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Operationalizing crowdsourcing through mobile applications for disaster management in India

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ABSTRACT

The lack of real-time data on emergent disasters often restrains the decision maker's ability to counter its impacts, especially in developing countries like India. In this regard, the idea of leveraging mobile applications 'apps' for crowdsourcing disaster-related information has recently gained high prominence. To operationalize app-based crowdsourcing, this paper methodically investigates the current state of 33 freely-accessible disaster-related mobile apps in India. The study finds that majority of these apps are primarily educational, and their overall outreach is highly limited. It concludes with specific suggestions for enhancing community outreach, ensuring user-friendly interface and promoting Global Positioning System 'GPS' based apps.

1. Introduction

Data is the source of information; information is the source of knowledge and knowledge is the source of power [1]. Thus, to empower human societies against the rising frequency and intensity of natural disasters, it is essential to ensure that real-time disaster information is timely collected and communicated to concerned stakeholders at all levels. However, poor data availability continues to be one of the weakest links of the international humanitarian sector [2–4], despite the revolutionary technological advances in the recent years. The limited resources coupled with varying level of disaster vulnerability further restrain the responding capabilities of decision makers in disaster situations, especially in developing countries like India. In view of the growing need for timely data collection for disaster management, substantial emphasis is now being laid in the field of Information and Communication Technology 'ICT' [5].

In recent decades, several researchers [1,6–10] have stressed that disaster management and ICT are closely linked in different phases of disaster management cycle including mitigation, preparedness, response and recovery. Kamal [11] comprehensively discussed the role of various ICT tools like Internet, Remote Sensing etc. in Indian context and underlined that disaster management activities are highly dependent on accurate, relevant and real-time geo-information. Undeniably, there has been a significant progress in technological aspects related to disaster monitoring and forecasting, however knowledge generation and dissemination through these technologies remains to be constrained due to issues like limited mobility and coverage [12].

To address the growing concerns of data availability, a genuine need for acquiring disaster-related data through portable devices has been realized. Resultantly, smartphones (generally known as mobile phones with extra features) [13,14] have gained considerable importance in the field of disaster management for communicating useful information to affected communities as well as to coordinate relief operations [15]. With recent technological advancements, mobile phones today could be used for a variety of purposes including messaging, social networking, location aware mobile computing, navigation, digital broadcasting etc. [14,16–18]. Customized mobile apps further make it easier to gather user information through various social media platforms such as Facebook and Twitter [18].

Kanjo et al. [19] underlined that majority of the people in India access to internet from their mobile phones rather than from a computer which establishes the importance of focusing on mobile-based technologies. Gupta [20] further underlined that mobile users spend most of their time on apps (around 82%) and only 18% on web browsers. This constant tendency of people to keep exploring mobile apps could be leveraged for data collection in unmonitored areas where it is difficult to deploy and maintain static sensors [12,19,21]. Through dedicated disaster-related mobile apps, up to the minute real information could be crowdsourced through citizens involved in crisis situations. Trained individuals can collect, process, store and transfer relevant disaster-related information such as photos and messages, which can be coupled with sensor data [19]. 'Disaster-related mobile apps', as defined by Ueno [22], refer to the mobile apps targeted on use before, after or during a disaster.

Although the importance of app-based crowdsourcing is widely recognized [12,17], the current research on disaster-related mobile apps is mostly focused on technical aspects like application development [12,17,23,24]. Ueno [22] and Leelawat et al. [12] pointed out that very

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limited research has been done on disaster-related mobile apps from the user aspect. In view of that, this research aims to study the current outreach of disaster-related mobile apps to general public in India. The two key objectives of the study are: (1). To assess the current state of disaster-related mobile apps in India; (2). To suggest suitable directions for operationalizing crowdsourcing through mobile apps in India. With 'current state of disaster-related apps', the authors refer to the app features like number of downloads, user rating, app interface etc. It is important to note that this study is mainly based on primary data collected by the authors on 33 freely available (that do not charge any fee) disaster-related mobile apps in Google's Android Operating System (OS). Apart from the primary data collected by the authors for selected apps, this paper also draws lessons from existing scientific literature and good practices of app-based crowdsourcing around the world. The key research questions that the authors try to answer through this paper are: How to assess the outreach of disaster-related mobile apps? What are the key shortcomings of current disaster-related mobile apps? In light of the limited research on the role of mobile apps in disaster management, this paper makes a genuine contribution in both the academic and practice aspects. It aims to build a stronger foundation for future research by highlighting the current shortcomings of disaster-related mobile apps and potential solutions to enhance their effectiveness.

