their locations to seek immediate assistance, (iv) one of them establishes an emergency call center where victims can report their status (under the debris, lost, injured, not able to find my relative), and (v) one of them (solution) allows users to listen to ambiance sounds in different frequencies to identify victims trapped under debris.

Information: Among 33 solutions, (i) 7 of them (earthquake) provide textual or visual information about previous or current earthquakes, and share field observation reports, preliminary investigation reports and fault analysis, (ii) 19 of them (aid) share information about emergency shelters, assembly areas and free services (such as food, shelter, container, clothing, blankets, medical support, pharmacies, gas stations, free cranes, volunteer crane operators), offer search functions for inquiries related to requests for help, list local producers, index aid websites, and provide a platform to share information about missing pets and related inquiries, (iii) 2 of them (legal) offer legal guidance for earthquake victims, coordinate volunteer legal experts and lawyers, create a platform to share frequently asked questions, essential legal information and videos, (iv) 2 of them (location) provide information about debris, real estate and zoning on maps, (v) 5 of them (health) share essential information about health, nutrition, and breastfeeding for children in earthquake-affected areas, and provide search functions for relatives seeking information related to the status of victims, (vi) one of them (verification) shares verified information to combat disinformation on the web, and (vii) 2 of them (education) facilitate placement of students from earthquake-affected areas in other schools as guest students.

These objectives reflect the diverse needs and challenges faced before and after the recent earthquake in Türkiye. The solutions aim to address areas such as housing, donations, support services, emergency response, and the dissemination of critical information to support the affected individuals and communities.

RQ3. *What are the most commonly used IT platforms during different disaster phases (preparation, response, recovery) of earthquakes in Türkiye, and how do they contribute to each phase?*

The most commonly used IT platforms during different phases of earthquake disaster management in Türkiye are web-based platforms (67 out of 81). These platforms are essential for information sharing, coordination, and resource management. Additionally, mobile platforms play a significant role in supporting communication and on-the-ground activities. However, the number of mobile platforms are lower than web platforms (8 out of 81). The web and mobile platforms (6 out of 81), which combine the benefits of both technologies, further enhance the effectiveness of earthquake disaster management efforts.

The analysis of solutions across different IT platforms also considers the providers involved. The providers of solutions in earthquake disaster management are classified into categories such as Public, Private, NGO, Association, Foundation, Union or Hub. Based on the findings given in Figure 5, among these entities, it is evident that Private organizations demonstrate the highest usage of mobile platforms. On the other hand, Public entities and Foundations exhibit a comparatively lower usage of mobile platforms. Furthermore, Private organizations are also at the forefront when it comes to the utilization of web platforms. However, the utilization of platforms that combine both mobile and web functionalities is relatively low.

To sum up, Private organizations stand out as the most proactive participants in the development and provision of IT platforms for earthquake disaster management. They have a notable presence in both the mobile and web domains. While Public entities, Foundations, NGOs, and Unions also contribute to a lesser extent, their involvement is not as extensive as that of Private organizations.

Based on the distribution given in Figure 7, it is observed that web-based platforms are widely utilized across all disaster phases, indicating their importance in earthquake disaster management in Türkiye. Mobile platforms have a notable presence during the response phase,

enabling immediate communication and support. The combination of mobile and web functionalities is relatively less common but still contributes to various phases.

