Metro flood Management and Efforts of Urban Civic Authorities A Case Study of Municipal Corporation of Greater Mumbai and Emerging Horizons

Dr. A. A. Attarwala
Director

C. S. Balasubramaniam
Professor of Finance

Kohinoor Business School,
Vidyavihar (West), Mumbai -40070

Abstract

Indian cities lack basic urban infrastructure planning. Most cities have grown over time with little or no planning. Metro cities like Mumbai though have monsoons every year, its people miserably suffer hardships with water logging and traffic jams in railways and roads and undergo chaos. Coastal cities like Busan (South Korea) and San Francisco (USA) have developed with detailed disaster risk management plans. They have advanced forecasting techniques and use underground tanks, submersible pumps, levees, stream gates to handle such eventualities and consequent calamities.

In a situation where human beings cannot prevent nature's fury in the form of heavy monsoons, Urban Civic Authorities have to undertake massive efforts to control and rescue the people and their physical properties .In this paper, it is proposed to study and analyse data related to the Mumbai Metro city's vulnerabilities including topography, rainfall pattern, high tides, river water and storm water drainage system and flood preparedness and management in Mumbai Metropolitan area. The study would evaluate the efforts of Municipal Corporation of Greater Mumbai (MCGM) in to enhance the internal competency to prepare, manage and eventually reduce its vulnerability to flood related disasters in comparison to Chennai which had massive floods in 2015. **Business Analytics and its applications in the form of the advanced statistical methods would be used in predicting and managing the floods and in avoiding consequential huge disasters.** It includes critical information required for creating awareness and could come in very handy in case of a natural disaster.

Keywords: Urban Infrastructure, Disaster Management, Topography, Big Data, Data Driven analytics