The remaining paper is structured as follows. Section 2 establishes the need and significance of mobile apps in disaster management before explaining the concepts of crowdsourcing and citizen science. The section also discusses the good practices of app-based crowdsourcing from around the world and the identified challenges based on literature survey. Section 3 presents a brief overview of risk profile of India, followed by the prevailing issues of data availability and recent digital initiatives. Section 4 explains the research methodology adopted for the study including the method of data collection and research design. Section 5 presents the current state of disaster-related mobile apps in India, based on the primary data collected for 33 freely accessible disaster related mobile apps in India. The section also discusses the identified key shortcomings of selected apps. Section 6 discusses the key considerations for operationalizing crowdsourcing through mobile apps in India. The main conclusions and the limitations for this study have been briefly discussed in Section 7.

2. Literature review

This section is divided into three sub-sections. The first sub-section deliberates on the need and significance of mobile apps in addressing the prevailing data issue, specifically for disaster management. In the second subsection, the concepts of crowdsourcing and citizen science are briefly explained. The third sub-section elaborates on the two good practices of PetaBencana.id and Ushahidi, amongst others, followed by identified challenges in crowdsourcing. For literature review, the authors took in consideration the existing scientific research, online grey literature, academic research and websites based on disaster-related mobile apps. By discussing the potential of crowdsourcing through mobile apps in India, this section lays a strong foundation for achieving the key objectives of this paper.

2.1. Need and significance of mobile applications

Normally, after a disaster strikes the first thing people consider is gathering real-time information to monitor their current situation, however it is mostly difficult to access with the traditional means such as television, radio and newspaper. Subsequently, mobile phones have become the first priority (higher than wallets and identification) during disasters that the victims prefer to take along while evacuating to safer locations [12,25]. It is important to note that with increasing penetration of mobile phones, around 90% of global population is presently covered by mobile signals [26]. The revolutionary advances in wireless technology have further enabled mobile devices to have advanced computing ability and data connectivity through wireless services, such as Wi-Fi and 4G [14,27]. Smartphones today are helping to revolutionize the disaster communication by enhancing the upstream and downstream coordination of information during disasters. From simple early warning text messages to detailed hazard maps with affected locations, mobile technologies are connecting the users to real-time disaster information at one go [19]. The compatibility of contemporary cell phones, their widespread adoption, internet connectivity and rapid infrastructure restoration makes them the most proficient means for disaster communication [10].

'Mobile apps' are generally referred to as the end-user software programs that are specifically designed for a mobile phone OS and extend the mobile phone's capabilities by enabling users to perform specific tasks [17]. In the current scenario, mobile apps facilitate for many important tasks like entertainment, social interaction, bank transactions, navigation, weather, news etc. Markedly, the most popular android apps in India are the social media apps like WhatsApp, Facebook, Twitter, Whatsapp etc. [28]. However, these social media apps are general purpose social networking platforms and therefore present certain limitations to be employed for the purpose of disaster management like privacy issues, restricted filtering and interpreting options, language barriers, unclear location sensing etc. [29]. While there are millions of smartphone apps in the market today [30,31], very few apps are designed specifically for disaster-related purposes [16,31] like FEMA, Red Cross Mobile Apps, Disaster Alert etc. All these apps have different features and are intended for a variety of purposes like alert notification, location sensing, hazard mapping, disaster message board, educational purpose etc. [17,22,31]. Notably, certain mobile apps allow for data collection from the disaster struck areas in offline mode also, as GPS and some other sensors continue to function even without network access [14].

2.2. Citizen science and mobile-app based crowdsourcing

McKinley et al. [32] defined citizen science as the practice of engaging general public in a scientific project that produces reliable data and information usable by scientists, decision makers or the public. Citizen science has for long been contributing to several domains of science like biodiversity conservation, resource management, environmental science etc. and is by no means a new phenomenon [33]. The idea of citizen science has recently gained renewed prominence, in the wake of technological advances such as mobile apps, cloud computing etc. which enable innovative means of engagement in research [34,35]. The recent developments in information science, especially in areas of data informatics, user-interface and GPS based apps, which can now be ported to smartphones and other portable devices, have been vital to the emergence of citizen science [36–38].

In the field of disaster management, crowdsourcing refers to a data collection technique that encourages the 'crowd' (the public) to voluntarily provide answers to questions or content for consumption through open transmission systems like mobile phones [39]. In recent decades, the idea of first-hand reporting, particularly in the form of visual documentation through mobile phones has emerged as the prime need for responding to disasters [40]. Kanjo et al. [19] and Sweta [18] discussed several advantages of using mobile phones over unattended wireless sensor networks for reporting disaster information like portability, light weight, larger coverage, ease of collecting sensor data and multifunctional capabilities of delivering multiple types of geo-coded information such as messages, calls, emails, photos and videos which can be coupled with sensor data. de Albuquerque et al. [41] stated that the use of geographic information for disaster risk management has attracted great interest both in research and practice, primarily because of the possibility to tap into the 'collective intelligence'. According to Goodchild [42], humans can behave as intelligent mobile sensors depending on the individual's ability of interpretation and integration. These abilities could further be enhanced through smartphones, digital cameras and tracking devices [43].

