# Real-Time Flood Mapping for Disaster Management Decision Support in Chennai

by


**Maanasa Priyaa Dharmapuri Sridhar**

B.E. Computer Science and Engineering (2012)

PSG College of Technology, India


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Signature redacted

Signature of Author________________________________________

System Design and Management Program
May 12, 2017

Signature redacted

Certified by________________________________________

Miho Mazereeuw
Thesis Supervisor
Director, MIT Urban Risk Lab

Signature redacted

Accepted by ________________________________________

Joan Rubin
Executive Director, System Design & Management Program

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## ABSTRACT

Crisis informatics: the multidisciplinary field combining computing and social science knowledge of disasters has become an important field of study in the last decade (Palen and Anderson 2016). With the unprecedented growth of social media, the disaster knowledge has transformed from being expert-driven knowledge to an everyday knowledge produced by different stakeholders (Hui and Tsang 2016). The aim of this research is to implement the concept of 'People as sensors' (Goodchild 2007) in India during disasters. People share granular geo-located information and broader dissemination of this Geo-social intelligence (Holderness 2014) outside of the traditional channels of emergency response.

Chennai, the capital city of Tamil Nadu, is located in the southeastern India on the shores of the Bay of Bengal. With its low elevation coastal zone, inadequate provision for storm water runoff, and unregulated growth over wetlands (Parkash 2016), the city is prone to unpredictable rainfall and heavy flooding events during northeast monsoon season between October and December. The floods during December 2015 were one of the costliest natural disasters the city (T. E. Narasimhan, 2015) had witnessed and it exposed the critical need for providing real-time geospatial data to disaster managers to assist with their preparedness, rescue and relief operations. This project, initiated by Urban Risk Lab and supported by MIT Tata Center for Technology and Design (MIT Tata Center, 2016), involves developing RiskMap, a web-based platform to collect and validate real-time crowd-sourced flood reports via social media to enhance the city's resilience to extreme weather events. This thesis elaborates on the system design, development and analysis of the platform and provides suggestions for the future work.

Thesis Supervisor: Miho Mazereeuw

Title: Director, MIT Urban Risk Lab

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## TABLE OF CONTENTS

## TABLE OF FIGURES

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## ABBREVIATIONS

| | |
|---|---|
| API | Application Program Interface |
| AWS | Amazon Web Services |
| DDMA | District Disaster Management Authority |
| DWE | Disastrous Weather Events |
| GCC | Greater Chennai Corporation |
| GIS | Geographical Information System |
| IMD | Indian Meteorological Department |
| JS | JavaScript |
| NDMA | National Disaster Management Authority |
| NDRF | National Defense Response Force |
| NGO | Non-governmental Organization |
| PGR | Public Grievance and Redressal |
| RDS | Relational Database Service |
| REM | Risk Evaluation Matrix |
| SDMA | State Disaster Management Authority |
| SNS | Simple Notification Service |
| SQL | Structured Query Language |
| URL | Uniform Resource Locator |

# 1 INTRODUCTION

## 1.1 PREAMBLE

I write this thesis with a sense of satisfaction of studying and working on an issue of deep interest to me and with the motivation of seeing the project through completion. The technologies discussed in the thesis and used to develop the described solution have significant structural and functional advantages over legacy approaches that are currently in use for disaster management pertaining to data gathering. The tools and solutions described here are aimed at complementing, instead of disrupting the existing protocols in Chennai. The amenability of a technological solution to seamlessly integrate with current infrastructure is critical for its adoption in the context of disaster management. I am working towards making the solutions detailed in this thesis find widespread application in the field. I have made my best effort to accurately report the work I have performed both individually and in collaboration.

## 1.2 CONTEXT

This thesis reports the work I undertook at Urban Risk Lab at MIT under the supervision of Professor Miho Mazereeuw. The focus of my research was to build a web platform that would capitalize the tendency of participatory data gathering to improve a city's resilience during disaster times. The culmination of my work is RiskMap.in, a web platform that gathers real-time geo-tagged flood reports from residents on the ground and visualizes it on a map platform to assist disaster managers in recovery process. My research was anchored to a personal interest to study the issue and to contribute to solving it using my Systems Design and Computer Science Engineering background, and as an effort to give back to the country I belong to.

## 1.3 THESIS STRUCTURE

This thesis is divided into 6 chapters. Chapter 1 establishes the scope and context of the project, offers an overview of the state of urban flooding and disaster management in India and the need for usage of social media in disaster management that underlie the premise of the project. Chapter 2 reports the survey of literature relevant to the project. The survey is categorized as per the key themes of the project – Disaster Management framework in India and usage of social media in Disaster Management. Chapter 3 reports the knowledge gained from field visits to Chennai during August 2017 and

January 2017 to understand the city's existing disaster management protocols and reporting mechanisms. Chapter 4 offers details of the system design and development of the RiskMap platform through dedicated sections to constituent software components. Chapter 5 details the system analysis of the project. Chapter 6 lays down the future work to be done on the platform and reports the synthesis of knowledge through the project.

## 1.4 MOTIVATION

### 1.4.1 DISASTER PROFILE OF INDIA

India's geo-climatic conditions as well as its high degree of socio-economic vulnerability, makes it one of the most disaster prone country in the world. The deadliest disasters that happened in the last decade are –

| S.No | Disaster | Year | State & Area | Fatalities |
|---|---|---|---|---|
| 1 | Tsunami | 2004 | Coastline of TN, Kerala, AP, and Andaman Nicobar Islands | 10,749 deaths<br>5,640 persons missing<br>2.79 million people affected<br>11,827 hectares of crops damaged<br>300,000 fishermen lost their livelihoods |
| 2 | Maharashtra floods | 2005 | Maharashtra State | 1094 deaths<br>167 injured<br>54 missing |
| 3 | Kashmiri Earthquake | 2005 | Kashmir State | 86000 deaths (includes Kashmir & surrounding Himalayan region) |
| 4 | Kosi Floods | 2008 | North Bihar | 527 Deaths<br>19323 Livestock perished<br>222754 Houses damaged<br>3329423 persons affected |
| 5 | Cyclone Nisha | 2008 | TamilNadu | 204 deaths<br>$800 million damages |

Source: (Affairs, 2004)

Among these, floods are the most devastating one causing loss of lives and economic damage worth million dollars during the last thirty years (Affairs, 2004).

### 1.4.2 URBAN FLOODING IN INDIA

Due to floods, on an average every year, 1,588 lives are lost, 7.5 million hectares of land is affected, and the damage caused to crops, houses and public utilities is roughly USD 1000 million (Kailash Gupta 2009). Between 1953 and 2005, a total of 84,207 lives were lost with maximum of 11,316 in 1977, and a minimum of 37 in 1953 due to floods (Ibid.). Five of the world's forty most populated cities (Mumbai, Bangalore, Chennai, Kolkata, Delhi) are located in India(Most Populous Cities, 2017). In 1991, just under 220 million people lived in the country's urban areas. This rose to 380 million in 2011 and is forecast to increase to over 600 million by 2030 (Ahluwalia, Kanbur, and Mohanty 2014). This significant shift in population to major urban cities and demographic explosion enhances further the vulnerability of these urban conglomerations to coastal floods, flash floods, and floods caused by release of excess water from reservoir or failure of dam on the upstream side (De, Singh, and Rase 2013).

One of the major floods in the recent times the country faced was the December 2015 Chennai Floods during the period of Northeast monsoon which resulted in the death of about 500 people (Business Line, 2016) and property damage of about USD 3 billion (Deccan Chronicle, 2015). Chennai recorded a rainfall of 1218 mm in the month of November, three times more than its normal rainfall, and it was the highest received since 1918 (Unit 2013). Beyond the magnitude of rainfall, poor management of the drainage system was mainly attributed to the severe crisis of flooding (Ibid.). The illegal encroachment of city's drainage channels through unsustainable development was the one of the causes of not keeping the city alive for days after the heavy rainfall (Ibid.). The garbage dumps and solid wastes on storm water drains significantly reduced the city's drainage capacity, which magnified the ill effects of heavy rainfall several fold (Ibid.).

The complex administrative set-up of cities, where multiple authorities and agencies function with competing jurisdiction, lack of actionable real-time data from the ground, and network failure made disaster relief during the floods difficult[1]. That is why steering disaster management in urban areas through stages – from early warning and response to relief and recovery – will present a huge challenge.

### 1.4.3 SOCIAL MEDIA AS A NEW PARADIGM IN DISASTER MANAGEMENT

Urban and emergency management literature commonly mentions social capital or networking and information, and communication systems as critical sources for urban

[1] From meetings with officials in GCC's Control Room on August 29, 2015

resilience (Aldrich 2012; McEntire 2012). Use of information and communication systems is highlighted to inform decision makers and the public in responding to emergency situations, overcoming uncertainty, managing collective actions, and improving resilience (Comfort, Boin, and Demchak 2010). Social media opens up an array of new opportunities for enabling participation of a broader public in the process of coping with a disaster (Grunder-Fahrer et al. 2016). Due to the immediacy of social media messages, it is often used during disasters where location information is of vital importance (Holderness 2014). This can improve situational awareness of the disaster managers because of its timeliness and huge and fine-grained spatial coverage (Ibid.).

## 1.5 PROPOSED SOLUTION – RISKMAP.IN

This project aims to bring these concepts together by making residents of the city as part of the disaster management process. The proposed solution, RiskMap, is a web platform that enables users to submit flood reports using card interface via existing social media channels such as Facebook, Twitter, and Telegram. Geo-tagged reports from all the channels will be mapped and visualized on a single map interface making validation and data aggregation simpler. It also aims to integrate with the existing system by incorporating the reports from the city's PGR System and from the Corporation's helpline thus providing a seamless communication channel between the Government and citizens.

RiskMap addresses the following two key problems mentioned in Section 1.3 and 1.4:

- *Availability of real-time geo-tagged data during flood times*

  As described in Section 1.4, it was difficult to execute the disaster management efforts efficiently by the city officials during the 2015 floods in Chennai due to lack of real-time data from the ground. The field engineers had a turnaround time ranging anytime between 6 – 12 hours to collect reports from all the areas in the city. This platform aims to solve this problem by actively engaging with residents on the ground via different social media platforms and collects real-time flood reports with location information.