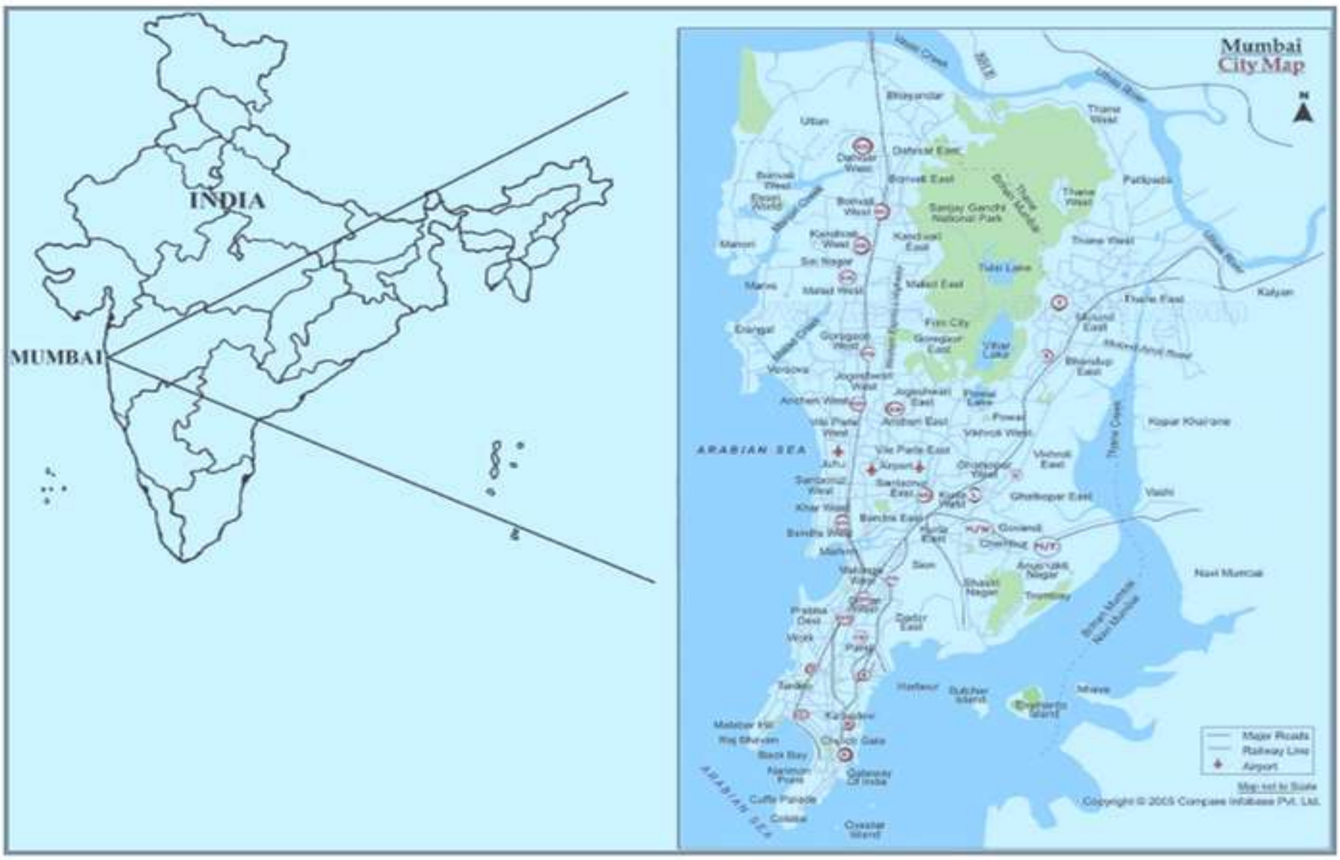
I. Introduction

Greater Mumbai serves as the core city of the Mumbai Metropolitan Region, which is among the ten most populated urban agglomerations in the world. It has been the country's financial capital, and its main driver of growth. Geographically, Greater Mumbai is severely constrained and occupies a land area of only 458.28 sq km. India's commercial capital in the Western state of Maharashtra, the populous metropolis of 22 million, is inundated for at least one day every year with heavy rains. Suburban railways, road transport, air traffic and normal public life are severely affected for a few days each time. Flooding is a chronic and a recurrent problem in Mumbai during the monsoon season from June to September, particularly when spells of intense rainfall coincide with high tide. Floods are basically meteorological events conditioned by the characteristics of the drainage basins. If rainfall exceeds the retention capacity of the basins, drainage increases both in speed and volume causing floods. Three different types of flooding are evident in Mumbai: localized flooding due to inadequate drainage, flooding due to overflows from Mithi River and other local rivers becomes flooded due to combination of high tides and high river flows. Localized flooding occurs mainly due to informal settlements in the drain path, improper drainage network and reduction in drain capacity due to siltation. Land use practices, solid waste management practices and inadequate drainage maintenance in the city have also accentuated the flood hazard. As such the city faces significant challenges due to an extremely limited supply of land, proliferation of slums due to non-availability of affordable housing, long commutes as people reside farther away from places of employment, an overburdened public transport system, insufficient social and physical infrastructure and an increasingly degraded physical environment.

Topography

Mumbai city lies on what were formerly two groups of islands, stretching southward of the Ulhas estuary. The southern group currently referred to as Mumbai Island City originally consisted of seven separate islands. Since the 17th century, these islets have been joined through drainage and reclamation projects, as well as through the construction of causeways and breakwaters to form one landmass. The northern island group, originally known as the Salsette group, on which the present Mumbai Suburban District is situated, also consisted of seven islands. The district is named after the main and the largest island of the group. Topographical Zones, namely, the Island City, Western Suburbs and Eastern Suburbs (Map below). The Wards within these Zones have been further subdivided resulting in 150 Planning Sectors excluding areas under the Special Planning Authorities and the National Park. The three Zones, the Island City, the Western Suburbs and the Eastern Suburbs have been named Zone 1, Zone 2 and Zone 3 respectively for ease of analysis and identification of the Planning Sectors. The number of Planning Sectors and their areas are given below in Table 1:

Map - 1



Source: MCGM

Table: 1: Planning Sectors in Mumbai

District	Total area in hectares (including SPA)	No. of Planning Sectors (excluding SPA and National Park)
Island City	7,140.71	50
Western Suburbs	22,239.29	62
Eastern Suburbs	16,448.48	38
Greater Mumbai	45,828.49	150

Source : MCGM

Population growth in Greater Mumbai

The population of Greater Mumbai (including the notified areas under SPAs), recorded in 2011 Census is 12.44 million as against the 11.97 million in 2001 indicating a net addition of nearly half a million over one decade. The population growth rate of Greater Mumbai has been experiencing a decline since 1961. However, there has been a sharp decline in the last decade has been indicated at 20.68% between 1991-2001 and 3.87% between 2001 – 2011 During the last decade, 2001-2011 , Island City of Mumbai has shown a population decline of 262,620 whereas the Western and Eastern Suburbs have shown an increase of 321,841 and 394,702 respectively. The data shows that geographically, there is a clear variation in the distribution of slums in Greater Mumbai. 51.91% of the total population in the Eastern Suburbs resides in slums as compared to 42.69% of the total population in the Western Suburbs and 27.88% in the Island City. Currently the population in MCGM area is 2.3 Crore. (2019)

II. Literature Review

Research on Flood damages and recovery have arisen on account of wide spread interest among United Nations Development Program(UNDP) , & other well-known International Development Agencies, Government of India , State Government of Kerala ,Government of South Africa , Government of United States of America (USA) and many other countries where Urban flood calamities have frequently occurred . Hence we present a **Key Summary of literature review of urban area calamities arising out of floods** with a brief description of the study /flood damages as follows:

Table – 2: Literature Review

S.no	Country / International Development Agency	Brief Description	Author & Source
(1)	Hyderabad ,India	Natural hazard, risk and disaster assessments, Disaster risk management or reduction, Climate change vulnerability, impacts and adaptation have been classified and studied in depth.	Zameer Ahmed et al .(2013)
(2)	Kerala State , India	Assessment of the nature of extreme rainfall in various districts of Kerala and the role of major reservoirs that have contributed in the severe rains & flooding (2018).	Vimal Mishra, et.al (2018) Dept. of Civil Engineering, Indian Institute of Technology, Gandhinagar (Gujarat)
(3)	Kerala State , India	Western Ghats Ecology Expert Panel (WGEEP) has designated (i) the entire Western Ghats as an Ecologically Sensitive Area (ESA) & (ii) No more inter-basin diversions of rivers shall be allowed in the Western Ghats.	Dr.Madhav Gadgil & Team - Kerala State Bio Diversity Board (2011)
(4)	United States of America	Analysis of flood damage estimates collected by the National Weather Service (NWS) between 1925 and 2000; Direct physical damage to property, crops, and public infrastructure studied in detail.	Roger A. Pielke, Jr. et.al 2002) National Center for Atmospheric Research, Colorado (USA)
(5)	United Kingdom	Average rainfall patterns, its Eigen vectors of locations with similar flood impacts during 2014–2015.	Tkachenko N, et al . (2016) Predicting the impact of urban flooding using open data. Royal Society (University of Warwick, Coventry

			UK) sci.http://dx.doi.org/10.1098/rsos.160013
(6)	International Disaster Law project , UK	Sendai Framework for Disaster Risk Reduction (DRR) highlighted the importance that states and the broader international community place on preventing, mitigating and preparing for known hazards(March 2015)	Centre for Criminal Justice & Human Rights School of Law, University College Cork, Ireland (UK) 2018
(7)	Oxford Research Encyclopedia of Natural Hazards	Assessments of flood risk management have broadened to flood impacts and flood risks.	Bruno Merz, (2017)
(8)	United Nations Development Program (UNDP)	Gender and climate change training modules and policy briefs directed at practitioners and policymakers in the Asia-Pacific region.	Senay Habtezion et al (2013) UNDP