2.3. Good practices of app-based crowdsourcing and identified key challenges

Although the importance of app-based crowdsourcing is increasingly recognized, there are very limited solutions that have been employed in disaster situations like Ushahidi, CrisisTracker, Twitcident, PetaBencana.id

etc. [44–48]. All these varying platforms build on different methods of crowdsourcing. Two selected good practices of PetaBencana.id and Ushahidi are briefly explained as below:

2.3.1. PetaBencana.id

PetaBencana.id is an innovative crowdsourcing tool that combines citizen reports over social media (mainly twitter) and other apps, with hydraulic sensor data to produce real-time flood maps in Jakarta. It initially started with the name PetaJakarta, with main focus on the city of Jakarta, however it is now scaling up to cover more cities around the world. The web-based, publicly accessible maps developed through this tool now provide precise flood information for the government, emergency responders and residents [47,49].

Despite the wide-ranging success of PetaJakarta (initial tag of PetaBencana.id), there were certain limitations and challenges that restrained their functions. The platform mainly utilized Twitter platform for crowdsourcing in view of the large number of twitter users in Jakarta, which could vary elsewhere. Ogie et al. [47] further enlisted some of the challenges that were experienced during this project like weak penetration at community level, errors due to varying user opinion, locational errors, limited coverage etc.

2.3.2. Ushahidi

Ushahidi is an open source crisis-mapping software that was first developed in Kenya to chart the 2007 election violence. The application of this platform post 2010 earthquake in Haiti was one of the first major examples of mobile phone-based crowdsourcing being used in disaster response. This software provided the humanitarian agencies with timely access to disaster-related information that was crowdsourced from the Haitian population through text messages and social media platforms [50].

Platform Ushahidi is widely recognized for its ability to capture, store and share critical information. However, post 2010 Haiti earthquake, it was faced with some unique ethical and technical challenges pertaining to privacy protection, data collection and management, and meeting the expectations of the victims [39].

Apart from these, several other researchers [16,18,29,47] have highlighted the multi-faceted challenges encountered in crowdsourcing disaster-related information through mobile apps, specifically social media platforms. Few of these key challenges are data quality, validation and accuracy, fraudulent or non-genuine reports, user perception, scalability and interoperability issues, privacy and security concerns, poor handling of voluminous data collected, legal and ethical concerns, poor sampling decisions, information extraction and uncertainty, incentivization, network congestion, connection reliability, lack of technological expertise etc. Schimak et al. [29] categorized these varying challenges into technological, societal and ethical aspects.

3. Case of India

The current section provides a brief outline of the India's risk profile followed by concerns of poor data availability in disaster management. Toward the end, the section enlists the recent policy initiatives of the national government that push for mobile based technologies.

3.1. Risk profile of India and concerns of poor data availability

India has been vulnerable to several natural and man-made disasters on account of its distinct geo-climatic settings. The country is home to a variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north. Correspondingly, the country is prone to a variety of disasters like floods, droughts, cyclones, earthquakes, landslides, avalanches and forest fires. Around 58.6% of the overall landmass is prone to earthquakes; over 40 million hectares (12% of land) are prone to floods and river erosion; around 5700 km of the coastline (total 7516 km long) is prone to cyclones and tsunamis; 68% of the cultivable area is vulnerable to drought and hilly areas experience landslides and avalanches [51].

The preparation of National Disaster Management Plan in 2016 [52] in lines with Sendai Framework for Disaster Risk Reduction 'SFDRR' 2015–2030 affirmed the country's strong determination to effectively counter the growing frequency and intensity of disasters. Today, the country has a wide range of institutions related to disaster monitoring and forecasting, which have enhanced the disaster management activities [53]. However, one of the biggest drawbacks in managing the disasters in India as identified by the Ministry of Home Affairs [51] is the lack of data availability. It has been underlined that the mechanism for preparing an integrated database for various disasters happening across the country still needs to be developed. The lack of central statistical database poses serious limitation for disaster risk assessment and data compilation. Resultantly, the figures of casualties and impacts vary in different data sources, eventually hindering an objective risk assessment. Goswami et al. [54] further identified issues like lack of proper administration, lack of effective help to victims, inadequate and slow relief operation which are all related with the issue of data availability.

