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Causes and Impacts of Urban Floods in Indian Cities: A Review

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ABSTRACT: Urban flooding was considered a concern of municipal and local governance only till the 1990s, but currently it draws the attention of disaster and environmental scientists. Urban floods have attained the status of disaster due to high vulnerability and risks. It leads to extreme fatalities and enormous economic losses in every country. Especially in developing countries like India, where population density is high and has enormous population growth during the last few decades due to high migration in urban areas and have a lot of issues about uncontrolled and inappropriate development. Population increase results in more urbanization, more impervious area, and less infiltration and greater surface runoff, change in topographical and drainage profile, increasing the flow of water in proportion to the urbanization rate.
Indian Cities are expanding outwards in the fringes of the cities having Greenfield development, engulfing several natural features like forests, water bodies, and agricultural land, transforming the cities into urban agglomerations. These urban agglomerations have numerous issue and problems which aggravates the vulnerability to urban flooding. Many Indian cities have experienced devastating floods in recent years which affect the routine life of residents and cause huge damage to property and fatalities and ultimately affected the economic growth of the country. Therefore, it is essential to understand the various reasons for urban flooding and its plausible impacts on the urban environment in cities.
This paper highlights the direct and indirect factors causing the urban floods and their impact on the urban environment in Indian cities. The role of urbanization and the existing pattern of urban development in increasing the vulnerability of urban floods in Indian cities are also discussed along with various lacunas in existing planning legislation related to urban flooding.

Keywords: Urban floods; urbanization; Indian cities; urban environment; planning legislation.

I. INTRODUCTION

An increase in the number of events of urban floods is turning into a world-wide phenomenon and is a great challenge to planners all over the world. The impacts of such disasters are very complex in developing countries like India, which are more vulnerable compared to developed countries. The scale of these incidents can range from neighbourhood level to a large-scale disaster, resulting in inundations in urban areas from a few hours to several days.

Flooding is a river or any other waterbody overflowing its banks. Urban flooding does not just mean "the flooding that happens in an urbanized area." The Federal Emergency Management Agency (FEMA) report 2016 defines urban flooding as: the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems [1].

The definition can be separated into three individual components: urban flooding is caused by heavy rain – falling on developed surfaces – where the capacity of the drains is not sufficient. Thus, the term Urban flood can be simplified as "excessive runoff in developed urban areas, where the stormwater doesn't have anywhere to go due to poor capacity of the drainage system, causing inundations."

Each of these components - rapid urbanization, increase in the amount of rainfall due to climate change, and outdated or insufficient stormwater infrastructure – form challenges to be addressed individually. Urban flooding is a complex problem that is a result of a combination of these factors happening simultaneously.

Urban floods are on an increasing trend at an alarming rate and have slowly become a regular phenomenon in most of the fast-developing cities of India and especially after 2000. The most damaging Urban floods amongst them in chronological order are 2000 in Hyderabad, 2001 in Ahmedabad, 2002 and 2003 in Delhi, 2004 in Chennai, 2005 in Mumbai, 2006 in Surat, 2007 in Kolkata, 2008 Jamshedpur, 2009 in Delhi and 2010 in Guwahati, Delhi, large scale floods in Uttarakhand and Kashmir 2013, Chennai deluge 2015 and Assam and Madhya Pradesh in 2016, Mumbai floods 2017 [2, 3]

II. FACTORS CAUSING URBAN FLOODS IN INDIA

Urban flooding occurs when stormwater flows into an urban area at a higher rate than it can be absorbed into the ground or moved to waterbody (lake, river, etc.) or stored in a reservoir. The increased flow of water can be due to river floods, flash flooding, coastal flooding, or rapid snowmelt [3]. Inundations tend to become more serious flood hazards by accentuated flood peaks [4]. Although the factors that cause urban floods are very diverse, they generally can be seen as the cumulative result of natural and human factors (Table 1).

Table 1: Factors causing urban floods in India.

