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# Flood Risk Management in Mumbai, India: Insufficient Resilience to Flood and the Approaches to Improve It

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**Abstract:** To be resilient to flood is critical for cities in the world to reach the United Nations Sustainable Development Goal 11. This article sets Mumbai as object, summarizing the problems, reasons and solutions to improve flood risk management in Mumbai, especially in slum areas.

**Keywords:** Flood; Resilience; City; Mumbai; Slum.

## 1. Introduction

Nowadays, cities are home to more than half the world's population and major drivers of economic growth. It is estimated that 7 out of 10 people will likely live in urban areas by 2050 [1]. But many cities, including Mumbai, are facing problems that prevent them from sustainable growth. Mumbai is the commercial capital of India. Millions of people live in Mumbai and 50% of the population living in slums [2]. Unfortunately, Mumbai is prone to floods, which had once made Mumbai suffer from huge economic losses and caused many casualties [3]. It is worth noting that people live in slums are more vulnerable to floods [3]. To make Mumbai more resilient to floods, NBS should be adopted, integrated with improvement in the drainage system, maintenance of infrastructure and raising public awareness. Moreover, participatory flood risk mapping can help engage communities living in slums in flood risk management. In addition, more investment, information, and partnership are needed to accomplish sustainable development.

The United Nations Sustainable Development Goal 11 is about making cities and human settlements inclusive, safe, resilient and sustainable [1]. The goal consists of – different targets. The case study in Mumbai can hopefully help to reach target 11.3 and 11.5(target 11.3 is about 'enhancing inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries by 2030' and target 11.5 is about 'by 2030, significantly reducing the number of deaths and the number of people affected and substantially decreasing the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations' [1]).

## 2. Background

Mumbai is located on the west coast of India. With rapid urbanization and a growing population, Mumbai become the commercial and financial capital of India, with 13.8 million people living in the municipal area of the city(as per Worldometer, United Nations 2020). But there are 50% of the city's population live in slum areas and hutments [2], one of which, Dharavi, is the second largest slum in the world.

Mumbai is heavily influenced by the monsoon, which can result in a prolonged period of heavy rainfall. The average annual rainfall in Mumbai is between 2500 mm and 3000 mm [4]. During the monsoon time, the cities will have to experience frequent spells of floods [5].

Mumbai city was reclaimed from two groups of islands, the Heptanesia and Salsette islands. The average elevation of it is 10-15 meters above mean sea level. The coastline is low-lying, with some points just one meter above mean sea level [6]

Mumbai is now one of the cities with the highest accumulated flood risk in the world in terms of the number of people and assets exposed to local (stormwater and tidal) flooding [4]. One severe flood can set a city's development back by many years and drive away investors. The natural hydrological cycle of the city has been dramatically changed due to explosive urban growth, resulting in a steep increase in runoff over the past decade [7]. On July 26, 2005, Mumbai experienced a high-intensity rainfall event of about 190 mm/h with high tides, which flooded the entire sub-urban part of the city and resulted in tremendous human, economic, and infrastructure losses [4]. Although there have been no major floods since 2005, Mumbai is regularly affected by flooding every year. An average of more than 70 waterlogging incidents are reported each year in the core cities [8].

It is worth noting that the floods in 2005 and each year were most severe in informal settlements or slums [9]. Researchers found that the livelihoods and economies in slums are particularly prone to annual flooding and slums have poor resilience to it [3].

Mumbai suffers huge economic losses due to economic and social disorientation resulting from annual floods, ultimately affecting the national economy. Therefore, strengthening Mumbai's ability to cope with flood risk is crucial for a more sustainable city.

## 3. Reasons Behind

The reasons for the flooding in Mumbai are as follows:

### 3.1. Reclamation of separate islands

The primary reason for the flooding is that Mumbai city was built through the reclamation of separate islands. The reclaimed space between the islands was below the high water level. When there is heavy rainfall, it can only drain slowly.

### 3.2. Heavy rainfall

The heavy rainfall resulting from the monsoon and tides can lead to poor drainage and compound flooding [5].

### 3.3. Poor drainage

The inappropriate levels of outfalls, the increase in the run-off coefficient due to the urban landscape, and the poor design of the drainage system are also parts of the reasons behind the problems [5].

### 3.4. Decrease in the number of forests and wetlands

The number of forests and wetlands, which are helpful in drainage, decreased due to the urbanization of Mumbai. It has indirectly increased the vulnerability of the city to flooding. What's worse, scholars believe that the same trend is continuing [10].