3.2. Digital initiatives in India

The widening adoption of smartphone and mobile broadband in the country [55] has made India the fastest-growing smartphone market in the world [56]. The number of smartphone users in India has increased from 220 million in 2014 to 400 million in 2017 [57]. Further, more android apps are downloaded in India than anywhere in the world. According to a recent report by App Annie, Indians downloaded 6.2 billion apps through Google Play store in 2016, up from 3.6 billion in 2015 and this increase in app downloads is likely to continue [58]. The recent policy initiatives inclined with the Mobile-First agenda are pushing the mobile based technologies deeper into the Indian communities. Budhiraja [59] summarized some of these government initiatives as below:

- The India Disaster Resource Network (IDRN) is been developed in collaboration with United Nations Development Program (UNDP) for systematically building the nation-wide disaster resource inventory.
- A GIS-based National Database for Emergency Management (NDEM) is been developed in collaboration with various Government agencies
- The flagship programme of the Government of India 'Digital India' aims to transform India into a digitally empowered society and knowledge economy by focusing on digital literacy, digital resources, and collaborative digital platforms.
- MyGov, an Indian Government initiative, is world's one of the biggest crowd sourcing and citizen engagement platform.
- The National Mobile Governance Initiative (Mobile Sewa) aims to provide government services to the people through mobile phones and tablets.

4. Methodology

Mobile phones today come with a variety of 'operating Systems' (OS) like Google's Android, Apple's iOS, Microsoft's Windows Mobile etc. [30]. Correspondingly, mobile apps are also developed specifically for different types of OS. These apps are available in different mobile phones via different platforms (app stores). Ueno [22], based on the global trend data [60] pointed that Google's Android has the largest market share (60.3% as of 2012) followed by Apple's iOS. In view of Android being the most prominent platform for mobile apps, this study analysed the mobile apps that were specific to the Android OS. It is important to note that the prevalence of mobile OS can vary according to country or regional preferences [22,61], however this study takes Android OS as the basis of the study.

Referring to the methodology adopted by Ueno [22], this study aims to assess the current state of disaster-related mobile apps in India. Notably, the general-purpose social networking platforms like Facebook, Twitter etc. have not been considered for the study. Based on a thorough search using

a variety of keywords like 'Disaster management', 'Crisis management', 'Emergency' etc., the official android app store (Google play store) presents a number of mobile apps. Fig. 1 presents few of the search results that appear using the keyword 'Disaster' through Android app store. Of the numerous apps related with disaster management, the authors find that there are only 33 android apps (as of March 2018), that are freely accessible and provide information that is specific to the context of India. The names of all the 33 mobile apps with their logo are as shown in Fig. 2. Notably, few of the apps like IOWA legal aid, Disaster Response team, Building eVac etc. are not specifically related to the Indian context, however they have been included in the study because they provide generalized educational information that is useful for everyone. Further, all the 33 mobile apps have been developed by a wide range of organizations from local, national and global level, including both the public and private sector.

For most of the 33 mobile apps selected for the study, there is information available on 'Number of downloads', 'User rating', 'User reviews' and 'Primary and secondary functions'. The authors reviewed the user interfaces for the selected mobile apps and manually collected the stated data on selected mobile apps from their mobile application store. This narrowed search method was intended to assess the outreach of freely available disaster-related apps to general public. It is important to note that this study is based on manual data collection for selected mobile apps, as the search capabilities of Google play store (as of March 2018) did not allow for online sorting for parameters like popularity or number of downloads.

Referring to Leelawat et al. [12] and Ueno [22], it is understood that the 'Number of downloads' and 'User Rating' of respective mobile apps can be interpreted as a user feedback, as it reflects their interest in using the application. Accordingly, this study analyses the effectiveness of disaster-related mobile apps in India based on the variables of 'Number of Downloads' and 'User rating'.

5. Current state of disaster-related mobile apps in India

In reference to the methodology adopted by Sung [17] and Ueno [22], the authors categorized the 33 selected apps into six areas based on their respective functions namely: (1) Educational/Games/Guides, (2) Alerts and Notification, (3) Helpline/Emergency Contacts, (4) Emergency tools/Resources, (5) Case specific and (6) GPS based. Table 1 below highlights the primary and secondary functions of all the selected mobile apps along with their user rating and number of downloads.

From Table 1, it is observed that there are a total of 16 apps which span beyond their primary functions and are multifunctional. Further, 5 of the 33 apps are found to be case specific (Mumbai, Sikkim, Uttarakhand, West Bengal and Kannur) and their functions are primarily concerned with people within a defined boundary. Off the remaining 28 apps, majority of applications (18) are found to be primarily educational apps. It is important to note that only seven of these mobile apps use GPS sensors, of which only four apps have primary functions based on GPS. Two of these GPS based apps (Disaster Message Board MAP and Family Disaster Manager) are intended to function as information boards for disasters, while the other 2 apps namely Disaster Management Vaishali and FDAS Disaster Management System are primarily intended for crowdsourcing disaster-related information.