Meteorological Factors	Hydrological Factors	Human Factors
Unprecedented Rainfall	Change in course of rivers	Surface sealing due to urbanization and deforestation
Cyclones and Hurricanes	Type of soil and water retention capacity	Building design without regard to flood risk
Heavy Thunderstorms	Infiltration rate and Ground water level prior to floods	Encroachment of floodplains and lowlying areas
Global warming (Snowfall, snowmelt and sea level rise)	Synchronization of runoffs from various parts of the watershed	Lack of maintenance of infrastructure and drainage channels
Influence of Urban microclimate	Very efficient drainage of upstream areas in comparison to downstream areas	Siltation and improper solid waste disposal in Drainage channels
	Presence / Absence of over bank flow and High tide impeding drainage	Unplanned release of water from dams / lakes located upstream of cities and towns
	Channelled storm water network. cross-sectional shape and roughness	Absence of administrative framework
	Landslides and soil erosion	Lack of preparedness

Source: Adapted from NDMA, 2010 [3] and improved upon.

A. Meteorological Factors

India being a tropical country, has very heavy rainfall throughout the monsoon season. Besides, there are other climatic factors that bring in a lot of rain. Global warming results in extreme weather conditions and is apparent to increase the flood risk significantly; the number of events is consistent with a warming climate. Even though climate change is an important factor increasing the chance of those events happening, all the extreme weather events can't be linked to climate change [5].

Changing climate and increased precipitation had a huge role to play in the devastating floods that happened across central Indian states, including the 2006 and 2017 Mumbai floods. IMD's data reveal that - In the past century (1901-2015), there has been a rise in widespread extreme rainfall events across the Indian subcontinent by three-fold, especially in the states of – Chhattisgarh, Gujarat, Jharkhand, Maharashtra, Madhya Pradesh, Odisha, Telangana, Assam; and parts of Western Ghats – South Kerala, Goa, north Karnataka and. Tamil Nadu. The extreme rise in the number of rainfall events are directly linked with increased warming of the Arabian Sea and Bay of Bengal causing fluctuations of the monsoon winds. This results in the occasional high-intensity cyclones from the Arabian Sea to the western coast and Bay of Bengal to the eastern coast, resulting in heavy rains lasting for at least 2–3 days, which when spread over a large region causes flash floods [6].

Observed past and projected future patterns of climate change could have an increased effect on existing flood risk, for example Cyclone like Nada, Roanu, Vardah making landfalls in coastal areas induce heavy rainfall finally leading to flooding [7].

Climate simulation models predict that average rainfall will increase by 20-30% in 60 years. Such an increase could result in urban areas suffering from an increase in flood risk (up to 200%) [8]. Tidal surges can also affect coastal cities/ towns.

B. Hydrological Factors

Flood risk arises when the surface runoff is more than the infiltration rate during precipitation. The infiltration rates depend upon the type of soil and their respective water retention capacity [9]. Vegetation and trees reduce the speed of the water, the presence of a pervious surface helps in percolation and increases the infiltration rates, hence avoiding heavy damages to life and property. Rapid urbanization has a direct impact on hydrology and surface runoff. Some of which are [10]:

- Restricting the natural change in the course of rivers
- Deforestation and soil erosion
- More impervious surface and decreased infiltration resulting in more runoff
- wastewater entering rivers and lakes – causing siltation further reducing the capacity of natural drains;

Topography plays a major role in carrying the runoff water outside the urban areas. Based on topography the urban settlements can be broadly classified into three major categories – Hill towns, Coastal towns and landlocked towns. The hydrology and topography differ in each of the types of towns and thus the causative factors and duration of inundations in urban areas.

Riverside urban settlements and coastal towns in the delta region are more susceptible to flood hazards during monsoon. Such towns may even be affected by floods happening inland on the river basin. In such cases because of expanded hard surface area, the increased surface runoff increases peak flows and reduces the time to peak in the drainage channels. Usually, a combination of two or more of the following factors: extreme climate-related events, unplanned development in the catchment area and under capacity natural drainage, blocked stormwater drainage system, are the major cause of the urban flooding [11].

Non- perennial rivers change course when huge amounts of water flow during extreme floods beyond the carrying capacity of the river, affecting the immediate surrounding [12]. Such changes in a developed urban area can cause devastating damages to life and property.

C. Human factors

Human intervention in the natural environment has increased the urban flood risk. These anthropogenic factors can be a direct result of Urbanization coupled with encroachments, Pollution which causes interference in the smooth flow of water in the drainage channels. Mining activities and tourism in water bodies can deteriorate the ecosystem. Negligence and lack of a proper governance framework have caused floods on a destructive scale.