- *Lack of intelligence from the aggregates of reports from various channels*

  The city's existing system indicates that flood reports are gathered via different channels and are handled on an ad-hoc basis. All reports are treated as data points and not as data patterns[2]. As a result, the disaster managers miss out on getting crucial knowledge out of the reports they have gathered. This platform aims to solve this problem with the REM interface where intelligence is built from the citizen reports is interspersed with the Geo-spatial layers of the city to assist disaster managers determine alert levels and risk regions in the city.

## 1.6 TOOLS/FRAMEWORKS USED

Following were the tools and frameworks used in building the software platform as described in the previous section –

| **Modules/Tasks** | **Tools/Frameworks used** |
|---|---|
| UX Design Mockups | Adobe Illustrator |
| Front end module | Aurelia JS, Leaflet JS |
| Server module | NodeJS |
| Reports module | AWS Lambda, AWS SNS & NodeJS |
| Continuous Integration & Deployment | Jenkins, Travis |
| Backend database | PostgreSQL |

[2] From meetings with officials in GCC's Control Room on August 29, 2015

# 2 LITERATURE REVIEW

In this section, I provide a detailed analysis of two verticals – Disaster Management Framework in India and usage of social media in crowd-sourced disaster reporting. Breaking this down, in the first subsection, I detail on the literature of India's disaster profile and the direction of disaster management. This would highlight the need for community involvement in the disaster management process. As a solution to this problem, I explore the possibility of usage of social media for participatory data gathering and on the demonstrated success of such platforms in other cities during disasters.

In the next section, I report the literature on recent flood events in metropolitan cities (Mumbai, Delhi, Kolkata, and Chennai) in India to highlight the high probability of urban flooding in the coming years and its causes. This would pave the way for the next chapter where I focus on Chennai city's most recent flood event, and its disaster reporting mechanisms to gather the requirements for the pilot version of RiskMap platform to fix the reported challenges.

## 2.1 DISASTERS IN INDIA

India, due to its unique geographical and geo-climatic characteristics, is prone to various disasters. During the last thirty years time span the country has been hit by 431 major disasters resulting into enormous loss to life and property.

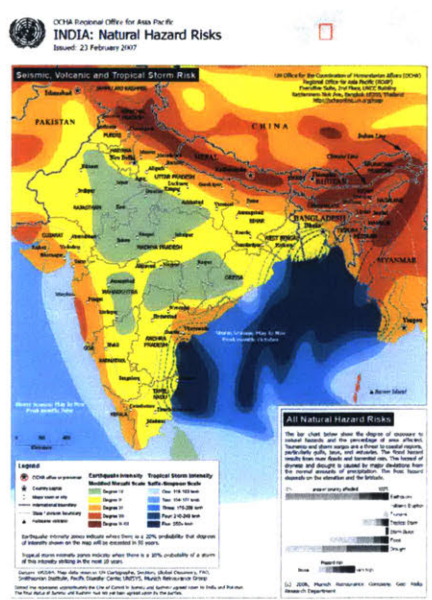


Figure 1: India: Natural Hazard Risks (OCHA ROAP, 2007)

According to the Prevention Web statistics, 143039 people were killed and about 1500 million were affected by various disasters in the country during these three decades. The disasters caused huge loss to property and other infrastructures costing more than US $48k million. Floods, earthquakes, cyclones, hailstorms, etc. are the most frequently occurring disasters in India. Out of 35 states and union territories in the country, 27 of them are disaster prone. Almost 58.6 per cent of the landmass is prone to earthquakes of moderate to very high intensity; over 40 million hectares (12% of land) are prone to floods and river erosion; of the 7,516 km long coastline, close to 5,700 km is prone to cyclones and tsunamis; 68 per cent of the cultivable area is vulnerable to drought and hilly areas are at risk from landslides and avalanches. The basic reason for the high vulnerability of the country to natural disasters is its unique geographical and geological situations. Along with the natural factors, various human induced activities like increasing demographic pressure, deteriorating environmental conditions, deforestation, unscientific development, faulty agricultural practices and grazing, unplanned urbanization, construction of large dams on river channels etc. are also responsible for accelerated impact and increase in frequency of disasters in the country.

## CONTRIBUTING FACTORS AND IMPACT

The developmental advantages to urbanization have been discussed in the Indian context (Beall, Guha-Khasnobis, and Kanbur 2012), urbanization in India comes with its own set of challenges. Urban population growth places enormous pressure on existing infrastructure and services, and Urban Local Bodies often lack the authority or capacity to make or implement policy independent from state or national bodies (Aijaz and Hoelscher 2015; Baud and De Wit 2009; Shatkin 2014).

There are also larger issues that are relevant for the country's cities. Primarily, the threats posed from current and future environmental change, and how this can exacerbate other challenges in urban settlements (Gasper et al., 2011). Taking into account this urgency, India has been pointed to as one of the countries most vulnerable to climate change in the world (Cruz et al. 2007; INCCA 2010).

In countries like India, urban settlements are frequently located in areas that (Aijaz and Hoelscher 2015) face greater exposure to physical hazards, are more vulnerable in their infrastructure and built environment, face rapid urban population growth, have large low-income populations housed in precarious locations, and lack the needed governance, technical and financial capacity to address the impacts of climate change (McCarney 2009). The impacts of environmental change will be most starkly felt in urban areas of developing countries (Hunt and Watkiss 2011). This will include a greater prevalence of extreme weather events (IPCC 2014) and exacerbated impacts of slow-onset changes such as sea-level rise, flooding and inundation, and desertification and water scarcity (Satterthwaite 2007).

## 2.2 INDIA'S DISASTER MANAGEMENT FRAMEWORK

Disaster management in India has now evolved from an activity-based setup to an institutionalized structure; from single faculty domain to a multi-stakeholder setup; and from a relief-based approach to a 'multi-dimensional approach for reducing risk' (Flora 2014). There has been a paradigm shift in the focus of Disaster Management, from response-centric covering rescue, relief, rehabilitation, and reconstruction to laying greater emphasis on the other elements of disaster management cycle—prevention, mitigation, and preparedness—as a means to avert or soften the impact of future emergencies (Commission 2012). Another significant change has been the move from government to public-private partnership, and community disaster management (Kailash Gupta 2009).

A huge and beneficial role was played by The Disaster Management Act enacted in 2005, which greatly empowered the setting up of an effective disaster management system that extends across the whole of India (Flora 2014). The NDMA chaired by the Prime Minister is responsible for laying down the national policies, plans and guidelines for disaster management and the SDMA for formulating policies and plans for disaster management in the states (Ibid.). And last, District Disaster Management Authorities (DDMA) for planning, coordinating, and establishing systems for disaster management at the district level in accordance with the guidelines laid down by the national and state authorities (Ibid.). All departments of the State Government including the Police, Fire Services, Public Works, Irrigation etc., work in a coordinated manner under the leadership of the District Collector during disasters, except in Metropolitan areas where the Municipal body plays a major role. NGOs have also participated in providing relief, rescue and rehabilitation in recent times (Commission 2012).

NDMA guidelines (NDMA 2010) highlight the need for community-based disaster preparedness and response during urban flooding. Even before the intervention of the state, community becomes the first responder at the local level (Ibid.). Capacity building is another important aspect and should not be limited to professionals and personnel involved in disaster management (Ibid.). Urgent training of volunteers from the community towards first response measures as well as mitigation measures is required (Ibid.). Generating awareness, involvement of common man in disaster management are some of the crucial steps that help in better recovery (Paton and Johnston 2001). In addition to this, there is a need for a central real-time GIS database to assist emergency responders to access information in terms of vital parameters (Flora 2014). The India Disaster Report (Parasuraman and Unnikrishnan 2000) identifies key issues in current system with respect to the availability of and access to high quality disaster-related information and the absence of coherent disaster preparedness and response policy.

## 2.3 USE OF SOCIAL MEDIA IN DISASTER MANAGEMENT

To mitigate the issues with respect to high quality data availability and access, we are trying to analyze and leverage the potential of integrating this isolated social media efforts into existing disaster management framework. Social media do not represent all of a population evenly but they do represent a range of behaviors, ideas and opinions that have a role to play alongside traditional disaster response (Palen and Anderson 2016). Disaster response can be better served if we accept and allow people to have a voice and to help in disaster response (Ibid.).

Analysis of Twitter microblog posts during the April 2009 Oklahoma Grassfires showed that 40% of all on-topic tweets were geo-tagged and 56% of these tweets gave situational updates (Vieweg et al. 2010). On March 11, 2011, a magnitude 9.0 earthquake hit the eastern part of Japan causing extensive damages resulting in at least 13,000 deaths and 14,000 missing population and also triggered the first nuclear crisis in the 21st century, when the accompanied tsunami struck the Fukushima Daiichi Nuclear Power Station (Hui and Tsang 2016). Twitter was extensively used during the earthquake for dissemination of information to families and friends about individual safety and to facilitate access of information (Ibid.). The website Safecast (safecast.org/tilemap/) was developed by a group of residents to monitor the changes in the level of radiation after the meltdown of the nuclear power plant in Fukushima (Ibid.). During the flood in 2013 in Germany and Austria, Facebook was used to organize voluntary support, mutual information and the distribution of donations in cash and in kind as well as emotional support to the people affected (Grunder-Fahrer et al. 2016). The Slándáil project deals with the collection and processing of data in different modalities (texts and images) and languages (English, German and Italian) and has a special focus on issues related to the legal and ethical correctness of data utilization (Ibid.).

From Sections 2.2, it is evident that there is a need for community involvement in disaster management and there have been successful social media initiatives towards achieving that goal. The key gap in these systems is that these efforts were ad-hoc, isolated, and did not integrate into the city's disaster framework. The proposed solution aims to bridge the gap between community and Government and enables community-based disaster preparedness.

## 2.4 FLOODS IN METROPOLITAN CITIES

Increasing trend of urban flooding is a countrywide phenomenon and poses a great challenge to urban planners. Although volume of water to be handled is not as severe as a flash flood of a river system, the property damages and indirect financial losses are significant as surface water runoff is controlled and managed by humans in a concrete world as this flooding occurs in highly populated areas. Urban flooding is significantly different from rural flooding as urbanization leads to developed catchments which increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. Consequently, flooding occurs very quickly due to faster flow times, sometimes in a matter of minutes. (Ahmed et al. 2013)

To understand this phenomenon better, I studied the flooding scenario in the following four metro cities - Mumbai, Delhi, Kolkata and Chennai. The details on profile of the city and the most recent floods in Mumbai, Delhi, and Kolkata reported in DWE, IMD are used in this Chapter. The profile of Chennai city, its flood events and unfolding of its most recent flood event will be elaborated in the next Chapter as part of Field research for the project.