The study finds that the total number of downloads (globally) for 29 selected apps (data not available for 4 apps) is 1.579 million out of which the major share has been contributed by three apps namely Relief Central (Medical aid), Disaster Alert (Real-time alerts) and Disaster Will Strike (Puzzle game). Notably, these three apps are not specific to the context of India and have a global focus. Despite the flourishing app market in India, the study finds that the average number of downloads for the selected apps have reached a minimal figure of 1119, if the three said apps are excluded.

Notably, the two apps that are primarily intended for crowdsourcing have supposedly failed to achieve their desired purpose as evident from their poor outreach (Table 1). One of those apps (FDAS-Disaster Management System) is found to have a user rating of '1 out of 5' which is very critical when compared to the average user rating of all the selected apps (4.33 out of 5) and the prime reason behind that is alleged to be the non-user-friendly interface (as observed from the user reviews). Based on the user reviews for the selected apps, the authors realize that the mobile apps having lengthy login process, performance issues, loading problems, frequent push notifications etc. are not been preferred.

6. Discussion

This paper reviewed a sample of 33 freely available disaster-related mobile apps in India that are designed specifically for Android OS and are

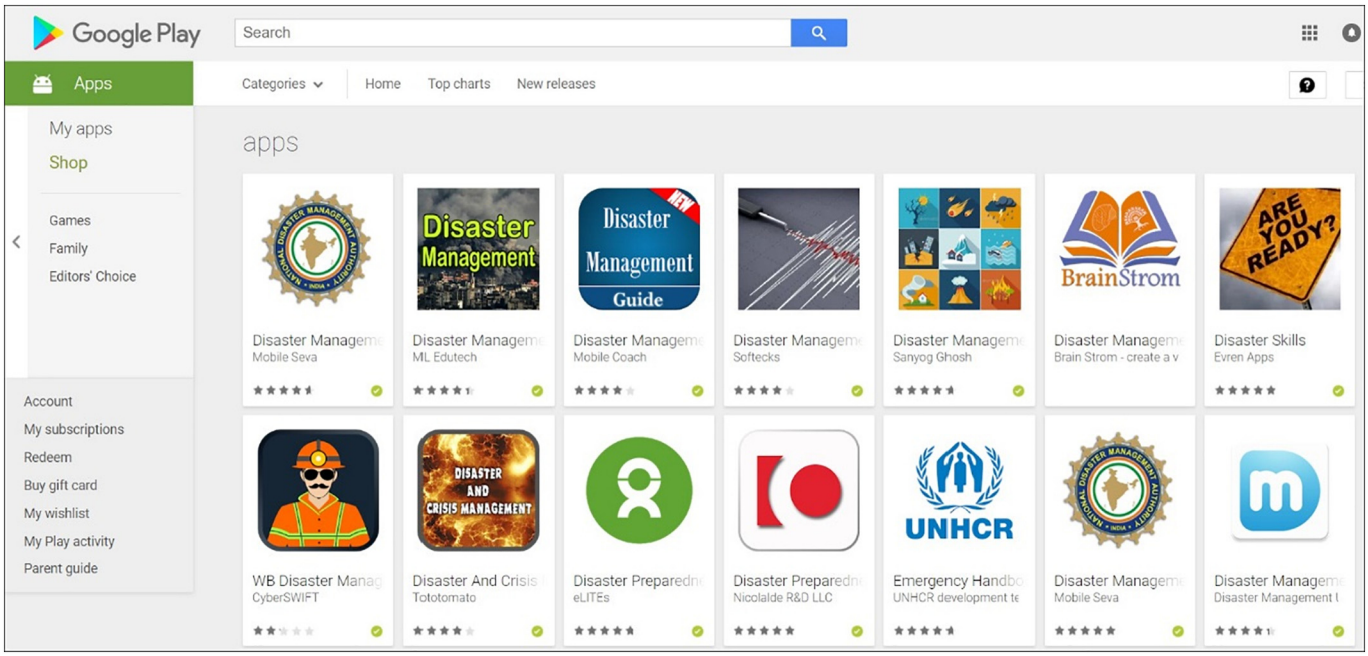

Fig. 1. Search results for 'Disaster Management' on android app store on 1st June 2018.