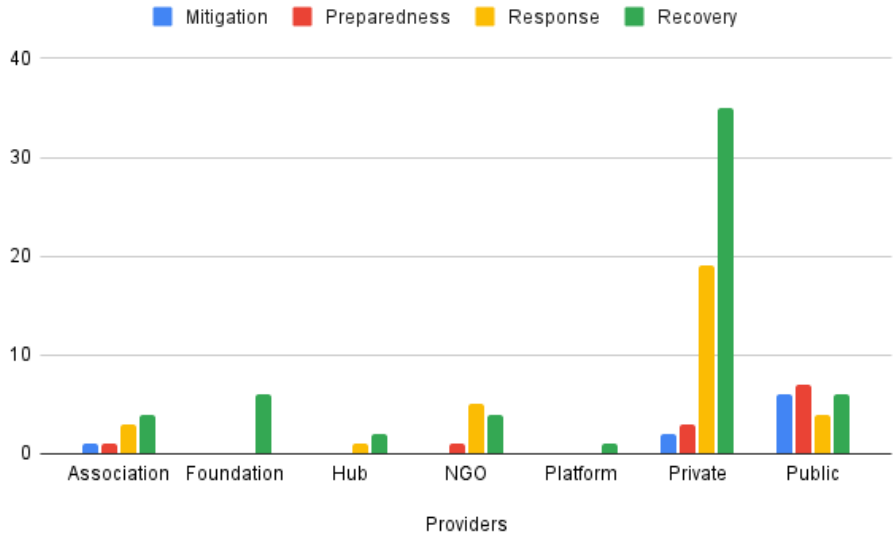

Figure 6. Distribution of IT Platforms by Providers

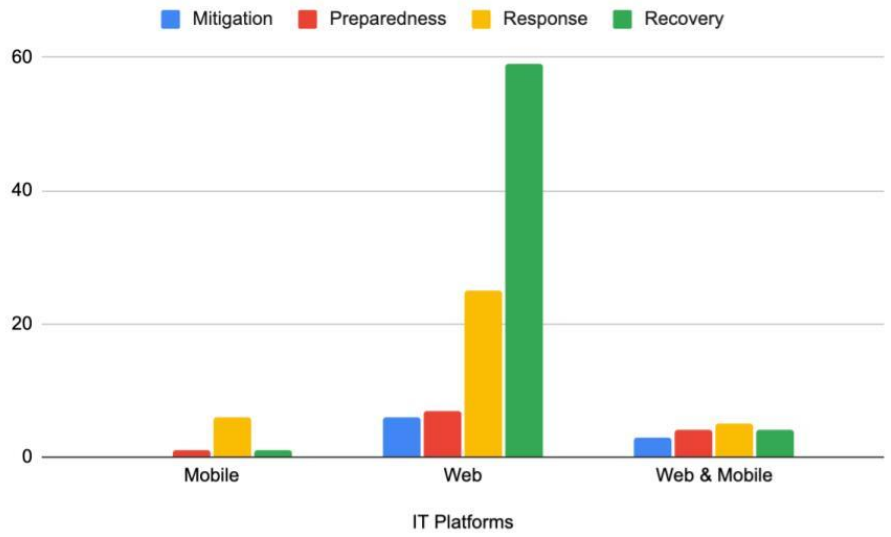

Figure 7. Distribution of IT Platforms by Phases

RQ4. *What impact did social media solutions have during and after the recent earthquake in Türkiye?*

The social media applications Twitter, Facebook, and Instagram are the frequently used ones that play a crucial role in facilitating communication among individuals; victims, their families, official institutions, charities, and medical services. While misinformation is unavoidable in these

platforms, they offer a means for people to send “I’m alive”, “I’m under the debris”, and “I’m in need” messages. They help in organizing charitable efforts, in gathering volunteers in fieldwork, locating victims, and guiding them to assembly areas. A remarkable charity organization, Ahbap (URL 3) by proactive utilization of Twitter demonstrated exceptional efforts in channeling rescue requests to relevant organizations, recruiting volunteers to be commissioned in earthquake-affected areas, coordinating the distribution of donations to priority regions, sharing their progress updates, and asking for further contributions.

One notable solution, deprem.io (URL 4) is developed by a dedicated set of volunteer software engineers right after the earthquake. The solution focuses on collecting and organizing information publicly shared on Twitter. This structured data helped to locate victims requiring urgent assistance or trapped under the debris, to collect a list of supplies (e.g. tent, food, clothing) from victims, and to share up-to-date and accurate information about assembly locations, aid stations, and food shelters.

5. CONCLUSION

Solutions provided to support activities before and after disasters are of paramount importance in increasing the effectiveness of disaster management. These solutions encompass various aspects and cater to the needs of different phases of earthquake disaster management, namely mitigation, preparedness, response, and recovery. Examples of such needs are immediate aid and support, emergency response systems, and information dissemination. This comparative study aims to identify and analyze existing solutions, understanding their primary goals in meeting the diverse needs of individuals affected by earthquakes in Türkiye.

The results of the study reveal that the solutions are distributed across four main disaster management phases, with an increasing number of solutions focusing on post-disaster activities (response and recovery). The primary goals of these solutions mainly revolve around organizing aid campaigns, providing various support activities such as education, health, and recruitment, as well as notifying emergency status and disseminating critical information, such as location and recent earthquake updates. Private organizations take the lead in providing these solutions, and the majority of them are implemented in web-based platforms. In conclusion, the utilization of solutions, including both mobile and web-based platforms, by different entities significantly enhances communication, information dissemination, coordination, resource management, and access to services. This collective effort contributes to the overall effectiveness of earthquake disaster management in Türkiye.

In the domain of disaster management, several forward-looking strategies need to be applied to mitigate potential crises. Firstly, given the convenience and widespread usage of mobile devices, there should be an increase in the number of mobile applications available. Besides, it's of importance to raise public awareness about these applications, ensuring that they are widely known and effectively utilized. Another crucial element is tackling information pollution, which requires creation of solutions based on trustworthy sources to maintain integrity and reliability of information disseminated to the public. Finally, there is an urgent need to expand support in legal processes, especially in raising legal awareness and aiding collection of evidence during crises. These steps will help create a society that is more informed, collectively participant, legally aware and technologically prepared for disasters.

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