(i) Urbanisation: Urbanization in India is directly linked with the increase in impervious surface. This reduces the speed and scale of percolation and increases surface runoff from buildings, roads, and other hard surfaces. By the very definition of urban floods – It can be stated that urbanization is directly linked with the risk of urban flooding.

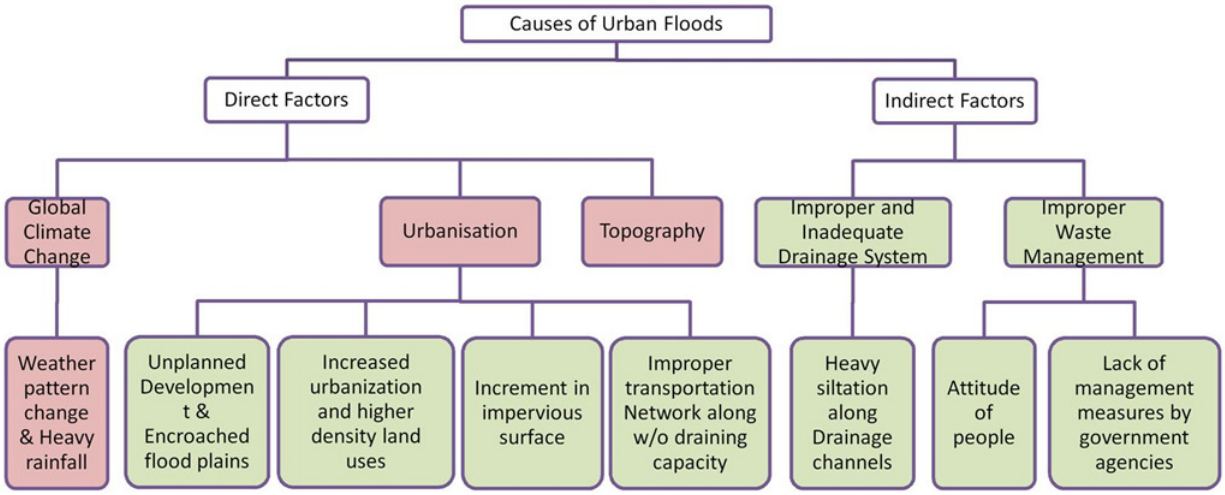

Fig. 1. Causes of Urban floods.

(ii) Encroachment: As more people migrate towards cities in search of employment, the demand of land for housing rises which increases the economic value of the available land. People start settling on the ownerless available vacant land i.e. Low-lying areas near water bodies. Sometimes these encroachments cover up the whole catchment area and in worst-case scenarios – there will be no trace of the existence of the water body [13].

Example: Ousteri Lake in Puducherry, Deeporbeel in Guwahati, Charkop Lake in Maharashtra, Pallavaram marshlands in Chennai.

Encroachments in the upper catchment areas of a river basin (i.e. hill towns) can create excessive runoff in the river causing flash floods in the towns situated in the valleys [14].

(iii) Pollution: Population densities in urban centres are increasing at an alarming rate than designed for. The supporting infrastructure facilities such as solid waste disposal, sewer lines, stormwater drains etc are not being developed to adapt to the increased demand [15]. This results in improper solid waste disposal into waterbodies, unattended street waste clogging drainage channels. The design capacity of the STP planned at the city level easily gets overwhelmed, resulting in the release of untreated sewage into rivers and canals. These result in chocking and siltation further reducing the flow capacity during a flood event

(iv) Illegal mining activities: Illegal mining of river sand and quartzite for use in building construction deplete the natural bed of the rivers and lakes and have an irreversible damaging impact [16]. This causes soil erosion and reduces the water retention capacity of the waterbody, increasing the speed and scale of stormwater flow and changes the natural course of water.

Example: Jaisamand Lake - Jodhpur, Cauvery river – Tamil Nadu

(v) Interference in the drainage system: These interferences can also be in the form of the poorly planned construction of roads, bridges, railway tracks, and check dams, which hampers the flow of water resulting in a flood. In Indian cities and towns, due to increased land prices and less availability of land near the city centre. New developments are coming up in low-lying areas, usually as encroachments over lakes wetlands and riverbeds.