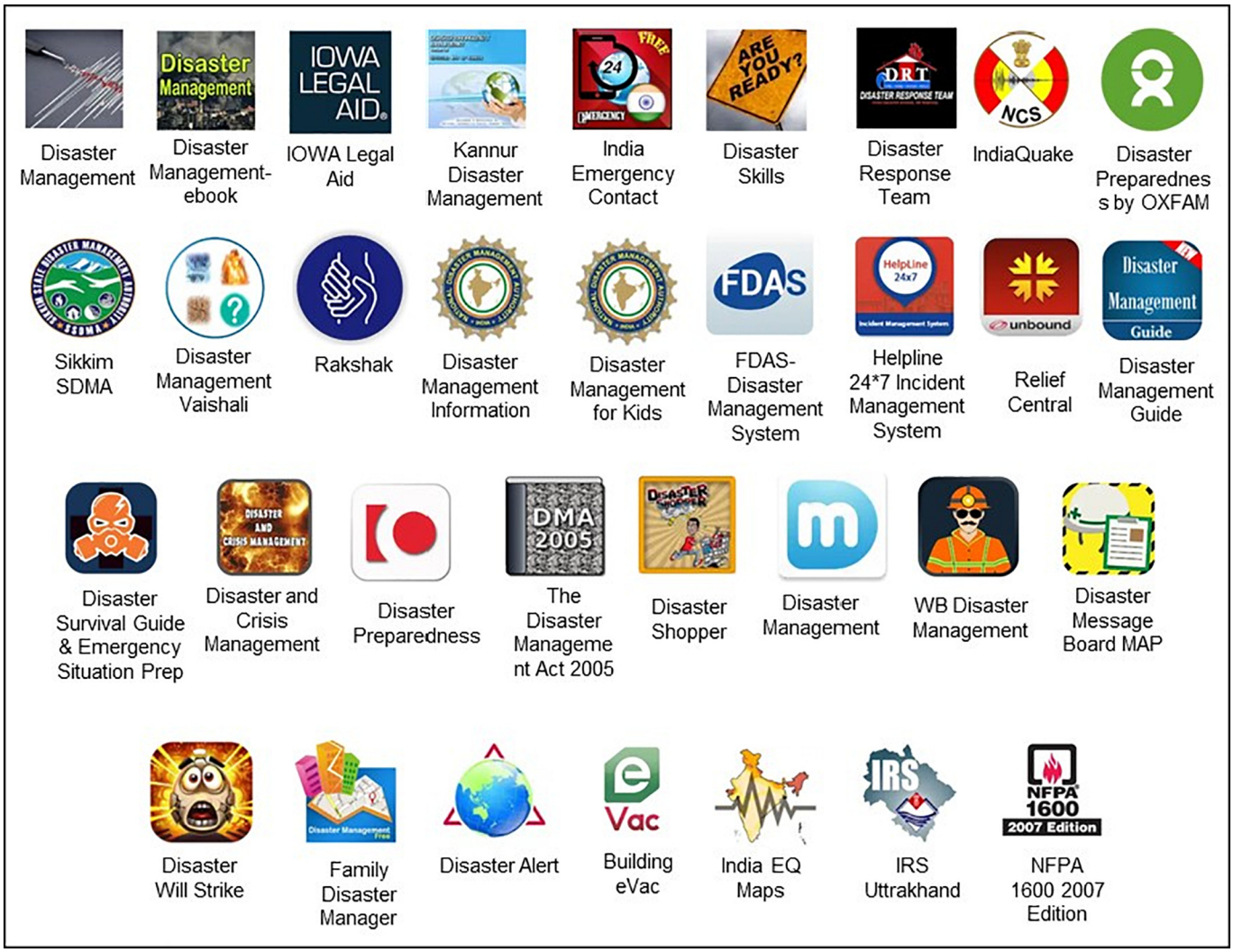

Fig. 2. 33 selected apps with the app logo (compiled by author).

available on the official Google play store. The authors assessed the current state of these selected apps mainly based on the primary data collected pertaining to three key parameters namely 'Number of downloads', 'User Rating' and 'Primary and Secondary Function'. The authors have methodically discussed the key findings related to each of these parameters below and have put forward suitable suggestions for their further development.

6.1. Enhancing community outreach of disaster-related mobile apps (downloads)

Ogie [62] pointed that the success of app-based crowdsourcing primarily depends on the active user participation. However, based on the limited outreach of disaster-related apps in India (as demonstrated in Section 5), it is inferred that the user participation is currently very much limited. To enhance the user participation for crowdsourcing disaster-related information, there is need to enhance the outreach of these apps so that necessary information during disaster situations could be sourced from wider areas. To enhance community outreach, there is need to address the key issues that limit the use of these apps at large scale like application interface, requirements of target population, type of apps depending on the purpose (game-based, open contests etc.). There is also a core need to learn and understand from mobile apps like Relief Central, Disaster Alert and Disaster Will Strike which have wide community outreach.

Through these results, the authors conversely highlight the huge potential for mobile apps in Indian market, as in a country with population of 1.35 billion [63], the current outreach of these disaster related apps is almost negligible. Undeniably, several initiatives have recently been taken by government bodies in India to promote mobile based technologies (as discussed in Section 3), there is still a genuine need for engaging local communities for operationalizing app-based crowdsourcing. There is need to raise awareness amongst the target communities and educate them about the significance of app-based crowdsourcing to ensure active community participation. In view of the limited resources and financial constraints, the government bodies in India should also lay emphasis on engaging private sector for the purpose of app-development and data collection in disaster management.