### 3.5. Poor living conditions and a lack of assistance

The poor and vulnerable are more vulnerable to disaster and people who live in slums take up more than half of the population.

Generally, slums are located in areas including low-lying abandoned places, wetlands, along railway lines, dumping grounds, footpaths, and Nullah (stream) sides, which are the most hazardous and disaster-prone areas, exposing the dwellers to a higher risk of floods. For example, slums along the Mithi River were the most affected area by the 2005 flood [3].

And there is a lack of assistance for them. It is found that slum communities in Mumbai do not receive any government assistance for disaster recovery, nor do they have insurance coverage [8].

## 4. Measures taken

The 2005 Mumbai flood resulted in the Government of India initiating significant policy and planning initiatives, and proposing various measures. Some of them are as follows.

### 4.1. The National Guidelines on Urban Flood Disaster Management

The guidelines are the products of an expert committee set up by the National Disaster Management Authority of India. They are considered to be quite comprehensive and identify the institutional framework required for improving flood resilience through better flood disaster management [11].

### 4.2. Flood mitigation measures

These measures include dissemination of real-time rainfall and flood alerts in Mumbai that can be accessed online, flood risk mapping, and construction of online detention pond on the Mithi River in Mumbai. Detention/holding ponds are an effective way of reducing flooding in Mumbai, although the availability of land for the design capacity is always a challenge [11].

### 4.3. Other action

In addition to the initiatives and measures of government, local participatory platforms and community-driven groups, such as ALM (advanced locality management), played a significant role in Mumbai disaster and environmental risk reduction activities.

However, a lot still needs to be done to make Mumbai flood resilient [11].

## 5. Solutions and Changes

Scholars believe that Ecological factors should be the basis of future planning and development of Greater Mumbai (and any other Indian city) to avoid future catastrophes [12] and integrated measures should be put into use when coping with the floods.

### 5.1. Nature-based solutions (NBS)

Nature-based solutions (NBS) are effective and adaptive interventions to protect, manage, and/or restore natural or modified systems. NBS can address multiple sustainable development goals, including climate and disaster-risk resilience. In many vulnerable regions, harnessing the power of nature is a promising and cost-effective strategy to strengthen climate resilience while fostering shared social and economic prosperity. The World Bank is scaling up the integration of nature-based solutions to climate challenges to help countries build resilience [13]. It can be used as a major solution to floods in Mumbai.

1)Restore and construct bioretention areas and wetland

Bioretention areas, including rain gardens and bioswales, are vegetated trenches designed to receive runoff in a specific location to help control stormwater. In addition to controlling peak flows, bioretention areas can filter pollutants and have been shown to remove up to 90 percent of heavy metals from stormwater [13]. And the wetlands, including Mangroves, act as a sponge in floods in an area by absorbing volumes of the excess water. The cost of constructed wetlands may range from $7 to $15/m2 and are usually less expensive than built (gray) options for the same function [13]. But in Mumbai, mangrove ecosystems along the Mithi River and Mahim Creek are being destroyed by construction activity [6].

Economic analysis has found in Sri Lanka that, the more wetlands are conserved, the greater the payoff in flood protection and other benefits, like wastewater treatment [13].

Mumbai should restore the damaged wetland and identify reclaimed parcels of land that have not been taken up for development and recreation long the water bodies to construct new bioretention areas and wetlands.

2)Construct or protect open spaces such as parks and greenways

Open spaces in urban areas help capture runoff from upstream basins and adjacent areas while reducing the built footprint through the redevelopment of certain areas [6].

A study in Beijing, China shows that the green spaces stored 154 million m3 of rainwater, which corresponds roughly to the annual water needs of the city's urban ecological landscape [14].

3)Install Green roofs and Permeable pavements

Green roofs reduce stormwater runoff by promoting rainfall infiltration on the tops of buildings. It can retain 50 to 100 percent of the stormwater they receive [14].

Permeable pavements are pervious concrete, asphalt, or interlocking pavements that allow rainwater to infiltrate where it falls. Some applications have demonstrated a 90 percent reduction in runoff volumes [14].

### 5.2. Improve poor drainage system

1)Restore river basins and buffer zones

Encroachments on river basins and buffer zones of water bodies causing hindrances in the functioning of the natural drainage system require urgent attention. The local bodies may have to clear the authorized and unauthorized

encroachments with the planned relocation of developments. Bioswales can be created in the buffer areas of water bodies, and the dumping of waste should be restricted [6].