### FLOODING EVENT IN MUMBAI ON 26 JULY, 2005

Mumbai is the financial capital of India with an area of about 600 $km^2$ and a population of 17.7 million (De, Singh, and Rase 2013). It received very heavy rainfall on 26 July 2005, the strongest rain ever recorded in India. The Santa Cruz observatory at Mumbai airport recorded 944 mm during the 24 hours ending 08:30h on 27 July 2005.

Over 60% of Mumbai was inundated to various degrees on 26 July 2005. The IMD was unable to issue advance warnings of this event. Even when there was heavy rainfall in the northern suburbs, the IMD was unable to monitor the rainfall and issue warnings in real time. The main causes of flooding in Mumbai were low ground levels, silts in drains, dilapidated drains, obstructions of utilities, encroachment along lakes, slums along outfalls, urbanization, loss of holding ponds, garbage dumping in SWD mainly in slums and increase in runoff coefficient (Kapil Gupta 2007).

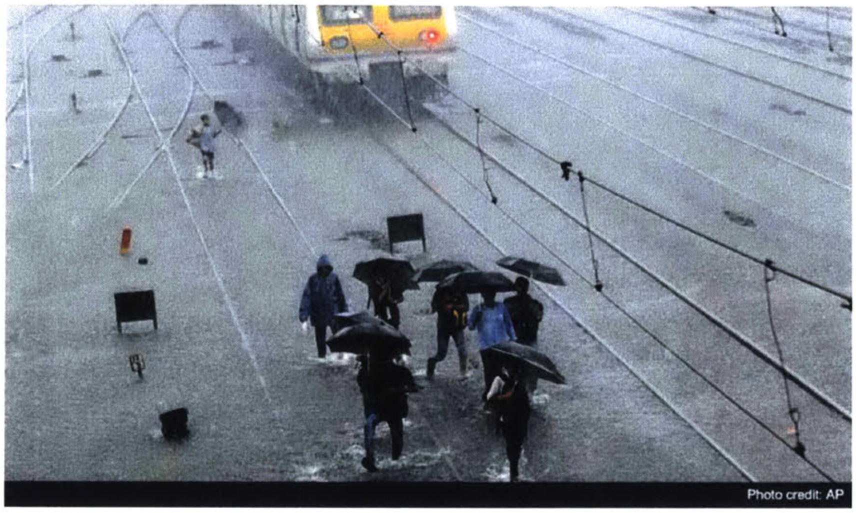


Figure 2: Mumbai residents seen walking on rail tracks (Associated Press, 2005)

The extreme rainfall event on 26 July 2005 was a wakeup call for Mumbai and it has indicated the perils of rapid development in highly concentrated urban areas. This event has resulted in Mumbai setting up a much better response mechanism based on real-time monitoring of rainfall at 27 locations in the city to handle recurrences of similar events in the future (Rafiq et al. 2016). The Central Water Power Research Station, Pune is currently (2007 – 2008) in the process of preparing a detailed scale model for carrying out the hydraulic model studies for the Mithi River (Ibid.). This model is intended to provide a basis for long-term planning of Mumbai taking into account the impacts of climate change and sea-level rise (Ibid.). It would also help in identifying the tidal impact on the flooding and estimate the extent of inundation of low lying areas through the progression of low and high tides (Ibid.).

## FLOODING EVENT IN DELHI IN SEPTEMBER 2010

Delhi, capital of the country, with an area of 1483 $km^2$ has an estimated population of 13.8 million. The average annual rainfall of Delhi is 670 mm, most of which falls during Southwest monsoon, in July and August. The flood season observed by Delhi govt. is from July to October. Delhi can be divided into three major geographical regions: the Yamuna flood plain, the ridge, and the Gangetic plains. Heavy rains in the past, over Delhi high land ridge area have not affected the city due to natural drainage system for rainwater to flow to the Yamuna River. Most populated parts of Delhi are inside the

Yamuna flood plains. In the recent past thousands of illegal colonies have emerged in this part as well as in Delhi. Many unauthorized colonies have been developed on agricultural land by local colonizers without considering city plans, drainage, and sewerage etc. Number of surface water bodies has been reduced from 800 to 600 due to encroachment (De, Singh, and Rase 2013). Since 1990, Delhi has witnessed 6 massive floods in different years (Rafiq et al. 2016).

The city was completely paralyzed due to heavy rains on 25-26 August 1991 resulting in the damage of roads and collapsing of bridges, causing traffic congestion. In September 2010, a flash flood in Uttarakhand raised the water level in River Yamuna above danger mark, which did not recede for several days. The ground water table in the low-lying areas rose so high that one of the buildings collapsed leading to death of 70 people (De, Singh, and Rase 2013). This may be attributed to providing concrete surface over the entire available surface on the pretext of beautifying the city. The non-availability of sufficient recharge surface has compounded the problem of water impounding. The drains in the Delhi were initially designed to transport excess storm water and sewerage flow. However, due to improper layout and improper maintenance and unsuitable geomorphological conditions, these now form pool of stagnant water in north-west and northern parts of Delhi (Rafiq et al. 2016).

### FLOODING EVENT IN KOLKATA ON MAY 27, 2009

Kolkata, with an area of 1851.41 $km^2$ and a population of 14.72 million, is one of the most densely populated cities of India. Much of the city was originally a vast wetland, reclaimed over decades to accommodate the city population. Floods in Kolkata are due to heavy rains in monsoon or because of tropical cyclones. In summer many of the depressions, which form in the head Bay of Bengal and move along monsoon trough, yield maximum rainfall in and around Kolkata region. Because of very flat flood plains of south Bengal delta, floods are a major concern for these areas. There are many non-permanent housing structures in Kolkata, which are subjected to heavy damage during floods. On 4$^{th}$ May 2005, heavy rains killed eleven people in Kolkata and in the same year, on 21$^{st}$ October, 7 lakh people were affected due to heavy rains. In September 2004, 17 people died and 2700 houses were damaged. On 27$^{th}$ May 2009, Cyclone Aila crossed the West Bengal coast causing at least 18 of the 45 total fatalities in Kolkata. (De, Singh, and Rase 2013)

# 3 FIELD RESEARCH

In this section, I detail on the profile of Chennai city and on the events that led up to the December 2015 Chennai floods highlighting the underlying issues. Then, I elaborate on the existing disaster reporting protocols followed by GCC and the ad-hoc crowd-sourced disaster relief efforts put together by city residents. This will highlight the gaps in the existing system and pave way for the system requirements, design and development in the chapter.

## 3.1 CHENNAI CITY PROFILE AND GROWTH

Madras (now Chennai) in 1600 was formed of scattered settlements separated by long distances (A. K. Gupta and Nair 2010). Topographically plain terrain with few isolated hillocks in the southwest, the city is bounded on the east by the Bay of Bengal and on the remaining three sides by Kancheepuram and Thiruvallur district (Ibid.). The city lacks natural gradient for free run-off necessitating an effective storm water drainage system (Ibid.). Sewage system in Chennai was originally designed for the population of 0.65 million at 114 L per capita per day of water supply, and was further modified during 1989 - 1991, and is now much below the required capacity (Krishna 2007). Due to its proximity to the sea, it has a low elevation coastal zone with the Adyar and Cooum rivers meandering through the city (Parkash 2016). These rivers are almost stagnant and do not carry enough water except during rains (A. K. Gupta and Nair 2010). Since the beginning of the 20th Century, Chennai has witnessed a steady deterioration of and decrease in water bodies and open spaces (Ibid.).

There has been severe encroachment on the banks of the three major watercourses (Cooum, Buckingham Canal and Adyar) in the city (Ibid.). The green covers reduced rapidly across the city between the years 1997 to 2001 leading to drastic depletion in water holding capacity of the city's surface (Ibid.). There were several past instances of catastrophic floods in Chennai (1943, 1976, 1985) caused by heavy rain associated with depressions and cyclonic storms, leading to floods in major rivers and failure of and drainage systems. The most recent devastating flood event the city faced was during the Northeast monsoon season between the months of November and December 2015. The events that unfolded during the floods are detailed in the next section.

## 3.2 THE 2015 CHENNAI FLOODS

A depression over the southwest Bay of Bengal on the morning of November 8, 2015 intensified into a cyclone, 'Rovan' and on November 10, it crossed the northern part of the Tamil Nadu coast between Pondicherry and Cuddalore (Ibid.). Heavy to very heavy rainfall resulted over many parts of Tamil Nadu with some parts reporting as much as 550 mm of rainfall between November 9 and 16 (Ibid.). There were torrential rains in Chennai and other coastal districts in TamilNadu on November $23^{rd}$, $28^{th}$ and $29^{th}$, 2015 resulting in floods (Ibid.). Between $1^{st}$ and $4^{th}$ of December 2015, Chennai received 1,522.7 mm of rain as against a normal of 662.6 mm (Ibid.). Stricken residents from Chennai, Kancheepuram and Thiruvallur districts attempted to flee their homes to safer places, with little success. Chennai airport had to be closed down, and re-opened only on December 5, 2015 (Ibid.).

Figure 3: Chennai Airport submerged during December 2015 floods (Commons, 2015)

Damages have been estimated at over US$737 million, with more than 450 deaths in TamilNadu, 81 deaths in Andhra Pradesh and two deaths in the union territory of Pondicherry (Ibid.). An overnight discharge from Chembarambakkam reservoir into the Adyar River became a watery grave for people who were trapped. A power breakdown during the floods killed 14 patients at a private hospital (Ibid.). On December 2, 2015, Chennai was officially declared a disaster area and the Coast Guard, the army, navy and air force were pressed into action for rescue. Insurance companies anticipate claims worth at least US$710 million, with motor insurance accounting for the bulk of the claims (Ibid.).

### CAUSES

In addition to the unchecked growth of the city described in Section 3.1, the causes of increased flooding events in Chennai are identified as

1. Uncontrolled urban sprawl and loss of natural drainage - Drainage channels have been blocked and urban lakes filled and encroached, canals degraded and polluted, heavily silted and narrowed (A. K. Gupta and Nair 2010).
2. Inadequacy of storm water drainage system and lack of maintenance (Drescher et al. 2007) - The city has inadequate provisions for storm water runoff with only 855 km storm water drains against 2,847 km of urban roads, resulting in frequent flooding after even a marginally heavy rainfall (Parkash 2016). Plastic and polythene constituents to the storm water stream along poor or no maintenance aggravates floods (A. K. Gupta and Nair 2010).
3. Increase in impervious surfaces - Paving of roadsides, park and open areas causing flood severity and condition for following droughts (Ibid.).
4. Disappearance of water bodies - Many of the water bodies including man-made wetlands, lakes and natural depressions and have disappeared due to human induced succession, filled with waste and unscientific development or slum encroachments (Sundersingh 1991).