The width and depth of the water bodies are greatly reduced, sometimes even creating blockages to the natural flow of water [15].

(vi) Unplanned tourism activities: Water bodies have been used as an attraction for tourism development for decades. Water plants and other eutrophication are being removed from rivers and lakes which are otherwise necessary for reducing the runoff speed. These activities have to be monitored in such a way that there are no ill effects on the environment and the water body [17]. Cultural or religious festivals also misuse water bodies by throwing non-bio degradable matter into the rivers and lakes, reducing the water quality. In the event of floods, the suspended particles and pollutants overflow into the neighbourhood posing health risks [18].

Example: Ashtamudi Lake in Kollam, Kerala - polluted from oil spillage from boats. Ganga Ghats in Kanpur – solid waste and oil by tourists and pilgrims.

(vii) Unplanned release of water from dams: Unplanned and sudden release of water from dams and lakes lead to floods in an urban area, without giving the public enough time to respond.

Example: Floods in Northern Bihar - Unplanned release of water from Nepal has caused [19]; Chennai Floods 2015 – Release of water from Chembarampakkam lake [20].

(viii) Absence of administrative framework: Protection of water bodies was not a primary concern of urban planning; this has come into light only after the recent incidents of inundations in major cities causing huge economic losses [21]. Instead of imposing strict laws to restrict or remove encroachments from drainage channels and wetlands, there have been cases where the local government has been given powers to regularize the development by giving them legal rights to own the land. There has been very little initiative from the government to place the waterbodies as a protected environment free from pollution and encroachment [20, 22].

The factors responsible for Urban flooding are identified and segregated into two categories: Solvable – Unsolvable through change in planning guidelines in Fig. 1 (Adapted from various sources and improved upon). Planning interventions should be aimed at mitigating the adverse effects of Urban flooding by addressing the factors which can otherwise be solved at root cause level.

III. IMPACT OF FLOODS ON THE URBAN ENVIRONMENT OF INDIAN CITIES

Urban floods have extensive effects especially as far as economic losses both direct and indirect. Flood risk is a component of exposure of the population and the economic activities alongside the vulnerability of social and economic components. The effect of such floods on the lives and livelihoods of individuals, a component of their vulnerability, should be comprehended [23].

An estimate by the Central Water Commission (CWC) states that 12% of India's available land surface is prone to floods. Flood losses accounted up to 0.86% of the total national GDP of the country in the 70s and 80s. The present decadal share of these losses has gone down to 0.1% of the National GDP. Considering that the Indian economy has grown a lot, the losses are huge in absolute numbers. Hence the government agencies should take long-term concrete measures to prevent recurrent floods [21].

The damages caused by the urban flood can be direct or indirect and can be broadly categorised as tangible and intangible losses.

A. Tangible losses

The losses that can be measured physically and can be assigned an economic value. These losses can be direct or indirect

- Direct - Structural damage to buildings, property damage, damage to infrastructure
- Indirect - Economic losses, Traffic disruption, and emergency costs

Flood damages the structural integrity of the buildings in an affected area, if the inundations last for a longer period. Buildings along the riverbed or the sloped are subjected to damage because of soil erosion weakening the basement. Small huts and temporary structures may get washed away. Croplands, shops, and industries get damaged heavily due to floods, especially warehouses [24]. These losses are not just momentary; the increased demand for the goods after the floods coupled with low production increases the prices of such goods and commodities. Physical infrastructure facilities get damaged during a flood. Electricity and water supply lines get affected which in turn hinders the communication network and media transmission gets hampered. Fire breakouts due to short circuits are common during inundations [25].

Urban Floods results in inundation of storm water on railway tracks, roads, underground metro lines, and even runways at airports when the level of precipitation is low compared to the city's drainage capacity. This causes hindrances in the traffic movement of goods, services, and people. Educational services, industries, and the service industry get heavily disrupted when transportation gets affected. Sometimes people may even get stranded for days without even access to basic amenities such as food and water. If the rainfall is substantial, even air rescue operations might be impossible.

