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Climate Resilient Infrastructure is Needed to Manage Urban Floods in Mumbai

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Abstract: ***This research paper analyses the reasons for urban flooding in the Indian city of Mumbai, Maharashtra, and the ways of mitigating heavy inundation by developing climate resilient infrastructure. Increased urbanization and rapid climate change causing a rising sea level has put Mumbai in a dangerous position wherein there are risks of a large magnitude urban floods. The direct impact can be seen by the lack of shelter and growing diseases in vulnerable and marginalized populations of Mumbai. The urbanization has caused lack of green areas and natural ecosystems that can absorb the stormwater and reduce impacts of urban flooding. Thus, ideating and developing climate resilient infrastructure that is adaptable to sudden changes in climate will do well in managing this issue.***

Keywords: Urban floods, Stormwater, Mumbai, Urbanization, Climate change, Rising sea - level, Climate resilient infrastructure, Blue - green infrastructure

1. Introduction

India falls victim to flooding annually, with flood damages increasing rapidly. Urban flooding is largely a man - made problem and efforts to mitigate this flooding will prevent long - term damages to a city. This can be seen by the OECD modelling of the potential impacts of a major flood in Paris found that 30% to 55% of the direct flood damages would be suffered by the infrastructure sector (OECD 2020).

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. Urban areas are also centres of economic activities with vital infrastructure which needs to be protected 24x7. In most of the cities, damage to vital infrastructure has a bearing not only for the state and the country but it could even have global implications. (NDMA 2021). Developing sufficient climate resilient infrastructure seems to be the way forward.

Climate resilient infrastructure is essentially infrastructure that can accommodate to sudden changes in the climate, and it can also recover from any disruptions caused by the climate rapidly. When it comes to floods, since there can be future uncertainty it is important to invest in infrastructure that is flexible and adaptable, and take into account all possible future factors.

Mumbai, Maharashtra is one such city that faces urban flooding. The Thane creek, the Harbour Bay and the Arabian Sea surrounds Mumbai, with Mumbai historically being formed from 7 islands. In 2005, floods in Mumbai were at an all - time high for the city with over 500 casualties, and up to 2 billion USD economic damages. A substantial number of buildings were damaged - 2000 residential buildings were fully damaged while 50, 000 were partially damaged and 40, 000 commercial establishments suffered heavy losses (NIDM 2009). This was however, not the only case of major floods plaguing the city. In more recent times, the floods in 2017 also paralyzed the city of Mumbai, and much like 2005, there was a lack of immediate and efficient damage control, causing the urban flooding incident to create large scale and long lasting damage to the city. The repetition of such an incident is a risk that becomes likelier as urbanization continues to increase in the city.

There has been an influx of people as Mumbai has seen rapid population growth in the past 2 decades. As of a 2011 census, Mumbai city has a population of 12, 442, 373, and the Mumbai metropolitan population is 18, 394, 912. The 2021 census was postponed due to the covid - 19 pandemic. However, the current estimate population of Mumbai city in 2023 is a staggering 17, 159, 000, and the 2023 Mumbai metro population is estimated at 25, 368, 000. Mumbai has a highly vulnerable population in that 52% of its residents living in informal housing, popularly known as slums. A lot of these slums are situated near water bodies or open water drains, causing damage when there is flooding. That being said, climate resilient infrastructure to curb urban flooding is crucial in the maintenance of a metropolitan such as Mumbai.

Causes of Urban Flooding in Mumbai

There are a few primary reasons for the inundation of floods in the city of Mumbai:

1) Heavy Rainfall and Rising Sea Levels

Rainfall, when it coincides with a high tide, is one of the primary reasons for Urban Flooding in Mumbai. Mumbai sees rain through the months of June to September. July has the highest rainfall with average precipitation being 868 mm in the month. Moreover, the average annual rainfall of Mumbai city is 2401 mm. According to the Indian Meteorological Department's weather station data, Mumbai has been experiencing four extremely heavy rainfall events annually for the past 10 years on an average. Mumbai has been witnessing a steady increase in extreme rainfall events. Over 35% of Mumbai's population lives within a 250m radius buffer of BMC - reported flooding hotspots. Ward F/N has the highest number of flooding hotspots (54) with 65% of its population exposed to the risk of flooding (MCAP 2022).

Global climate change makes matters worse as Mumbai has begun to combat rising sea levels, something that has led to high tides in the monsoon season. There are, in fact, threats that areas of Mumbai, specifically South Mumbai, will be

completely submerged by the year 2050 due to rising sea levels due to rapid climate change.