## 3.3 EXISTING DISASTER MANAGEMENT PROTOCOLS IN CHENNAI

The GCC is the municipal civic body that governs the city of Chennai and handles disaster management for the city. The city's disaster management plan is detailed in the following subsections[3]:

### 3.3.1 PREVENTIVE MEASURES BEFORE MONSOON

Before the onset of Northeast monsoon, GCC performs desilting and cleaning of the storm water drain network before the month of September. The blockage in the pipes and drains connecting the drains in the network are cleared. Trees that pose threat are cut down during the preparation phase. Vaccination is administered via health officials to prevent water borne diseases. Regional Meteorological Research Institute issues warning messages and reports to the residents starting 5 days in advance. There are five mandatory relief centers that are setup right before floods. In addition to that, the officials set up ad-hoc centers as and when needed. Residents are informed of this by

[3] From meetings with officials in GCC's Control Room on August 29, 2015

word of mouth as many are already aware of these locations (Corporation schools, community wedding halls, etc.) and assemble there for food and other basic amenities. The GCC guide lists all the helpline numbers, relief centers, low-lying areas, community wedding halls, and all relevant information to be prepared for floods.

### 3.3.2 ACTIONS TAKEN DURING FLOOD

Residents living in low-lying areas are removed and sheltered in community centers and schools owned by GCC. The GCC is also responsibility of distribution of food from cooking section of the relief centers set up, and water with the help of Chennai Metropolitan Water Supply and Sewerage board to the people in relief centers. Sanitation facilities are made available through construction of temporary toilers, drinking water facility by erecting water tanks, and health care facilities are provided by setting up health posts in the relief centers. The electrical department of GCC ensures uninterrupted power supply to the relief centers. In addition to these relief efforts, arrangements are made to pump out the stagnated water from low-lying areas using diesel pumps.

### 3.3.3 ROLES AND RESPONSIBILITIES

The GCC municipality is divided into three regions (North, South, and Central) and it has fifteen zones that are equally divided across the three regions. The city is divided into 200 divisions (the smallest unit) that are unequally divided among these 15 zones.

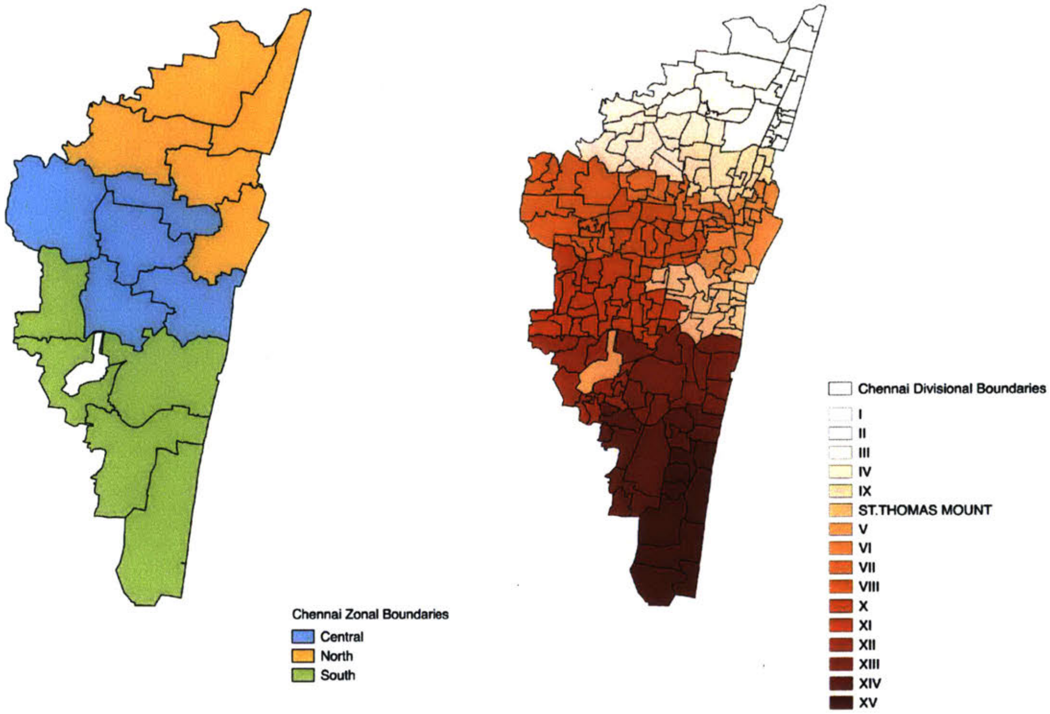


Figure 4: Chennai's Administrative Zonal (L) and Divisional (R) Boundaries[4]

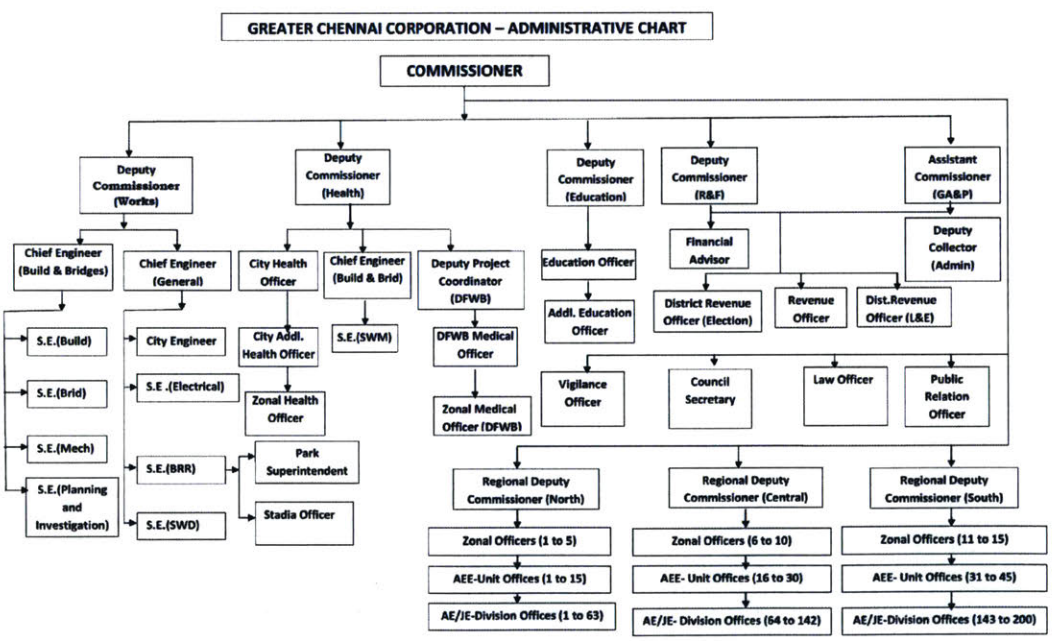


Figure 5: GCC Administrative Chart (GCC, 2015)

[4] From meetings with officials in GCC's Control Room on August 29, 2015

The Regional Deputy Commissioner heads each region and directly reports to the GCC Commissioner. A zonal officer to whom Assistant Executive Engineer (AEE) from each unit reports heads each zone. Assistant/Junior Engineer (AE/JE) from each division report to the AEEs. AE/JE mobilize sanitary inspectors and field workers to report from on the ground and for relief work.

### 3.3.4 DISASTER REPORTING MECHANISMS

The following are the channels via which the control room gathers actionable flood reports:

1. The SDMA has an established streamlined process for disaster management and response. During floods, SDMA, Fire, Police, and all state departments collect the complaints via their field engineers and send it across to the control room via phone calls or emails based on the frequency and the nature of emergency. Walkie-talkies were used in case of network failure.
2. The control room has an official email and landline numbers to register complaints. They also have setup a couple of tablets with WhatsApp installed and have advertised these numbers among residents.
3. 1913, the Corporation helpline number serves as another main complaint entry point.
4. There is an online PGR system where people can submit municipal complaints.


Figure 6: Online Public Grievance System (PGR, 2015)

5. The Public Relations Office goes through newspaper dailies and collects citizen and journalist reports and sends them as complaints to the control room.

The GCC also has an internal module to report and address complaints and update status. All the complaints received are sent to respective zonal officers, which in turn are assigned down to AE/JEs to look at. The field engineers validate the reports and communicate the status via WhatsApp/phone calls. In addition to this, they inspect their assigned locations and file flood reports as well. This happens at the division level and it rolls up to zonal level. Then, all these reports from fifteen zones are sent to the control room.

| Zone | Time of Report | No. of Relief Centres | | No. of people staying | No.of cooking centres | No.of food packets Supplied | | | No. of water stagnations & Locations | | No. of pumps in operation | | | No. of trees fallen | | Subway | | No. of Electricity Cables Snapping |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Opened | | | Morning | Afternoon | Evening | Total | Cleared | 5 HP | 10 HP | 25 HP | Total | Cleared | Total | Cleared | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
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Figure 7: Reports submitted by Field Engineers[5]

For unfolding events like flood, time is of the essence and all these channels take significant amount of time to provide actionable data. Also, there is a lack of geo-tagged data and a unified visualization platform to view all the reports.

## 3.4 CROWD-SOURCED EFFORTS DURING 2015 CHENNAI FLOODS

Parallel to the Government's disaster recovery efforts, people from different regions of the world came together to render help to the flood victims. Social media platforms like Facebook, Twitter, and social messaging app WhatsApp played a significant role with the help of hashtags, in drawing the attention of individuals, groups, and government

[5] From meetings with officials in GCC's Control Room on August 29, 2015

toward flood-stranded residents. Facebook had also launched its Safety Check updates, which informs the Facebook users by checking in and setting their status as safe. Residents used Twitter not only to share information through images and updates about the natural calamity, but also to arrange and co-ordinate various rescue and relief operations. Various hashtags like #ChennaiRainsHelp to help the residents, #ChennaiRescue to share information about rescue events conducted by government and voluntary organizations were used. It also assisted the volunteers to mobilize the resources like food, shelter, safe places, etc. Twitter page like @ChennaiRains sent live updates regarding the flood situation in Chennai (Yadav and Rahman 2016).