Our literature review is emphatic on nature and indicates the intensity of floods, extent of damages, recovery, flood preparedness guidelines, disaster recovery etc., A comprehensive study on the monsoon rains and the occurrence of floods in Mumbai Metropolis and aftermath with the application of the Big Data / advanced analytics/ data-driven research have not been attempted in the past . Hence in our research study, a rich variety of data from Municipal Corporation of Greater Mumbai, India Meteorological Department, United Nations Development Programme, International Red Cross, Government of India, State Government of Maharashtra and other authenticated and reliable sources have been collated and presented.

III. Research Methodology

Big Data / Data-driven Analytics have emerged as a powerful tool to understand and learn from past performance as a guide to more accurately predict trends. **Data driven methods have the "innovative" ability to generate valuable insights from large amounts of data.** Data Analytics derive value when big data and advanced algorithms are applied to infrastructure project to yield a solution that is measurably better than before. Data Driven techniques can be segmented as follows:

Table 3: Data Driven Techniques

Data	Reporting	Descriptive Analytics and Dashboard	Advanced Analytics
Raw Data	Standard Reporting	Data filtering and analytics	Predictive Analytics
Clean Data	Adhoc query based reporting	Alerts/signals	Optimization techniques
Clean Data		Clustering	Simulation Modeling
Clean Data		Trend analytics	Prescriptive Techniques
Clean Data		Statistical methods	Advanced Statistical Methods

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Objectives of the Big Data / Data Analytics Techniques in Flood Disaster:

Over the last decade, big data has become a strong focus of global interest, increasingly attracting the attention of academia, industry, government and other organizations. The term "big data" first appeared in the scientific communities in the mid-1990s, gradually became popular around 2008 and started to be recognized in 2010. Today, big data is a buzzword everywhere on the Internet, in the trade and scientific publications and during all types of conferences. Big data has been suggested as a predominant source of innovation, competition and productivity (Manyika et al. 2011), and has caused a paradigm shift to data-driven research (Kitchin 2014). **Studying in the above research methodology would provide us a powerful and wider insight into the past.**

Research objectives:

1) Identifying the key causes of Floods
2) Study multiple impacts of floods in economic , financial and societal damages
3) Gain Insights with applications of Big Data /Data Analytics
4) Describe the effects for DRR and develop an exploratory approach towards adopting policies of economic recovery.

IV. Main Findings

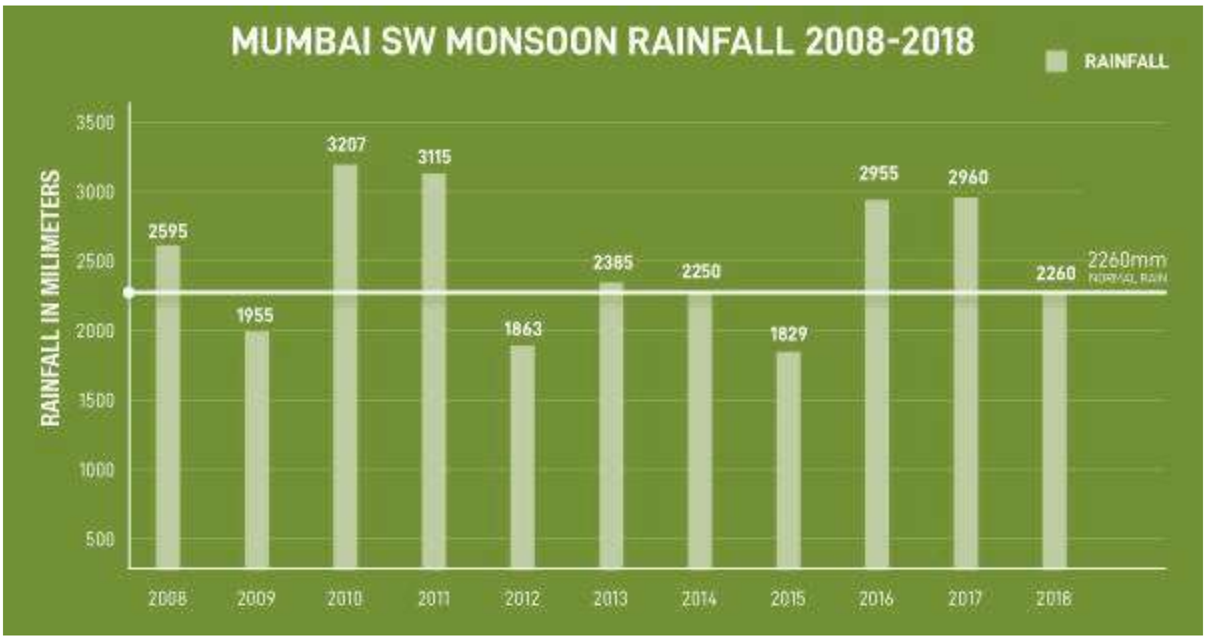
An understanding of the factors which cause floods is vital in view of the need to implement a range of flood risk mitigation measures.