2) Excess Land Reclamation

Historically, Mumbai consisted of seven islands that were linked together to form the city as we now know it. As urbanization continues to rapidly grow, there has been a steep decline in pathways that allow drainage of rainwater as housing and industries continue to increase on the daily and block these pathways. Stormwater drains have reduced as development has taken place in order to ensure that the Mumbai's growing population's needs are met. Due to this, there are few adequate stormwater drains in the city, causing a large overflow due to a lack of prioritizing sufficient drainage infrastructure.

3) Overflowing Mithi River

The Mithi River serves as an integral part of Mumbai's drainage network. The river functions as the division between Mumbai city and its suburbs, and over the years, its catchment has been encroached upon by development. Furthermore, due to large amounts of plastic and other solid waste disposal by neighbouring industries, the river has been clogged even more, leaving it with even less space and larger potential to overflow. The population living on the banks of the Mithi River is highly vulnerable because of the overflows, and this population mainly consists of slum dwellers. Additionally, due to the Chatrapati Shivaji National Airport runway been extended, and that too, over the path of the Mithi river, the path of the river has been changed. However, when there is high pressure rainfall, a lot of the times the rain just falls over the land and floods rather than changing paths, causing damage.

4) Drainage System

The storm water drainage system of Mumbai is highly antiquated, having never been updated since the time of the British Rule, and thus does not account for the over 10 - time spike in the city's population. The system comprises of about 400 km of underground drains and laterals, built on the basis of the population and weather conditions of the times it was constructed in. This antiquated storm water drainage system is capable of handling rain intensity of 25 mm per hour at low tide. If the rain intensity exceeds 25 mm per hour and a high tide occurs, there is always a possibility of inundation (Kadave et al.). The lack of attention paid to modifying the drain in accordance with the change in infrastructure and population has caused it to be an inadequate piece of infrastructure for urban flood management. These unchanged stormwater drainage systems have already failed us in the past during the 2005 Mumbai floods.

Impact of Urban Flooding

Urban flooding disrupts all aspects of the workings of a city, from infrastructure, to power transmissions and human lives. The hygiene and sanity of urban floods are also questionable as they carry multiple disease through the solid waste that is mobilized from the open water drainage systems in the city. After the flooding of 2005 for example, the risk of epidemics of water - borne diseases such as gastroenteritis, hepatitis, leptospirosis, malaria and possible cholera was high (NIDM 2009).

Loss of shelter is also a huge issue as marginalized groups living in slum areas lose their homes during the floods. There is a risk of fatality as well, as seen by the casualties in the 2005 Mumbai floods mentioned above. For example, almost every monsoon season, a lot of the M East Ward which has over 800, 000 inhabitants, and consists of over 40% of Mumbai's slum population is flooded, causes potential mould diseases to inhabitants. Moulds are a common type of fungi that spread rapidly on damp surfaces and release tiny spores into the air which can be inhaled easily. Dampness has been suggested to be a strong, consistent indicator of risk of asthma and respiratory symptoms, says a report by the World Health Organisation (WHO).

Furthermore, the coast line of Mumbai has severely deteriorated as mangroves alongside the coast have begun to disappear and are endangered. This serves as a large problem since the mangroves have the ability to absorb water and to an extent neutralize the impact of storms or heavy rainfall on the coast line.

Lastly, the rising sea levels in Mumbai due to global climate change poses a risk of eventually causing parts of the city to be entirely submerged underwater. A report by WMO suggests that Mumbai is one of the most affected cities when it comes to rising sea level, with the sea level rising by 4.5 mm a year between 2013 and 2022. This is an extremely alarming growth rate, especially since this will increase the rate of storm surges, flooding and damages to coastal areas such as Mumbai. Climate change causes the magnitude of these floods to increase as well, and thus the capacity of climate infrastructure must adapt to accommodate these future rises, and any type of uncertainties.

Plans for Climate Resilient Infrastructure in Mumbai

After the floods of 2005, the Government of Maharashtra set up a fact - finding committee that would identify the root causes of flooding and suggest possible measures that can be taken to prevent this. Through this Chitale committee, a number of solutions were identified and brought to the attention of the government.

1) Mumbai Climate Action Plan 2022

The Mumbai Climate Action Plan (MCAP) 2022, which is led by the Municipal Corporation of Greater Mumbai (MCGM) and the Ministry of Environment & Climate Change, outlines steps Mumbai plans on taking to meet climate goals by 2050 as per the Paris Climate Agreement. The report highlights the sparsity of coverage of Stormwater Drainage (SWD) Networks in certain areas of Mumbai, specifically the north, northwestern and central parts of the city as compared to the south. Thus, plans for a carrying capacity report of these networks has been suggested as a starting point, and this can be followed by development of appropriate infrastructure once a thorough analysis has been conducted.