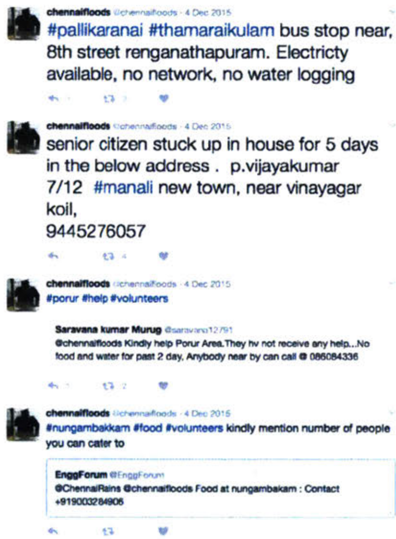


Figure 8: Tweets from @ChennaiFloods account[6]

A Google India database for missing person like Google Person Finder also helped to locate the missing residents. Google also initiated a Crisis Response Page, which delivered information on resources, helpline numbers, rescue numbers, flooding tips, satellite imagery, news on flooded streets, rescue and relief camps, and safe places (Yadav and Rahman 2016). A Google Spreadsheet launched by Chennai people, contained a list of shelter areas, and other information on help offered by people[7].

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[6] Screengrab from https://twitter.com/chennaifloods/status/673028126062997504 (Accessed on Dec 5, 2015)

[7] Source: https://twitter.com/sowmyarao

#ChennaiRains (Available Shelter, Rescues Needed, Helpline Numbers, Other Resources)

Available for Shelter - Wednesday 2 Dec | Food Offerings | RESCUE NEEDED | Helpline / Doctor / Other Numbers | VOLUNTEER DETAILS | Available for Shelter- Tuesday 1 Dec

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Timestamp | Area in Chennai where shelter is available | Accomodation available for (No of people) | Twitter Handle/Facebook Profile | Mobile Number | Original Source Link for information | Other Details/Contact Info |
| 2 | 24/07/2015 23:47:10 | Tambaram, Perungalathur, Vandalur and Urapakkam | | @squrahms | | Boat Help at Tambaram, Perungalathur, Vandalur and Urapakkam contact no's : 9176666431, 9840920186,9962634858 , 9500002000. CP: Mohamd yunus | |
| 3 | 25/07/2015 23:47:10 | Adyar | 3 | @priyavprabhakar | 9500061122 | SELF | 3rd floor, lift, women welcome |
| 4 | 26/07/2015 23:47:10 | Adyar | 3 | priyavprabhakar | 9500061122 | SELF | 3rd floor, lift, women welcome |
| 5 | 27/07/2015 23:47:10 | Adyar | 1 | @sarpanch__ | 9791408802 | | Food and stay for 1 person |
| 6 | 28/07/2015 23:47:10 | Adyar | 3 | @mumbaicentral | 9884045265 | https://twitter.com/MumbaiCentral/status/671730187919233024 | |
| 7 | 29/07/2015 23:47:10 | Adyar | 5 | 9944200211 | 9944200211 | https://twitter.com/jiljilramamani/status/671664174598983680?s=09 | Can accommodate 5 ppl |
| 8 | 30/07/2015 23:47:10 | Alwarpet | | @ThasanVJ | 9003233127 | https://twitter.com/ThasanVJ/status/671774886151458816 | |
| 9 | 31/07/2015 23:47:10 | Alwarpet | 10 | @pras_venkat (Contact @Payyaloo at 9176107473 if you are stranded near Alwarpet. Will try our best to pick you up and bring to our place ) | 9176107473 | https://twitter.com/pras_venkat/status/671686785773146112 | 10 ppl |
| 10 | 01/08/2015 23:47:10 | Alwarpet | n/a | @dhwanisabesh | | https://twitter.com/dhwanisabesh/status/671659625863766016 | n/a |
| | | | | | | | accommodate 10 to 15 ppl at |

Figure 9: Google Spreadsheet with flood relief information[8]

Despite the huge success of these efforts, there are several issues to be fixed. All the efforts were isolated and there was repetition of reports across all these channels. Validating the reports from these different channels was resource-intensive, tedious and difficult[9]. The resident volunteers and the NDRF did not have access to each other's information[10]. Social media was amplifying reports from the affluent, tech-savvy part of the city. There was a visible asymmetry in aid delivered to different parts in the city (Krish, 2015).

[8] Screengrab from http://chennairains.org/ (Accessed on Dec 5, 2015)

[9] From interviews with ChennaiRains.org on Sep 25, 2016

[10] From meetings with the officials in GCC's control room on Aug 29, 2016

# 4 SYSTEM DESIGN AND DEVELOPMENT

From literature review and field research described in Sections 2 & 3, I have synthesized the following observations -

- Urban flooding is a high-probability high-risk event in metro cities in India.
- Though India's disaster management system is heading in the right direction, the efforts are uneven and there is suboptimal community involvement.
- Chennai, one of the cities with high-risk for urban flooding, is a perfect place to pilot the RiskMap platform to bridge the gap between Government and citizen's disaster relief efforts.
- The best way to improve community involvement is by tapping into the power of social media as is evident in the cases across other cities in the world.

In this chapter, I elaborate on how these observations translated into system requirements and how the system was designed and developed to be efficient and effective. The most challenging facet of this platform is that it aims to make use of the evolution of social media networks as a methodology to improve a city's resilience instead of developing new applications or sensors for crowd-sourcing data collection. The following sections explore the development of RiskMap.in and its underlying software CogniCity as a Geosocial Intelligence Framework for civic co-management during periods of flooding in Chennai.

## 4.1 SYSTEM REQUIREMENTS

From literature review and field research, the primary users for the platform were identified as Disaster managers and city residents. The requirements for city residents are – ability to submit a geo-tagged flood report with less bandwidth usage and effort and visualization of city's flood situation on a map platform. The requirements for disaster managers are – ability to view all reports in one unified interface, data aggregation to provide actionable intelligence to assist in disaster recovery efforts. In addition to this, the platform needed to scale well for different cities and different disaster types. On analyzing the tweets and Facebook posts during the December 2015 floods, location, image, flood height and a short description about the event were identified to be the vital pieces of information reported. These requirements were met by the system as described in the next section.

## 4.2 RISKMAP

Residents on Facebook and Telegram can initiate interaction with the bots set up on the platform or tweet #ChennaiRains to engage with the platform. On receiving a conversation trigger from the user, the bots will guide them through the conversation to submit the report. They will receive a one-time flood link that will take them to RiskMap's card stack.

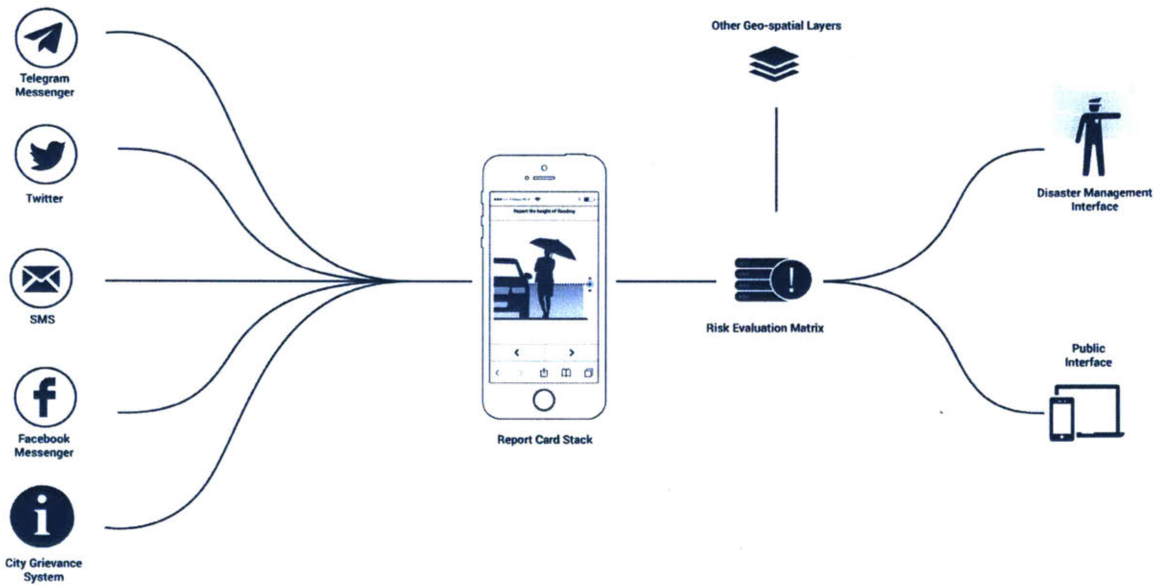


Figure 10: RiskMap Process Flow[11]

On this card stack, the users will have the provision to add their location on the map, select the flood height at their location, take an image real-time or choose one from their gallery and upload. On filling all the details, they can review all the details and submit the report. Research shows that a feedback loop to social media communities provides for full usage of the versatility offered by human sensor networks (Slavkovikj et al. 2014). Learning from this, the platform has been designed such that the residents a confirmation message with a unique link to their reports is sent to them on successful submission of a report.

[11] Product of MIT Urban Risk Lab

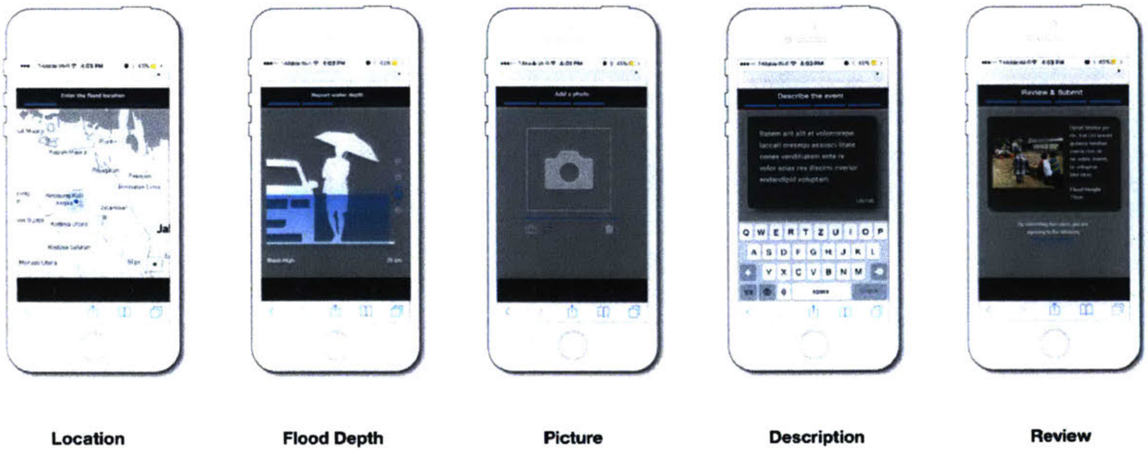


Figure 11: RiskMap Card Stack[12]

The unique report link will take the user to the citizen map interface from where they can share their reports with their friends and family via Social Media. They will also be able to view the reports submitted by other citizens across all channels.