1. Rainfall Characteristics in Mumbai Metropolis:

The average annual rainfall in Mumbai during 2007-2017 was about 2354 mm. The variation in rainfall from year to year is quite appreciable. During 2004-2013, the annual rainfall varied from a minimum 1433.9 mm at Colaba in 2012 to a maximum 3328 mm at Santa Cruz in 2010. The rainfall is usually higher in the suburbs than in the city. Almost 60 % of the average rainfall falls in July and August, though figures vary considerably from year to year. In 2007, 46% of the rainfall was received in July and August whereas in 2004 these two months accounted for 78% of the rainfall. July is the rainiest month, usually receiving more than one-third of the annual rainfall. In 2006, 51% of the annual rainfall in the suburbs occurred during this month. The average monthly rainfall for July alone during 2004-2008 was 851.2 mm — higher than London's average annual rainfall of 611 mm. In addition, 50% of this rainfall is received in just 2-3 events. The maximum annual rainfall ever recorded was 3,452 mm in 1954. The highest rainfall recorded in a single day was 944 mm at Santa Cruz (1200 mm is the average annual rainfall for India) on July 26, 2005. An analysis of the probability of such extreme events and their expected return period based on data going back to 1886 for Colaba and 1957 for Santa Cruz reveals that in any year, the probability of 24-hourm rainfall exceeding 200 mm is 50% for Santa Cruz and 33% for Colaba is available .

The phenomenon of flooding in urban areas is extremely complex and subject to change. Incidents are no longer restricted to obvious areas where a river or 'nullah' exists; many urban floods are simply caused by huge amounts of rain falling very quickly (flash floods) in an area where the drainage system is unable to cope or due to unexpected underground basin recharge and rise of the groundwater levels. As a consequence, there is an emerging motivation to understand how accurate knowledge can be about flood risk—its location, timing and duration—and how data collection and analysis can assist Urban Civic Authorities like MCGM. The situation is even more delicate when the risk has to be quantified for important infrastructure objects, such as breaching of a large dam or flooding of Bhabha Atomic Research Centre (BARC) Rashtriya Fertilizer Corporation, Petroleum Refineries owned by PSUs and other several large, medium and industries. Such events are practically unrepeatable. People usually make an effort to stay aware of what happens in their neighbourhoods, especially if their health, wellbeing or prosperity is at stake. It has already been shown that public information sufficiency, risk perception and self-efficacy can predict risk-information seeking behaviour. Diagram depicts Mumbai Monsoon Rainfall between 2008-2018.