2) iFLOWS - Mumbai

This is an integrated flood warning system created as a joint initiative by the Ministry of Earth Sciences (MoES) and Brihan Mumbai Municipal Corporation (BMC). This allows alerts to be sent between 6 to 72 hours in advance if there is

any risk of inundation and flooding. Taking into account the rainfall in Mumbai alongside the storm tide as well as the tidal waves, it is able to make these predictions.

3) Storm Water Pumping Stations

Furthermore, plans to storm water pumping stations in order to adapt to a range of intensities of rainfall has been established. Mumbai already has a number of pumping station in identified key areas wherein there is a risk of flooding, and plans to expand this project is already underway. Pumping stations allowing water to be drained out from land, which can be caused due to flooding, using a pump and can relocate said water to another area. Currently, there are six pumping stations around Mumbai, and there are plans to create more around the city. This will help in evacuating inundations in an efficient manner, and can be adapted so that road infrastructure can be able to withstand large scale climate shocks when it comes to rainfall and floods.

4) Mithi River Floodgates

The major problem of the Mithi River swelling each monsoon season has been identified since the floods in 2005. The proposed solution for the same is to create floodgates surrounding the river, however there has been a delay in finding an appropriate tender due to the bureaucratic process and various other factors. As of March 2023, the BMC has been looking for tenders to create 27 flood gates in the tidal influence zone of the Mithi River area. Each floodgate includes a pumping station and this allows there to no additional land acquisition requirements as compared to if regular pumping stations were used. This way, when there is a high tide, the floodgates will be closed, and during low tides the floodgates will be open in order to allow storm water to flow into the river.

5) Automatic Weather Stations

Automatic Weather Stations (AWS) allow forecasting predictions to be made, and helps authorities anticipate upcoming threats for floods or storms. In 2019, the BMC committed to creating 100 AWS in the city of Mumbai in order to ensure that the BMC was thoroughly prepared for any sudden change in weather. The correct and efficient usage of this date however is still to be mapped out.

Additional Climate Resilient Infrastructure

While there seems to be certain infrastructure that have already been planned to be implemented in Mumbai, the core problems that lead to urban flooding in the city will continue to prevail until the bigger picture is seen, and infrastructural flaws in the design of the city is paid attention to.

The increased urbanization and lack of land in the city has caused such a problem that, there is a lack of green, natural areas to absorb rainwater, causing excessive and unmanageable flooding. For successful urban management, the model should be such that the problem can be contained without disrupting the lives and integrity of the people and structures in the surrounding environment.

Green Infrastructure: Sponge City Model

The BMC can look to adopt a sponge city model in within the Mumbai. This is essentially when highly urbanized areas ensure the presence of green areas with plants, and treesso that the water that would otherwise flood can be absorbed by nature. In terms of Mumbai in particular, since the existence of mangroves is depleting by the coast, the presence of such a model is the need of the hour in order to compensate and then add to the city. However, lack of space is an issue that the city continuously faces, with the population of the city rising daily, and thus there is a need to ideate methods of incorporating and integrating the sponge city model within Mumbai. Green infrastructure such as this is crucial in handling stormwater, as the amount of water that reaches sewer systems gravely reduces.

Blue Infrastructure

Alongside green infrastructure, if Mumbai looks into also integrating blue infrastructure methods, a combination of the two would be ideal. Blue infrastructure is essentially attempting to replicate and mimicking the natural water cycle in urban areas. This entails recreating or restoring water bodies such as lakes, ponds as well as developing rainwater harvesting systems.

Since space may be a constraint in a city like Mumbai, rainwater harvesting is a viable solution in order to reduce the amount of stormwater on streets and roads. Another way of achieving this is by creating blue roofs on structures in flood prone areas so that stormwater is held temporarily and can slowly be released in order to avoid major flooding.

2. Conclusion

As urbanization increases, so does the threat of urban flooding, damaging numerous aspects of surrounding environments. This is as current infrastructure available for mitigation efforts remain insufficient in solving the problem and remaining resilient when combatting frequent and unexpected changes in the climate. Thus, the requirement and need for climate resilient infrastructure and planning is brought out through the paper.

The paper highlights the various causes for urban flooding in the city of Mumbai, as well as the impact it has on the city. Once these factors have been identified, and the scale of damage has been quantified, the paper analyzes possible government frameworks and plans for infrastructure that can be developed in order to help mitigate large - scale inundations in the city of Mumbai.

Acknowledgements

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