The cost incurred by the government agencies and the public to rebuild after a disaster is generally very high. Some businesses may even go bankrupt. All the losses in cumulation reduce the Gross Domestic Product of the state and in turn the country. Urban floods have been attributed to be one of the costliest types of disasters to recover from [3].

B. Intangible losses

Intangible losses include loss of life, secondary health effects, and infections or damages to the environment which are difficult to assess in monetary terms since they are not traded.

- Direct - casualties, Health effects, ecological losses
- Indirect – post-flood recovery process, mental damage to the people

Urban floods are often associated with loss of life and physical injury either directly due to the effect of floods or indirectly due to infections by water-borne diseases spreading during the inundated period. Loss of shelter and relative creates emotional turmoil in the mental health of the stranded. These damages can be long-lasting psychological trauma. The ecological losses include trees and plants being washed away during an extreme flood event. Sewage and solid waste being washed into houses and neighbourhood create a huge array of issues like disease outbreak, economic losses to the households. The recovery process in case of such incidents is a tiresome process and time-consuming.

Removal of the population in low lying regions and crumbled structures, for the most part, meets firm opposition. An interruption in the supply of necessary wares incorporating power requirements results in agitation [26]. Because of traffic interruption, disposal of wastes gets hampered and water bodies get polluted. Gathering of waste at dustbins, the stagnation of stormwater in the localities, and contamination of consumable water – leads to various health problems resulting in plagues/epidemics. Mishaps because of pits kept open, covered up sewer vents under amassed inundations adds to issue. The upset in traffic hinders the timely provision of medicinal help [27].

IV. ROLE OF URBANIZATION IN INCREASING THE VULNERABILITY TO URBAN FLOODS

Urban flooding can be caused by either natural factors such as climate change or hydrological events and

human interventions, or a combination of these. But in the case of recurrent floods, it is a man-made disaster caused by rapid urbanization. The level of damage and vulnerability of an urban area is directly proportional to the density of development in that settlement. Overburdened drainage infrastructure, unregulated, and unplanned construction without regards to the hydrology, topography, and geomorphology in an urban area increases the flood risk [13, 15].

Metro cities of India have reached a saturation point in terms of both population and physical growth. The total share of population living in urban areas was 27% in 2001 and grew to 31% in 2011, and is projected to be 50% by the end of 2050 [28]. With no vacant land available to expand, new developments have started to shift to the low-lying areas and wetlands. Squatter settlements and slums start developing in the buffer zones of nullahs and railway lines. These areas are the first to get affected in case of an unforeseen amount of precipitation.

Example: Yamuna pushta area, Delhi – Slum areas getting flooded every year. Chennai International Airport – Built over the flood plains of Adayar river, Mithi river basin, Mumbai – 70% occupancy by slums and pavement dwellers [29].

Urban flooding is differed significantly from flooding in rural areas. As the city gets urbanized, the risk of urban floods increases by up to 3 times. Due to faster flow times, peak flows result in inundations in a matter of minutes. In the densely population residential clusters, the number of people affected is huge and heavy losses to industry and commerce in terms of infrastructure and economic value. The losses can be reduced by measures like providing alternative storm water drainage path, maintaining existing channels, reducing impervious surface to allow better rainwater infiltration, keeping the drainage systems free of pollutants and solid waste, etc.

The Center for Science and Environment's report on the state of urban water bodies of Indian cities, outline the fact that urban water bodies have been exploited for the past two decades. This is a result of urbanization without monitoring in India. Major threats to the surface area of water bodies by the rapid urbanization are "urban sprawl, encroachment upon waterbodies, unplanned tourism activities, solid waste and sewage disposal, the decline of groundwater and soil moisture leading to the low water level on the lakes and the lack of proper maintenance and monitoring.

Analyzing the Table 1, it can be observed in general that the number of Urban flood events is more in the coastal and delta settlements compared to that of the landlocked towns, even when the percent loss of spread area of water bodies is more. This can be attributed to the topography of the settlements and their height from mean sea level. In the case of delta towns, during monsoon storm water from the whole mainland gets drained into the rivers which when flooded, both tangible and intangible losses are multiplied.