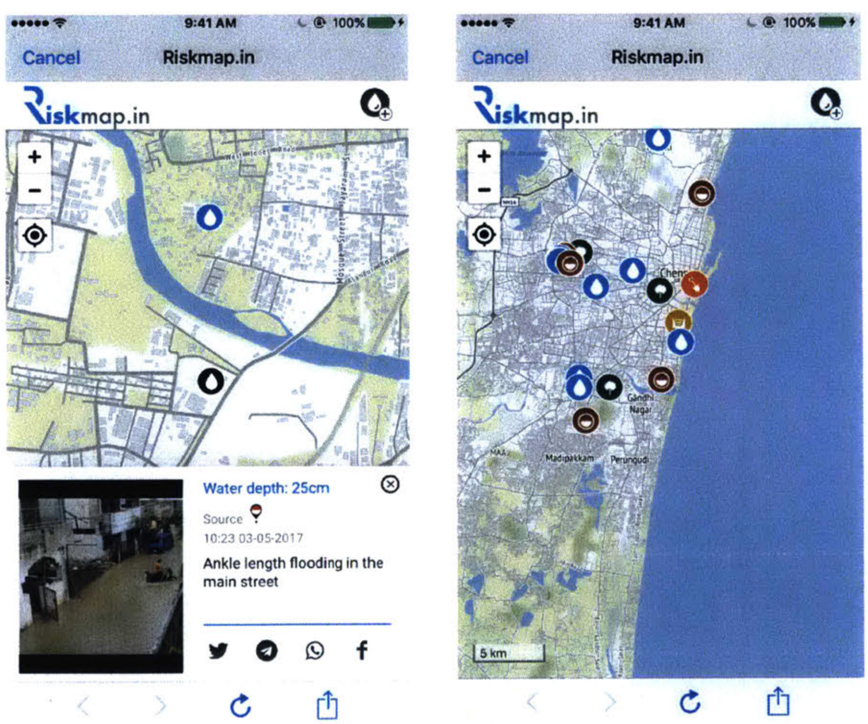


Figure 12: Individual flood report (L) and Overview of all reports (R)

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12 Product of MIT Urban Risk Lab

## 4.3 COGNICITY FRAMEWORK

CogniCity is an open source framework for urban data, which harnesses the power of social media by gathering, sorting and displaying real-time situational reports from infrastructure issues such as flooding (Holderness, Turpin, and Wickramasuriya 2015). RiskMap.in builds on CogniCity framework to gather citizen reports from the social media sites Twitter, Facebook, and Telegram and create geospatial visualizations of this information.

## 4.4 ARCHITECTURE OVERVIEW

The high-level architecture diagram for the system is shown below –

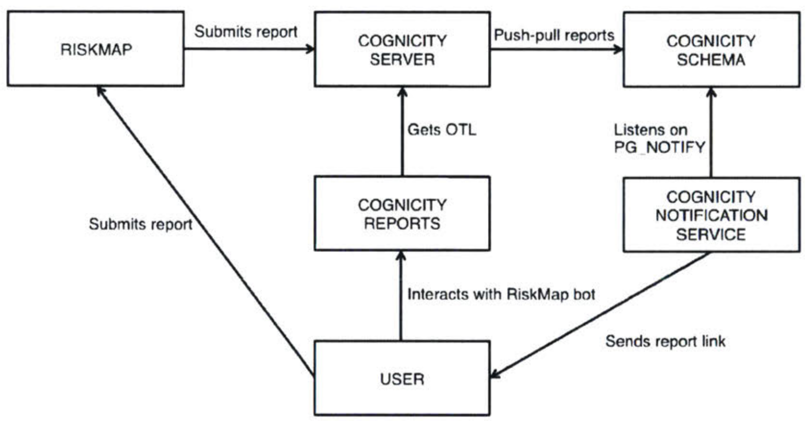


Figure 13: High level architecture diagram

User starts conversation with bots or tweets disaster specific keywords, which will initiate the reports module. The reports modules for each of the social media interact with the server to fetch one-time unique links to be sent to the user. On clicking the link, the user will be redirected to the RiskMap's cards interface. The frontend (RiskMap) interacts with the backend schema via secure CogniCity Server to submit flood reports and to collect reports for visualization. Server is the most vital piece of the platform that handles all the PostgreSQL operations. There is a notification service that listens in on PostgresDB and sends confirmation message to the user with a link to the report. The following section elaborates on each of the modules in the platform architecture with a detailed architecture breakdown diagram.

### 4.4.1 RISKMAP

GitHub repository URL: https://github.com/urbanriskmap/petabencana.id

RiskMap.in has four key interfaces – Cards, Map, REM, and Docs. Cards are the modular screens where users add the flood information. Map interface shows the reports from different users via different social media all in one place. The server works on these reports to create actionable knowledge which is then visualized on the REM interface. Docs contain detailed documentation on all the open APIs to the platform.

All the interfaces except the Docs are built on Aurelia, a JavaScript client framework for mobile, desktop and web applications. The framework is extensible, modular and supports creation of plugins and custom components to suit the platform's needs.

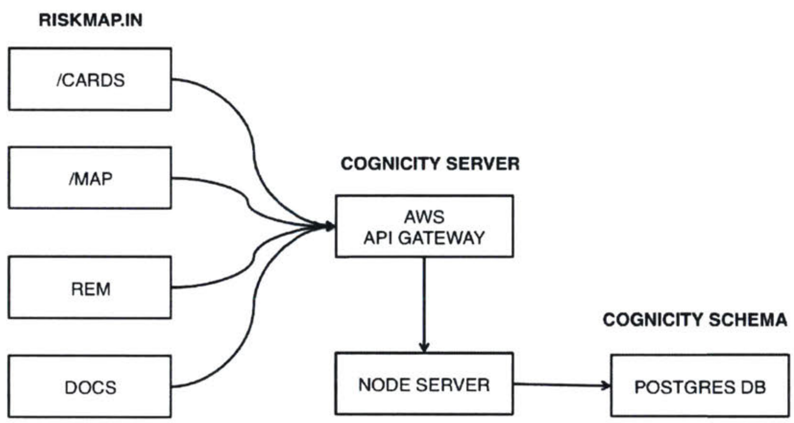


Figure 14: System design of frontend – backend interaction

### 4.4.2 COGNICITY SERVER

GitHub repository URL: https://github.com/urbanriskmap/cognicity-server

The Node.js data server interacts with the PostgreSQL DB in the backend to push and pull flood reports and is exposed to the front end via API Gateway. All the reports modules interact with the server via the gateway to get one-time card links when a user engages with the bots on different social media. NodeJS has the following advantages relevant to the platform – it is fast and I/O event-driven which makes it perfect for chat engine based platform like RiskMap and it also provides a vast shared repository of tools and modules to add enhanced capabilities to the platform.

### 4.4.3 COGNICITY SCHEMA

GitHub repository URL: https://github.com/urbanriskmap/cognicity-schema

The database runs on the open source PostgreSQL object-relational database management system and uses the PostGIS extension to support geospatial data. PostgreSQL offers many advantages over other database systems – it can handle high volume of data, it ensures high reliability and scalability, and it is extensible. List of databases of tables included in the Appendix.

### 4.4.4 COGNICITY REPORTS

The reports module is the CogniCity framework's interface to social media. Report modules are set up for each of the social media – Facebook, Twitter, and Telegram as AWS Serverless Lambdas. AWS Lambda provides the capability to run code without provisioning or managing servers and ensures scalability and high availability. All these modules programmatically engage with users via social media and share unique card links if the users want to report a flood event.

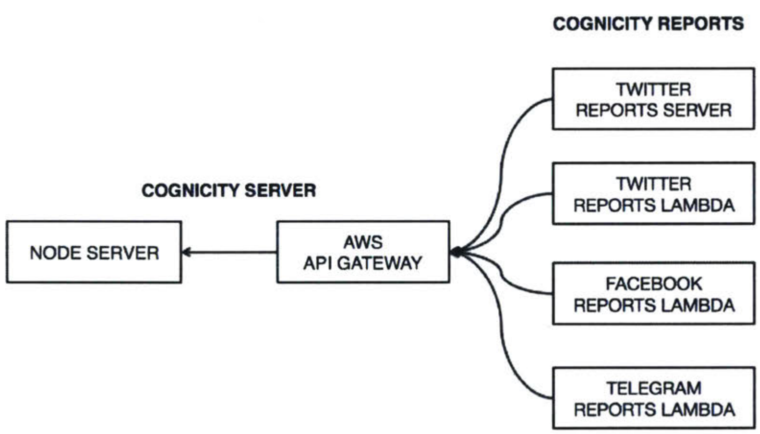


Figure 15: System design of reports module

#### *4.4.4.1 REPORTING VIA TWITTER*

GitHub Link: https://github.com/urbanriskmap/cognicity-reports-powertrack

Twitter reports module is set up as a Node.js server that connects to Twitter Powertrack stream and listens in on tweets in the Twitter Chennai bounding box for relevant hashtags (#chennairains) and keywords (Flood, rains) or tweets to the official @RiskMap account. The RiskMap twitter account would then programmatically respond to relevant tweets with a welcome message asking if the user wanted to report a flood event. On a successful response, the account would reply back to that tweet with a unique card link to report the flood event. If a report is submitted via Twitter interaction, the Twitter reply module set up as a AWS Lambda function would receive the relevant information from the Twitter SNS topic and send a confirmation message and the report link to the user.