Diagram 3



Source: India Meteorological Department & MCGM

Mumbai has the precedence to exceed its normal in all four months, which happened in 2017 when total rains occurred was at 2960 mm. During this time, the city saw 300 mm in 24 hours twice. If rain amounts are to be seen between 2008 to 2018, the best performer has been 2010 with total rains at 3207 mm. While some months see lesser rains than the other, Southwest Monsoon has never failed in all the four months. Even during the El Niño years, Mumbai has seen less rain for three months i.e. in 2009 and 2015. However, 2009 July was the saving grace, wherein the rain received was at 1120 mm. During a very few months, four-digit rains are seen. 2009 saw three occasions, where three-digit rains were seen in 24 hours. For the El Niño years, 2015, June was the saving grace with rains being at 1111.6 mm during this time and thrice did the city record three-digit rains in a span of 24 hours. For El Niño 2009 year, the month of June was the poorest; while for El Niño 2015 June was the rainiest. The months of June and July are the favourites for three-digit rains in 24 hours. At times, onset is also preceded by three-digit rainfall. The year 2019 has also seen El Niño finally marking its arrival however, this is a devolving El Niño year due to which we may face shortfalls of rains, but nothing to panic about. On the other hand, 2009 and 2015 were growing El Niño years due to which some months performed really poorly. Efforts have to be made by MCGM by various types of information seeking; Web search has become a key reference source. Although not always 100% accurate, it is fast and free of charge. Built-in traffic monitoring engines within websites help to collect data about information-seeking behaviour and one such example is Google Analytics, which is capable of tracking hourly information about unique page visits, number and duration of individual sessions at the level of cities and towns and—in some cases—at the level of postcodes. A number of recent studies have provided evidence that 'big data' can reveal a great deal about the real-world, collective decision-making and responses to events and can even help to predict the prevalence of heavy rains , floods and such phenomena during the monsoon which occur in every year . Interest has therefore emerged in analysing records of flood warning information seeking, which, coupled with geolocation records, could be potentially useful not only for Web designers, but also for flood risk modellers. In these studies, MCGM can analyse whether Web-based information on the flood risk occurrences can help in understanding how badly those locations have been, or may be, affected.

Data

All datasets used in such analyses would be observed from the category of open data / restricted use. They can be divided into three main groups: (i) datasets available for direct download online, (ii) datasets available for public use, but where prior registration or permission of the data officer is required, and (iii) datasets contained in commercial databases, but accessible via application program interfaces or by crawling Internet resources. Owing to the varying characteristics of the original data sources, data pre-processing and filtering /cleaning was found essential in order to standardize the analysis to the ward scales of MCGM.

All wards identified by codes intersecting Metro city boundaries considered in such analyses. (*b*) Geographical extent of Historic Flood Warnings fragments close to the city boundaries. Mumbai Metropolis comprises severe flood-warning areas; each has a unique attributed ID and dates of the previously issued communications. The attribute format of the Historic Flood Alerts dataset is very similar to the warnings, but has coarser spatial resolution: thus, Mumbai urban and suburban areas are covered by such designations, which extend far beyond its geographical boundaries. In our analysis, all the alerts and warnings issued in any of these fragments, if intersecting any part of the city, are considered attributable to that particular urban locality.

Early Warning System: MCGM has installed 60 automatic rain gauges at 60 locations, of which currently 54 transmit rainfall data to the Disaster Control Room of MCGM every 15 minutes. Many of the rain gauges have been installed at Fire Brigade stations as they are the first respondents during disasters and are on 24-hour alert. The rain gauges also have a console capable of giving an audible alarm if preset rainfall intensity exceeds 10 mm in 15 minutes. MCGM is augmenting the drainage network for a rainfall intensity of 50 mm/hr which corresponds to a design return period of six months.