6.2. Ensuring user-friendly application interface (user rating)

Based on the poor user ratings of selected GPS-based apps, the study finds that the application interface plays a key role in its success as users give higher preference to mobile apps that are convenient and instantly accessible. Accordingly, there is need to work toward making the current disaster-related apps more user friendly with simple login features and easy to understand processing. It is important to ensure that mobile app takes into consideration the varying needs of target community including the language, age and gender groups, relevant information sharing etc. There is also a need to ensure that the disaster-related apps cater to the mobile phones used by the target population in terms of interoperability, OS compatibility etc. [22] depending on country and regional preferences. Although there are technical limitations of mobile apps to function only in

Table 1
Current state of 33 selected apps (compiled by author).

S. No.	Name of the Application	Downloads (In thousands)	User Rating	Primary Function	Secondary Functions					
					Educational/ Games/Guides	Alerts & Notifications	Helplines/ Emergency	Emergency tools /Resources	Case Specific	GPS Enabled
1	Disaster Management	1	4.3	Educational	--					
2	Disaster Management-ebook	5	4.5	Educational	--					
3	IOWA Legal Aid	NA	5	Alerts	√	--		√		√
4	Kannur Disaster Management	0.1	3.5	Case Specific		√	√	√	--	
5	India Emergency Contact	0.1	NA	Helpline			--			
6	Disaster Skills	0.1	4.8	Educational	--		√			
7	Disaster Response Team	NA	5	Educational	--		√			
8	IndiaQuake	5	4.6	Alerts	√	--				
9	Disaster Preparedness by OXFAM	0.5	4.6	Educational	--		√			
10	Sikkim SDMA	0.5	4.7	Case Specific	√	√	√		--	
11	Disaster Management Vaishali	0.1	4.8	GPS based				√		--
12	Rakshak	NA	5	Alerts			√	√		√
13	Disaster Management Information	1	4.8	Educational	--		√			
14	Disaster Management for Kids	0.5	4.8	Educational	--					
15	FDAS-Disaster Management System	0.1	1	GPS based						--
16	Helpline 24*7 Incident Management System	NA	4.3	Helpline			--			√
17	Relief Central	50	4.1	Educational	--	√				
18	Disaster Management Guide	0.1	3.8	Educational	--					
19	Disaster Survival Guide and Emergency Situation Prep	1	4.1	Educational	--					
20	Disaster and Crisis Management	0.1	4	Educational	--					
21	Disaster Preparedness	0.1	5	Educational	--					
22	The Disaster Management Act 2005	1	5	Educational	--					
23	Disaster Shopper	0.5	4.1	Educational	--					
24	Disaster Management (Mumbai)	5	4.3	Case Specific	√	√	√	√	--	
25	WB Disaster Management	0.1	2.2	Case Specific					--	
26	Disaster Message Board MAP	0.5	4	GPS based		√				--
27	Disaster Will Strike	1000	4.5	Educational	--					
28	Family Disaster Manager	0.1	5	GPS based		√				--
29	Disaster Alert	500	4.1	Alerts		--				
30	Building eVac	1	4.1	Educational	--		√	√		
31	India EQ Maps	0.5	4.6	Educational	--					
32	IRS Uttrakhand	0.1	5	Case Specific					--	
33	NFPA 1600 2007 Edition	5	5	Educational	--					

*NA-Information not available as of April 2018, *(−) Primary Function, *(√) Secondary Function

selected OS, due consideration should be given to the OS used by majority of target users.

6.3. Promoting GPS-based mobile apps for crowdsourcing (key functions)

The study results highlighted that there are very limited GPS-based disaster-related mobile apps in the current scenario. The study suggests that the notion of app-development and app-based crowdsourcing can potentially be encouraged at large scale, if integrated with the ongoing policy initiatives in India like Digital India. Utilizing GPS-based mobile apps in disaster research for data collection and organization shall provide a genuine scaffolding to all the concerned stakeholders for drawing out information patterns and management strategies especially for the unmonitored areas. Accordingly, there is need to develop innovative means of data collection by capitalizing on the widespread mobile phone penetration and tapping on to the collective intelligence of varied users.

In view of the growing penetration of smartphones and mobile apps in India, the study underlines that a widespread sensing infrastructure (in form of smartphones) is already in place. While India is prone to a variety of disasters due to its distinct geo-climatic settings, the issue of poor data availability has always been a major challenge in disaster management. To overcome this challenge, there is need for micro-level data collection around the country. Few case-specific apps in India are already operational (as discussed in Section 5), however there is need for further development of existing apps as well as developing new apps at micro level considering the diverse and scattered Indian communities. Further, there is also need for a variety of information in different stages of disasters. Fig. 3 highlights the potential focus areas of data collection in various stages of disaster management cycle which the app developers can take in consideration.