V. LACUNAS IN EXISTING PLANNING LEGISLATION RELATED TO URBAN FLOODING

As a part of its responsibilities, an effort has been made by National Disaster Management Authority (NDMA) in preparing the National Guidelines on Management of Urban Flooding. Proper attention was not given to prepare and plan guidelines to deal with urban flooding, even though it is recurrent over the past few decades in India. The past strategies on flood risk management were mainly focused on riverine floods which affect rural areas to a great extent. The eye-opening event for NDMA was the floods in the month of July 2005 in Mumbai. The causes inundations were unique and so are the interventions required to deal with them, The problem and the scale of urban flooding were finally addressed by NDMA, considering it a separate disaster [3].

Table 2: Loss of water bodies and the number of major flood events in various Indian cities

Type of settlement	City	Projected population 2021 (in millions)	No.of major flood events	Loss of water-bodies due to urbaniz-ation (%)
Hill towns	Srinagar	3.00	2	50
	Guwahati	2.30	5	60
Land locked	Delhi	24.40	3	62
	Ghaziabad	3.24	1	75
	Udaipur	1.08	2	50
	Lucknow	4.50	4	46
	Bhopal	3.35	1	29
	Raipur	0.56	1	80
	Hyderabad	9.90	5	10
	Bengaluru	10.60	4	79
	Kolhapur	0.82	2	75
Coast-al/ Delta settlem-ents	Thiruvana-nthapuram	1.03	7	50
	Chennai	11.20	7	50
	Mumbai	28.60	9	25
	Surat	6.40	4	95
	Kolkata	22.30	5	45
	Ahmeda-bad	8.50	7	47

In collaboration with the Ministry of Finance (MoF) and the Planning Commission NDMA, for adherence to safe sitting and disaster-resilient technology - appropriate mechanisms have been laid out for monitoring all new infrastructure and construction related projects. The project information formats of Detailed Project Report (DPR) and the Expenditure Finance Committee (EFC) have been revised accordingly. The Central Ministries have been issued instructions regarding these by the MoF in June 2009. To prevent the delay in implementation of the projects, self-certification process is advised to be adapted. All ongoing and new projects will be addressed with disaster management concerns, while review of the existing infrastructure for necessary mitigation measures is to be carried out. NDMA mandates the States to prepare and implement disaster management plans and monitor the projects/programmes on a regular basis [3].

- The preliminary work of Mapping and documentation of the surface water bodies even though mentioned in NDMA under the National Database for Mapping Attributes – NUIS, has not been mentioned in most of the Disaster mitigation plans prepared by the SDMAs. This work has been initiated under the AMRUT scheme at the urban local body level, but absent for rural and peri-urban areas.
- During floods of Uttarakhand in 2013, there were questions about the role of NDMA, where it failed to implement the early warning systems to inform people about the floods and landslides. The post-disaster relief response had been equally poor. Though IMD released rainfall predictions, the poor planning, unfinished projects for flood and landslide mitigation of NDMA and SDMA that lead to the disaster getting worse [22].
- In the states of Assam, north Bihar and eastern Uttar Pradesh, there were huge delays in implementation of schemes and river management works which were supposed to provide long-term solutions for floods.
- The importance of preparedness for the disaster situation like urban floods was realized by the government agencies only after the devastations during Chennai Floods in 2015 and Kerala Floods in 2018, till then the government's approach was towards response rather than mitigation. CAG termed it to be a "man-made disaster" and holds the Tamilnadu government responsible for the catastrophe [20].
- Sufficient training, equipment, and facilities for immediate response and to tackle the disaster situation efficiently is not being carried out by the local governments [31] .
- Misutilization of Funds- National Disaster Response Fund and State Disaster Response Fund constituted by the government to deal with the disasters, were used for expenses that were not sanctioned for disaster management. There were cases of financial indiscipline in state management of funds. where there were delays in releasing the funds thereby delaying the projects. Some States did not invest the allotted funds, incurring huge losses in interests [20].
- Operational guidelines were not framed to integrate urban flood management into development. The problem of recurrent floods can only be solved by evolving the Policy guidelines at the macro level dynamically in coordination with all the other departments required to develop disaster-resilient infrastructure through proper investment in research and development.
- Guidelines for source control options for reducing surface runoff and their method of implementation has not been talked about in detail in NDMA's document. Hence there was no mention of these in the disaster management plans prepared by different states.
- Framework for real time flood warning, water level monitoring systems has not been devised for installation in all urban areas susceptible to flooding.