This design recommendation was based on the intensity-duration frequency curves obtained from an analysis of the daily rainfall records since 1843. A "risk warning" is issued to the catchments concerned and their main river channels. If the hourly intensity exceeds 80mm in an hour, rescue operations are put in place. Our analysis is summarized in the table below:

Table 4

Efforts of MCGM	Mithi River	Dahisar River	Poisar River	Oshiwara River
Location	Mithi River originates at the Sanjay Gandhi National Park from the overflow of Vihar and Powai dams	Originates at Tulsi Lake and has an approximate length of 12 kms. The river flows through National Park, Sri Krishna Nagar, Daulat Nagar, Leprosy Colony, Kandarpada, Sanjay Nagar and Dahisar Gaothan before entering the sea at Manori Creek.	Originate at Sanjay Gandhi National Park near Appapada and Kranti Nagar (Kandivali East) which is also the boundary of R-south and PNorth wards	It originates at Aarey Colony (Goregaon East) and has an approximate length of seven kms.
Major causes of Floods	Narrowing of the banks for housing and slums. Reclamation of the river bed by	Narrowing of the banks due to structures which include the bridge. Marble shops near	Narrowing of the banks for housing. Slum encroachments	Narrowing of the banks for housing Encroachments by industrial

	industrial units. Diversion of the course of the river for construction of Santa Cruz runway and taxi bay extensions. Construction of walls around Air India and Indian Airlines colonies. Bandra-Kurla Complex reclamation. Reclamation of natural ponds. The main river has been forced to turn four times in rapid succession. Construction of a culvert across the river. Bunding of the river with walls and embankments on both sides in some sections	the Western Express Highway. Leprosy Colony located between Dahisar and Borivali. Slum pockets between Bhagwati Hospital and Rustamji Park, and Ranchhoddas Marg	along the river bank Slums and tabelas Reclamation of the riverbed by small industrial units Reclamation of secondary channels of the river	units Loss of extensive mangrove stands in the downstream region of the river

Damming of upper reaches of the rivers, infilling and levelling of the first and second order streams, constriction of the mouth of Mithi River and Mahim Bay and reclamation of river line wetlands have taken place. MCGM has identified Chronic Flooding sites, Areas prone to cyclone / Strong action during the monsoon, Slums vulnerable flooding and becomes prepared to severe vagaries of the monsoon every year.

Brimstowad Project

Government of India sanctioned special grant of Rs. 1200 crores as per detail project report submitted to Government of India to implement "BRIMSTOWAD "project since year 2007. Out of these, MCGM has received Rs. 1000 crores till date. Brimstowad project is proposed to be implemented in 2 phases . There are 20 works in phase-I and 38 works in phase-II. The scope of the BRIMSTOWAD project is defined as under:

1. Rehabilitation and augmentation of underground drains in city
2. Construction of new drains in RCC
3. Training in nullahs in RCC M-40
4. Widening and deepening of nullahs and construction of access road along the nulla
5. Construction of Storm Water Pumping Stations
6. Major deficiencies of the existing system identified
7. The Storm Water Drainage (SWD) system has been designed for rainfall of 50 mm/hour with run-off coefficient of one i.e. the system is being augmented four times

Every year, MCGM ensures that the clogged drains in city are cleared before the monsoon by appointing register contractors by inviting tenders. About 60% of the silt (City area, Western Suburbs and Eastern Suburbs) have to be removed before the monsoon.

The establishment of the National Disaster Management Authority was the first step the Government of India took to provide an effective institutional mechanism for implementing disaster management plans. It envisaged, among other things, a holistic, coordinated and prompt response to any disaster situation from various wings of the government. The Disaster Management Act, 2005 came into force on December 26, 2005. According to the Act, at the state level there is a State Disaster Management Authority (SDMA) which functions under the chairmanship of the Chief Minister. The SDMA has a clearly defined line of command and control. It is responsible for laying down policies, plans and guidelines for disaster management.

In the pre-monsoon stage, the Disaster Management Department of MCGM conducts review meetings with external and internal stakeholders. MCGM's monsoon-preparedness plan is published in newspapers and by way of Information, Education and Communication (IEC) material. Mock drills are conducted at the ward-level in order to be in a state of readiness and to ensure prompt response and deeper coordination with other agencies. Fully equipped ward control rooms are commissioned; information is updated on flooding spots, landslide-prone areas and dilapidated buildings; Standard Operating Procedures are prepared by various agencies and compiled by the Disaster Management Unit. Fire stations and regional command centres, communication devices and other equipment are kept in a state of readiness.