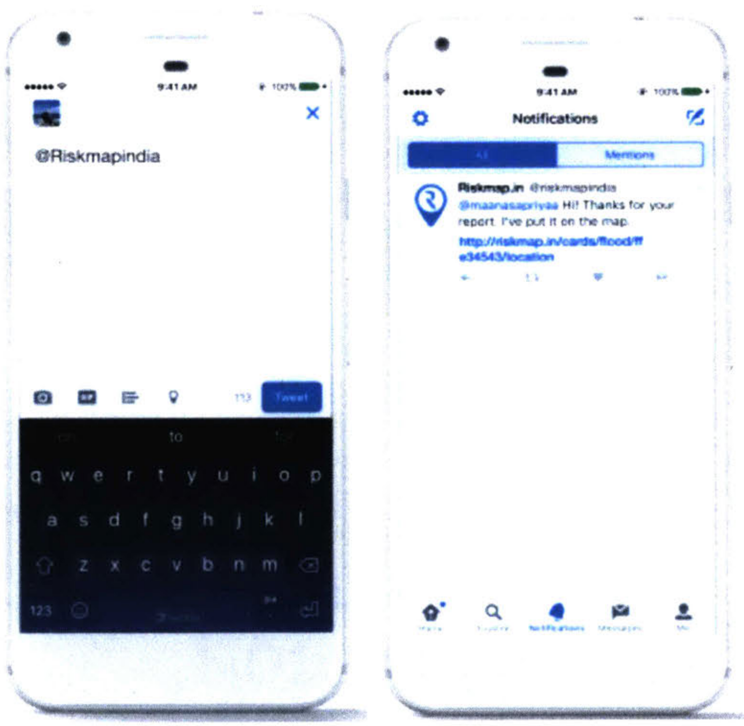


**Figure 16: Twitter Bot Interaction**[13]

[13] Product of MIT Urban Risk Lab

#### 4.4.4.2 REPORTING VIA TELEGRAM

GitHub repository URL: https://github.com/urbanriskmap/cognicity-reports-telegram

Telegram reports module is set up as independent Serverless AWS Lambda functions, a compute service that responds to events, runs the configured code, and, manages underlying resources and scale automatically. It has two functions – webhook and reply. Webhook is exposed via API Gateway and is configured with the official Telegram bot. When a user engages with the bot and posts the specified command '/flood', the Telegram service makes a POST call to the webhook API lambda with the message content and user details. This lambda also handles fetching card links from the server and sending it to the user. The second function, Reply, listens in on Telegram SNS topic for messages and when a message is published to that topic, this lambda processes it and sends a confirmation message and report link to the user.

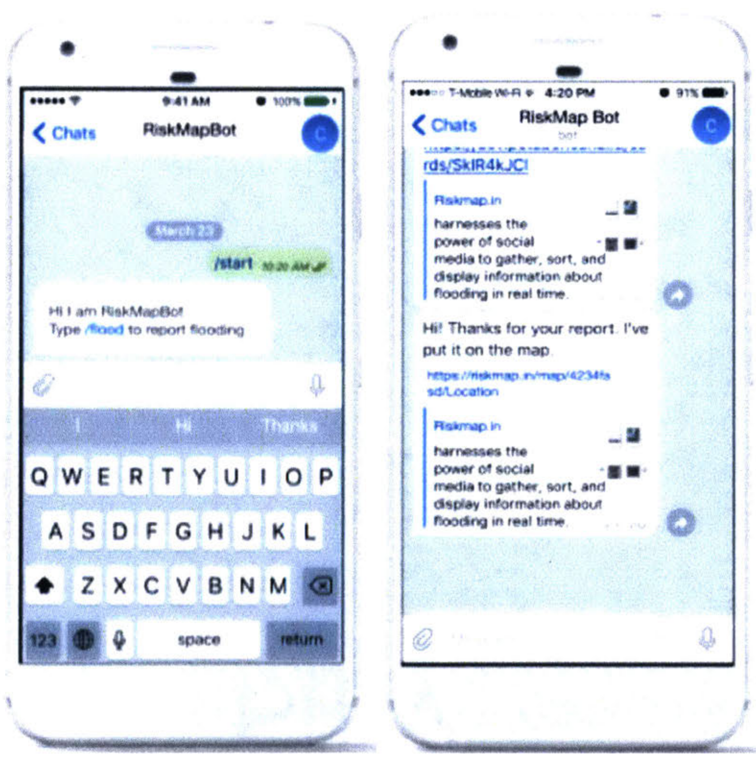


Figure 17: Telegram Bot Interaction[14]

[14] Product of MIT Urban Risk Lab

### *4.4.4.3 REPORTING VIA FACEBOOK*

GitHub repository URL: https://github.com/urbanriskmap/cognicity-reports-facebook

Just like Telegram's module, Facebook reports module is set up as independent Serverless AWS Lambda functions. It has two functions – webhook and reply. Webhook is exposed via API Gateway and is configured with the official Facebook bot. When a user engages with the bot, it is designed to be user friendly with easy interaction options. When the user selects the 'Report flood' button, Facebook makes a HTTPS POST call to the webhook API lambda with the message content and user details. This lambda also handles fetching card links from the server and sending it to the user. The second function, Reply, listens in on Facebook SNS topic for messages and when a message is published to that topic, this lambda processes it and sends a confirmation message and report link to the user as a reply to the user's previous message.

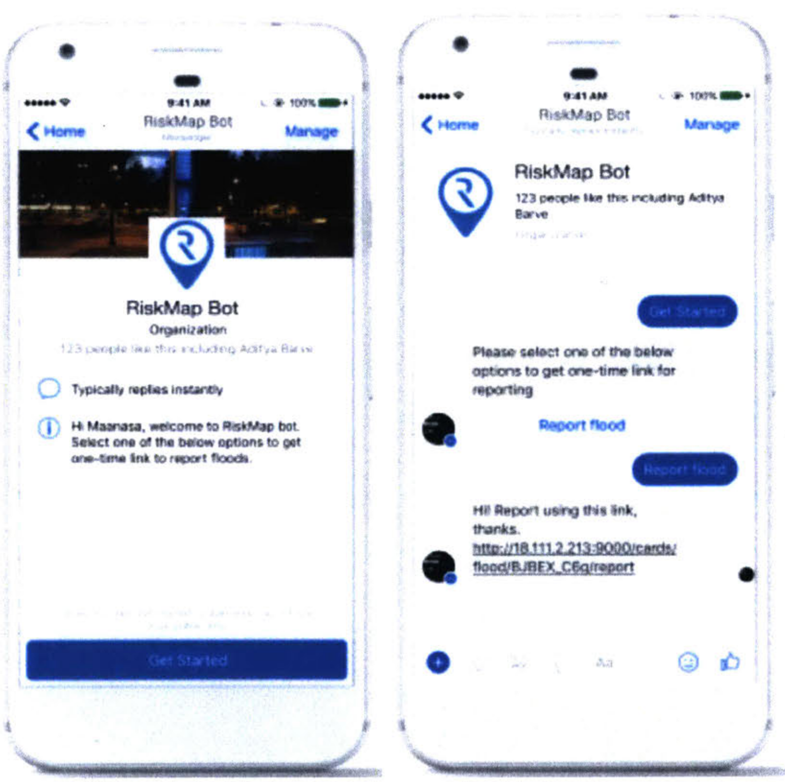


Figure 18: Facebook Bot Interaction[15]

[15] Product of MIT Urban Risk Lab

### 4.4.5 NOTIFICATION SERVICE MODULE

GitHub repository URL: https://github.com/urbanriskmap/cognicity-notification-service

This module is setup as a Node.js server and its sole purpose is to listen in on PostgresDB notifications. The pgnotify trigger has been setup on the database side to push the payload with report information to all clients listening to the channel. This server then classifies the report based on the source from which they were submitted and pushes report information to the corresponding AWS SNS topic. AWS SNS provides a highly scalable, flexible, and cost-effective capability to publish time-sensitive messages from an application and immediately deliver them to subscribers or other applications. This eliminates the need to periodically check or "poll" for new information and updates and provides an easy mechanism to incorporate a powerful notification system with the platform. The reply lambdas for each media defined in the previous sections get triggered on a publish event to the SNS topic they are listening to. The lambdas handle sending the confirmation message and report link to the user via the same platform from which they submitted a report.

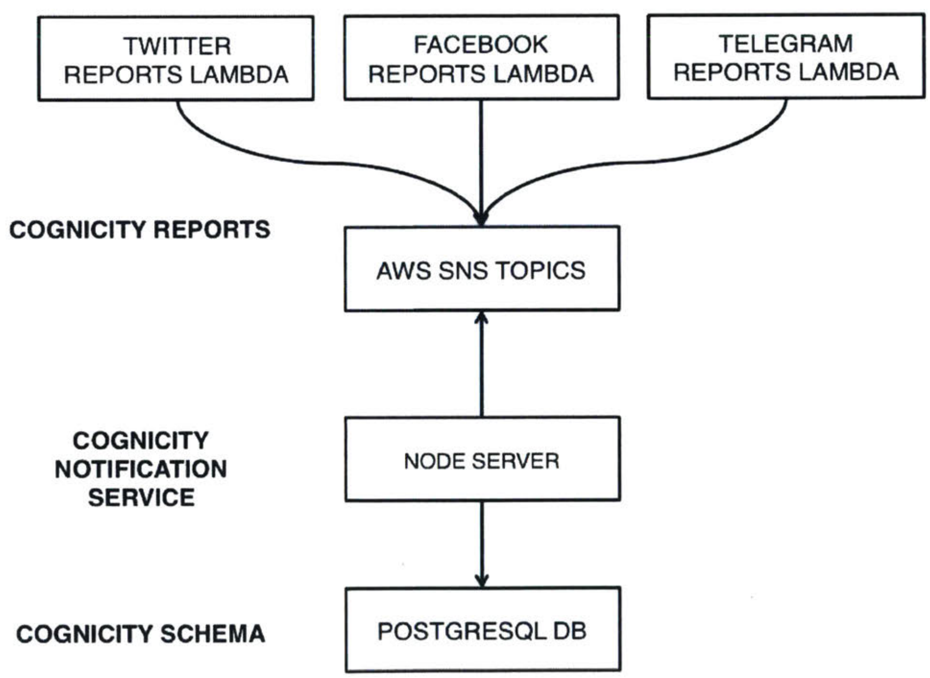


Figure 19: System design of Notification service

# 5 ANALYSIS OF THE SYSTEM

The system analysis of the RiskMap in the previous chapter provides an understanding of the architecture, design and implementation. This chapter discusses the same aspects of the system in the context of scaling and replication along with the long-term implications of the current design.