VI. WAY FORWARD FOR MITIGATING URBAN FLOOD IN INDIAN CITIES

After intense rainfall when the city floods, the major hit areas include difficulty in the transportation of goods and services, breakdown in the public service sector, schools closing, etc., These factors bring life in the city to a standstill. Understanding who gets hit worse and how will provide a better way towards a flood resilient future? [30].

Floods in Urban India are a result of both natural and manmade factors. Hence comprehensive urban planning which reconciles both environment and economic needs is required. Mitigation and rehabilitation measures should be the main focal area in solving the problem of recurrent floods.

- Maintaining a record of all the water bodies and wetlands at city and village levels.
- Catchment areas of Rivers, lakes and other water channels have to be brought under protected areas and included in city development rules.
- Planning guidelines with sufficient weightage to topography, drainage, rainfall, lithology with improved storm water disposal system.
- In the case of newer developments, urban water problems should be studied in union with all the planned and unplanned change in land-use, and application of planning strategies.
- Flood vulnerability mapping should be the primary step involved in risk reduction. Identification of the vulnerable areas can be done by analysing topography and historical data of inundations – extent and duration.
- The flood pattern at least for the past five years has to be studied using hydraulic and hydrological models. The results can be used to guide strategic planning.
- Watershed management: De-silting, timely cleaning and deepening of drainage channels have to be taken up along the whole river basin instead of just the urban areas. Catchment areas of water bodies need to be maintained well and should be free from encroachment and pollution, thus keeping the course of water free from obstructions [32].
- Construction of Flood walls, raised platforms along flood prone river basin and coastal areas. For mitigating floods town protection works must be implemented with proper monitoring.
- Public facilities like hospitals and schools should be

relocated from such areas. Critical emergency and livelihood services such as food, water, health and sanitation should be made disaster resilient. They should be located such that they are able to function without hindrance during inundations.

- The damage in a vulnerable area is directly proportional to the density of development and population. Encroachments should be relocated to sites where the flood risk is low. No development zones should be marked out in the flood prone low-lying areas. Such areas should be the primary concern for response during a monsoon.
- Strict control on the land use will reduce the tangible and intangible losses, especially in hill towns, coastal towns and flood plain areas.
- Protecting the existing green cover, Reforestation, and removal of debris from catchment areas could help prevent soil erosion, which might further damage the resources of an urban settlement.
- The amount of runoff can be reduced by reducing the area of hard surfaces and providing more green cover, conservation of water bodies and rainwater harvesting from built spaces. Measures such as rain gardens, green roofs, bio-retention swales, artificial ponds and underground storage sumps can also enhance percolation and reduce runoff. Current guidelines have to be revised to drain runoff from up to 1:30 year per day rainfall, as opposed to the existing 1:10.
- Floods can be diverted through measures like construction of embankments, levees and dams etc.
- River-front water development plans help the primary and secondary stakeholders manage flood control plans more efficiently and create awareness about the benefits of maintaining a water resource.
- Awareness to be created about flood preparedness and mitigation measures along with response drills. People participation from all economic classes in the decision-making processes for flood reduction policies should happen with experts on a regular basis.

VII. CONCLUSION

The major part of the study focuses on identifying the drivers that cause inundations in an Urban area in relation to the rapid pace of urbanization in India. Urban flooding is caused mostly due to human interventions than by natural causes. Even though changing climate has a huge role to play in increasing the hazard, climate change is an indirect result of man destroying the environment. It has been observed that due to population expansion and change in land use types, a large increase in surface runoff can be induced. Analysing the causes, it has been observed that the main focus for urban flood mitigation should be runoff reduction and keeping the flood plains free from obstruction. The loss of surface water bodies is directly linked to increasing the vulnerability of the settlement, as it gets more urbanized. To make better planning decisions, policymakers need to understand the sensitivity of the natural drainage pattern and topography. Assessing the current and future urban drainage in coping with the increasing risk of urban floods created by regional and local factors should be the primary concern. The impacts of urban flooding can be minimized only by making changes to the way we plan our cities.

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