Diagram – 4 Network of internal stakeholders with Emergency Operation Centre

Source: MCGM

V. Experience of Chennai Floods 2015

(1) On December 1 - 2, 2015, the Indian city of Chennai received more rainfall in 24 hours than it had seen on any day since 1901. The previous record for rainfall in a single day in December dates back to 1901 when the city received 261.6 mm of rainfall in a span of 24 hours. On December 1, 2015, the city received around 290 mm of rain in a single day causing catastrophic flood disaster. The deluge followed a month of persistent monsoon rains that were already well above normal for the Indian state of Tamil Nadu. Tamil Nadu, especially Chennai city was terribly hit by the flood during November-December 2015 which claimed more than 400 lives and caused enormous damages, both domestically and economically. Mainly the districts nearby the coast of Chennai, Kanchipuram and Tiruvallur were the most affected. It was found out that Chennai flood was due to the high intensity rainfall caused by the unfavourable atmospheric condition, rainfall distributed spatially and temporally, quantity of flow occurred in the rivers namely Kosasthalaiyar river, Cooum river and Adyar river.

(2) Chennai flood was basically claimed to occur due to improper drainage system and underlying strata which was found to be landfill over the ponds and lakes. The Coouam River which flows through the centre of main city was found silting due to the improper drainage facilities and encroachment by the local peoples who causes flood.

(3) In addition to that, the lack of wetland, which acts as a sponge, soaking of rainwater, played vital role in floods. This severe flood disaster was caused due to mismanagement and violation of protocols during urban planning.

VI. International experience in Flood situation

Two – third of the Singapore city's land surface serves as a catchment area, with the completion of the Marina, Punggol and Serangoon Reservoirs. Flooding has come down. Water supply has improved. Massive public parks have been built on the banks of these reservoirs. They have become tourist spots.

Coastal Cities like Busan in South Korea and San Francisco in California are developed with detailed disaster risk management plans. Like most coastal cities they are prone to typhoons and cyclones, flooding and earthquakes. They have advanced flood forecasting techniques and use underground tanks, submersible pumps, levees, stream gates to handle such eventualities. **Indian coastal towns have no such preparedness and usually a two – day warning by IMD to manage the fury of nature.**

VII. Limitations

1) As digitalization increases, data analysis of such huge amount of data becomes biggest challenge.
2) Data mining techniques are highly used and such technology is highly expensive.
3) The data on Flood Management are collated/analyzed from the database and reports of MCGM and IMD and it is used for academic research only.

Suggestion and Recommendations

- The only place where Mumbai City's drainage system can ultimately send water is into the sea. And if a monsoon deluge coincides with the high tide, flooding cannot be avoided. Logically, if we have a place to send the water to, even during high tide then flooding can be avoided. A barrage at the edge of Mumbai's bay, the tiny bay of Breach Candy, the massive bay off marine drive and the huge Mahim Creek and Malad Creek. We can block the sea out, and create reservoirs. From being a flood prone city, Mumbai will become an urban catchment area for four large fresh water reservoirs. The flooding problem can reduce dramatically. More importantly, we can use the saved water for the city's need once the monsoon season is over. The banks of these urban coastal reservoirs can become lovely public waterfront parks and walkways, a symbol of urban revival.
- Significant attention has to be given to the development of tools that attempt to measure the vulnerability, risk or resilience of communities to disasters. It is suggested to develop a disaster focussed index, the choice of variables may make the index indistinguishable from generic development and welfare indices, as found with the Predictive Indicators of Vulnerability, and thus offer very limited insight into disaster specific resilience and vulnerability. This has the potential to feed in to the broader international discussion on measurement of progress in the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals, which both have a substantial focus on data and measurement.

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