## 5.1 IMPORTANCE OF LIFECYCLE PROPERTIES "ILITIES" OVER TIME

The "ilities" of the system are the developmental, operational and support attributes a software system must address. Specifically – Usability, Maintainability, Scalability, Availability, Extensibility, Security, Portability. Each of these system properties can determine the longevity of the system. Here is how RiskMap platform performed in the "ilities":

### 5.1.1 USABILITY

Software usability can be described as how effectively end users can use, learn, or control the system. RiskMap citizen interface UX design is consistent with the other apps they commonly use and it offers clean visual cues for better usability. In the Info tab, users will be able to watch a short video describing how to submit a flood report via the chat bots deployed on Facebook, Twitter and Telegram. The bot conversations are designed to be user friendly and the conversation is entirely guided by the bot requiring less time for user to adapt to the platform.

### 5.1.2 MAINTAINABILITY

The definition of maintainability implies how brittle the code is to change. The entire team understands the process flow and the code base, which enables easy transference of work. The code is regression tested before every code push and the system design enables easy feature updates. For example, adding Monsoon preparation card decks in parallel to the Flood report deck was done in a matter of few hours.

### 5.1.3 SCALABILITY

Scalability is the ability for the system to gracefully meet the demand of stress caused by increased usage. The server is deployed on Amazon Web Services (AWS) EC2 and Beanstalk that automatically handle the details of capacity provisioning, load balancing, caching and auto-scaling thus improving the system's scalability. The database is deployed on AWS RDS that provides both horizontal and vertical capabilities.

### 5.1.4 AVAILABILITY

How long the system is up and running and the Mean Time Between Failure (MTBF) is known as the availability of a program. The system combines horizontal scaling with load balancing so that a similar load is distributed to each horizontal implementation. This keeps the MTBF low and increases the system's ability to withstand failure during recovery.

### 5.1.5 EXTENSIBILITY

Extensibility is a software engineering and systems design principle where the implementation takes future growth into consideration. RiskMap is built keeping the following future enhancements in mind – scaling to new cities, functioning for different types of disasters like earthquakes and cyclones, and has a configurable card deck component. The pilot version of the platform also has Monsoon preparation card deck in addition to flood report capabilities. It enables residents of the city to report canal drain, fallen tree, de-silting and blocked drains issues that are part of the flood preparation process.


**Preparation Cards**

Figure 20: Monsoon Preparation Card[16]

[16] Product of MIT Urban Risk Lab

### 5.1.6 SECURITY

Security is the measure of system's ability to resist unauthorized attempts at usage or behavior modification, while still providing service to legitimate users. The platform adopts HTTPS that ensures that data sent via the platform is secured by Transport Layer Security protocol. In addition to this, AWS provides CORS (Cross-Origin Resource Sharing) configuration options to ensure that users work on a secure platform.

### 5.1.7 PORTABILITY

Portability is the ability for an application to run on numerous platforms. RiskMap platform is device and platform agnostic. It is designed to run on all supported Windows, iOS, and Android devices and was thoroughly tested using BrowserStack.

## 5.2 POTENTIAL RISKS

The inherent risks in using social media, as knowledge management tools are accuracy of information exchanged and technological limitations (Mehta, Bruns, and Newton 2016). The details of how the platform aims to tackle risks are described in the following section.

### 5.2.1 LIMITATIONS IN VALIDATION OF FLOOD REPORTS

Research shows that, in some instances, disaster managements have been hesitant to trust and act on user-reported information from social media platforms, owing to the inability of validate message content within a very short time frame (Crowe 2012; Haddow and Haddow 2013). RiskMap platform aims to handle the potential risks using two of the three models for building online trust in disasters (Mehta, Bruns, and Newton 2016).

- *Intelligence Gathering*

  By this approach, the platform treats social media as a source of intelligence on the situation in the crisis area during an emergency (Ibid.). It discovers unusual spikes in social media activity that references key crisis-related terms. For example, users on tweeting #ChennaiRains will receive a response tweet from RiskMap's Twitter bot asking for confirmation. The information identified through this approach is then further correlated with other data sources available to the disaster managers from staff on the ground as well as prior data on crisis-affected locations (Ibid.).

- *Quasi-Journalistic Verification*

  This approach requires direct intervention from the GCC's control room staff to take hands-on approach and validate the citizen reports using their own judgment, professional experience, and common sense in separating trustworthy from untrustworthy reports (Mehta, Bruns, and Newton 2016). The platform assists the disaster managers with this approach by recording the time at which the report is submitted and by mandating location and flood depth data in each report. The staff would be able to validate the flood depth data by crosschecking it with the image they have uploaded. In addition to this, the team is currently working on enhancing the platform with automated image recognition capabilities to validate the flood images uploaded. Thus, a combination of automated intelligence gathering and manual journalistic verification approach would have a tangible impact on the possibility and the efficiency of information flowing from social media sources into emergency management decision-making processes (Ibid.).

### 5.2.2 LIMITATIONS IN TECHNOLOGY

The primary technological limitations in using social media in disaster management are mobile network failure, power outage, and residents not having access to a smartphone or Internet connection[17]. RiskMap team aims to tackle these limitations by integrating the platform with the City's PGR system so that residents are able to submit flood reports via calls or sending SMS to GCC's helpline numbers. This will remove complete dependency on availability of Internet connection during disasters and ensure that the platform is inclusive of residents from all parts of the city.

[17] From interviews with ChennaiRains.org on Sep 25, 2016

## 6 FUTURE WORK & CONCLUSION

The goal of RiskMap is to improve a city's resilience by providing Geo-social intelligence based on crowd-sourced disaster reports. The next steps towards achieving that goal can be grouped into short-term and long-term action plans.

### SHORT TERM ACTION PLAN

- The immediate next step is to conduct field-testing in Chennai during summer of 2017 with the monsoon preparation cards and identify usability issues based on feedback. This testing process will also give the team valuable data to work with for the REM module.
- To get the maximum value out of this platform, it needs to be integrated with GCC's Online PGR system. Then, the process flow would get modified as follows: all the reports gathered via RiskMap platform, in addition to being mapped on Citizen interface, will also flow through GCC's existing backend system ensuring that reports are allocated to corresponding zonal officers according to their location and are tracked till completion. Also, all the flood reports gathered by the GCC's system from different channels will be mapped on RiskMap's Citizen interface. This will result in seamless integration of citizen and Government communication channels for disaster management.
- The long-term plan involves onboarding residents of the city on the platform and enhancing it with new features. Onboarding new users can be done in a couple of ways – enlist the help of the GCC's resources to advertise the platform on traditional and social media and reach out to NGOs and field partners to advertise it to people on their network. The most crucial task to be done for this to be successful is build a media package consisting of blog posts, articles and handouts to be posted on Twitter and MapBox's official blogs to gain traction amongst residents as well as the Software developer community.

### LONG-TERM ACTION PLAN

- Possible future feature enhancements are to add multiple useful geo-spatial layers to the map interface. For example, all the shelters set up by the city government could be added as a layer on the map interface to assist people during evacuations. It could also have other details like the quantity of resources available at a shelter, directions to the shelter, etc.

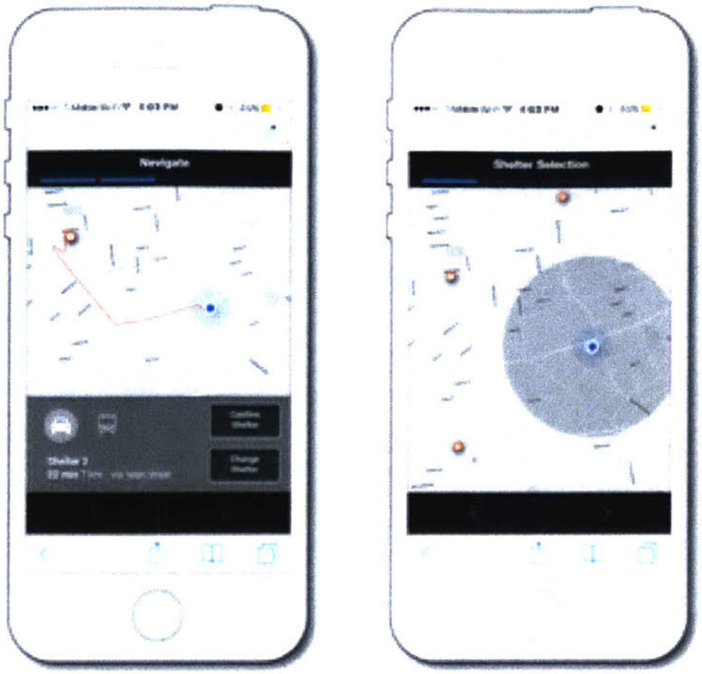

Figure 21: Mockups for Shelter feature[18]

- Another feature is to add Alerts: this would enable the city's disaster managers to push region specific alerts during disasters to the residents who have subscribed to those alerts.
- In addition to this, the prospects to scale and deploy this platform in major metro cities and different disaster types (Discussed in 2.4) with the collaboration of respective local government agencies and field partners should be researched.

I believe these short and long-term plans will ensure wide adoptability of RiskMap platform and its success in using the concept of geo-social intelligence in disaster management. This project, in addition to helping me use the theoretical tools and concepts learnt in system design in practice, has also provided me an opportunity to use technology to solve a societal problem.

[18] Product of MIT Urban Risk Lab

# APPENDIX

## List of Schemas & Tables in Cognicity Database

### Schema: Cognicity

| Table Name | Description |
|---|---|
| ALL_REPORTS | CONFIRMED FLOOD REPORTS FROM ALL SOURCES |
| INSTANCE_REGIONS | ADMINISTRATIVE BOUNDARIES OF CHENNAI MUNICIPALITIES |
| LOCAL_AREAS | ADMINISTRATIVE BOUNDARIES OF CHENNAI ZONES AND DIVISIONS |
| REM_STATUS | RISK STATUS OF CHENNAI ZONES AND DIVISIONS |

### Schema: Grasp

| Table Name | Description |
|---|---|
| CARDS | GRASP CARDS ISSUED VIA ALL SOURCES |
| REPORTS | VERIFIED AND UNVERIFIED REPORTS FROM ALL SOURCES |

### Schema: Infrastructure

| Table Name | Description |
|---|---|
| PUMPS | LOCATIONS OF WATER PUMPS IN CHENNAI |
| FLOODGATES | LOCATIONS OF FLOODGATES IN CHENNAI |
| WATERWAYS | LOCATIONS OF WATERWAYS IN CHENNAI |

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