The study acknowledges that there are many persistent issues [16,18] with developing such mobile apps like cost and handling the crowdsourced data, but there are also successful cases like in the case of Cyclone Hudhud [59] wherein the underlying barriers have successfully been overcome and the potential of citizen science has been effectually utilized. Given the high usage of social media apps in India, the study suggests that disaster-related operations should regularly be integrated with dedicated platforms like in case of PetaBencana.id and Ushahidi, wherein the people can effectively assist the humanitarian organizations by communicating the latest disaster-related information in the digital form (photos, videos, text etc.).

7. Conclusion

Although the current scientific literature presents a deep understanding of various challenges pertaining to app-based crowdsourcing, not much

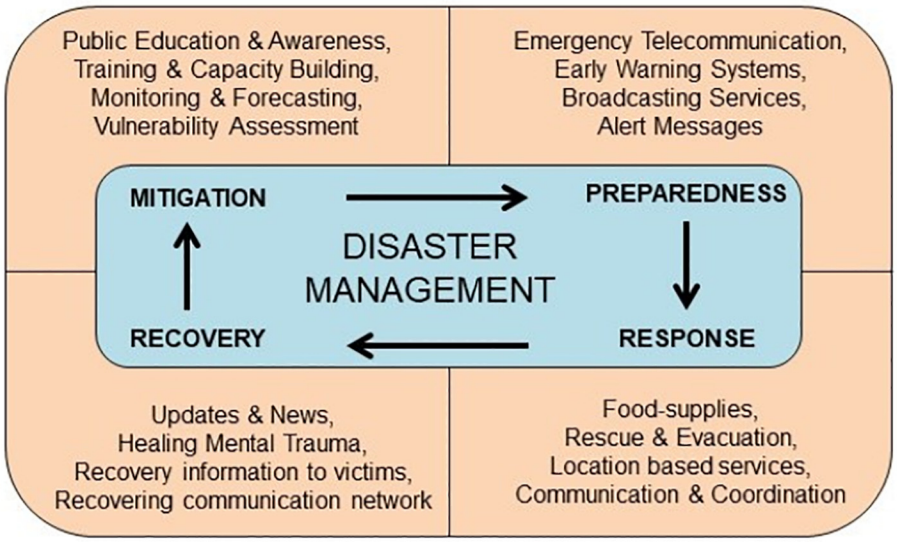

Fig. 3. Potential focus areas for app-based crowdsourcing in various stages of disaster management cycle. (Source: Author)

work has been done to understand this topic from the user aspect in different contextual settings. In view of the identified research gap, this study tries to understand the current state of disaster-related mobile apps in India. Through literature review and the analysis of primary data on selected disaster-related mobile apps, the authors have addressed the two key objectives defined in the beginning of the study. Based on the literature survey, it is evident that the idea of mobile app-based crowdsourcing is gaining increasing recognition in academic research, however there is need to learn more from real-world experiments like Ushahidi and Petbencana.id. The study listed some of the key identified challenges from literature survey that need to be considered for operationalizing crowdsourcing through mobile apps.

Further, the authors assessed the current state of 33 freely accessible disaster-related mobile apps that are specific to Indian context, based on defined parameters like number of downloads, user rating, primary and secondary functions etc. It was found that most of the current mobile apps are primarily educational apps and their overall outreach is very limited. In the wake of growing frequency and intensity of disasters in India, the urgent need for GPS-based mobile apps that substantiate crowd sourcing and spatial mapping of disasters has been realized to enhance data sharing and disaster communication at various levels. To ensure the greater outreach of disaster-related mobile apps, the varying community interests like easy functioning of applications need to be taken into consideration. It is realized that the success of the apps is primarily dependent on user-friendly application interface.

Notably, several researchers around the world have put forward their original research on the concerned research topic of app-based crowdsourcing, however to the author's knowledge, the outreach of disaster-related mobile apps to general public specifically in Indian context has not been discussed. It is therefore hoped that the study findings will provide valuable insight to app developers, humanitarian agencies, academic experts etc. on the key challenges (both on academic and field aspects) that restrain the operationalization of crowdsourcing through mobile apps and the potential areas of intervention.

The authors acknowledge that the mobile app search being made in the context of India has certain limitations and the findings may not generalize to other contexts. The study used the 'Number of downloads' and 'User ratings' as dependent variables to understand the outreach and effectiveness of the selected mobile apps. The study recognizes that there might be some influences due to these selected parameters by factors like promotion, advertisement etc., however it falls beyond the scope of this study. The future scope of this research includes exploring disaster-related apps in other operating systems (apart from Android OS) as well as apps that are not freely available and charge some fee. Further work could also be done in the field of developing user-friendly application interface and enhancing the outreach of disaster-related mobile apps.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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