2)Disconnect storm water drainage from sewage drains

While it is challenging to do so, it may be required to disconnect stormwater drainage from sewage drains in phases and set up treatment plants with advanced and natural treatment methods.

Smaller sewage treatment zones can be created to treat the waste close to the source and reuse some part of the treated water before discharging it into the water bodies [6]. This can be implemented in the large slum pockets which lack this infrastructure.

### 5.3. Raise the awareness of sustainable development

The issue of maintenance of water bodies and piped drainage needs to be taken up seriously by the local authorities. This may be tackled by creating public recreational spaces around the water bodies and conducting public awareness regarding the maintenance of these spaces [6].

### 5.4. Participatory flood risk mapping

Involving local community is a perquisite for effective implementation of disaster risk reduction strategies. Local community's deep understanding about the locality has considerable value for understanding disaster situation and designing community-based amelioration [15].

Participatory risk mapping is considered as a powerful tool to engage local communities in disaster risk management. It entails a process that enables local community themselves, in collaboration with experts or researchers, to physically locate—their disaster risks, the resources they possess and the actions they can take to reduce vulnerabilities. Participatory risk mapping plays a critical role in risk awareness because it enables visual representation of risk faced by the communities and the strategies that they propose for disaster risk reduction [15].

It was found that vulnerable, marginalized communities living in slums are not meaningfully involved in the disaster management and planning process, but they should be involved [15]. There is an urgent need to improve the resiliency of local communities. Participatory flood risk mapping may be a way to do so. An exercise was conducted in Dharavi, Mumbai, which had the moderate-level success to achieve the process objectives of community participation—continued and active engagement of the community and good facilitation [15]. This case is used as an example to introduce the implementation of participatory flood risk mapping.

1)The implementation of participatory flood risk mapping—a case study

The study was carried in Kalaqila Chawl, Dharavi. In this study, the research group used the participatory framework for disaster risk management proposed by Samaddar et al. (2018) to define the process criteria of community participation in risk mapping exercise. They are early engagement, representation of relevant stakeholders, clear and agreed objectives, continued and active engagement, fairness, power to influence decisions, capacity building, incorporating local knowledge, good facilitation, resource availability and time [15].

The steps followed to carry out the flood risk mapping exercise are problem identification and goal setting, site selection, identifying stakeholders and local leaders, rapport building, plan proposal for participatory flood risk mapping, base map preparation, orientation and training of the local leaders for mapping exercise, finalizing time and date of the exercise and communication with the community, flood risk survey and mapping, map digitization, data validation by local leaders, display the map to the local leaders and revising the map, completion of flood risk maps and information circulation [15].

A large range of tools were used for data collection and mapping. Some of the key tools used in this exercise are town watching, observations, open-ended interviews group discussion, photography, secondary data collection and mapping [15].

2)Evaluation

The study showed that under this process framework, local community valued very high achievement of five process criteria of participation through the exercise as follows: early engagement, clear objectives, fairness, power to influence decisions, incorporating local knowledge and understanding [15]. But, three criteria of participation including representation of relevant stakeholders, capacity building and resource viability had been minimally achieved. In addition, the participants reported that the project information should have diffused to larger communities, and the participation of all sections of the community was expected [15].

More researches are needed to get the structure and process of the participatory risk mapping updated and more effective in order to accomplish its objectives.

It was also found in this study that prevailing illiteracy, lack of technical skill and knowledge in addition to poor finical resources impede the Kalaqila Chawl community to carry out any community-led plans [15]. Therefore, the implementation of the practice in slums may rely on nongovernmental organizations. Technology and funds that needed should be provided, propagation of flood risk management is required before the practice and people concerned should be involved.

## 6. Recommendations

A Sufficient amount of investment is required to enable the construction involved. It may come from government and nongovernmental organizations.

In Mumbai, people's educational backgrounds, levels of income, and social status vary widely. Increasing citizens' participation and acceptance of these new sustainable solutions can be challenging but significant.

Having communities living in slums involved in the disaster management and planning process is an effective approach to improve the flood resiliency of local communities. But poor finical resources, prevailing illiteracy, lack of technical skill and knowledge can be obstacles.

Besides the solutions proposed, other factors should be taken into account when tackling floods in Mumbai, including governance issues, policies and more. A more localized and detailed version of solutions should be created based on the conditions in Mumbai.

A more sustainable future is the outcome of the joint efforts of the government, nongovernmental organizations, citizens, and more. At the same time, cooperation with foreign countries is needed to acquire advanced experience and technology.

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