International Journal of Applied and Natural Sciences (IJANS)
ISSN (P): 2319–4014; ISSN (E): 2319–4022
Vol. 13, Issue 2, Jul–Dec 2024; 17–42

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

RECOMMENDATIONS FOR A PROACTIVE FLOOD POLICY IN AHMEDABAD

Nikita Patel[1] & Rohan Thakker[2]

[1]Department of Environmental Studies, North Eastern Hill University, Meghalaya

[2]Department of Botany, Bioinformatics & Climate Change Impacts Management, Gujarat University, India

ABSTRACT

Ahmedabad is one of the fastest growing cities in the world. People migrate from remote areas and other cities for better prospects to Ahmedabad. Flooding and water logged roads is a common sight during the monsoons. Lack of proactive approach of Ahmedabad Municipal Corporation and brainless resurfacing of the roads is causing loss of property to people during normal monsoons and floods. The blocking of storm water drains happens due to improper solid waste management and lack of cleanliness on the roads. We believe that Urban Flooding is not a natural disaster but a political issue. We believe that the issue of pull migration and push migration can be resolved by constructing urban infrastructure between multiple small towns in regions like Saurastra and Kachchh. In this paper we have discussed the policy points which can really reduce the threat of urban flooding in Ahmedabad. The Budget is not a constraint for Ahmedabad Municipal Corporation as the budget figure of Ahmedabad Municipal Corporation is 8807 crore rupees for the year 2022-23.

***KEYWORDS**: Ahmedabad, Resurfacing, Single Contractor Policy.*

Article History

***Received:** 19 Dec 2024 | **Revised:** 21 Dec 2024 | **Accepted:** 26 Dec 2024*

INTRODUCTION

Urban floods are increasingly frequent and damaging environmental disastersacross the globe (Dewan & Yamaguchi 2009). In general, we can say that flooding is too much water in the wrong place and also it is considered a natural event or occurrence which occurs fast and disappears quickly or sometimes will take a longer time to build and discharge as defined by Kapinga, (2020).

Also, Gupta (2016) mentioned here that there has been a spike in the number of urban flood events across the globe. In August of 2017, South Asia, Nigeria, Sierra and U.S witnessed unprecedented levels of urban floods in the cities. This included cities like Houston, Bangkok on the global scale to Mumbai, Bangalore, Chennai, and Hyderabad at the national as followed by (Gupta, 2016).

Here, National disaster management guidelines describes that there has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Guwahati and Delhi in 2010. Also, Goswami *et al.*

(2006) and Rajeevan *et al.* (2008) adds that the consecutive flash floods over three major metro cities in the same year, i.e., Mumbai in July 2005, Chennai in October 2005 and again in December 2005 and Bangalore in October 2005 caused heavy damages in economy, loss of life, etc. some of the recent studies on extreme rainfall events over India were mostly concentrated in central India. Some Large scale floods in Uttarakhand and Kashmir 2013, Chennai deluge 2015 and Assam and Madhya Pradesh in 2016, Mumbai floods 2017 (NDMA, 2010).

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 areas, and less infiltration and greater surface runoff, change in topographical and drainage profile, increasing the flow of water in proportion to the urbanization rate as mentioned by Vazhuthi & Kumar (2020). In many developing regions of the world, this urban expansion and development lacks proper urban and regional planning and has led to large concentrations of substandard housing settlements with inadequate water, sanitation, and drainage infrastructure (Akanda & Hossain, 2012). As a result, a large portion of the world's urban dwellers has become vulnerable to natural disasters, especially during floods as followed by Farah, N. (2018).

Here, Dawson et al. (2008)adds for the period with changing climate that it impacts on both precipitation patterns and urban drainage will occur.Also, Dasgupta et al. (2015) says that urban flooding from intense rainfall is a recurring phenomenon that adversely affects life and livelihoods. Rapid and indiscriminate urbanization has aggravated the problem, contributing to the gradual filling up of low-lying flood plains, rivers, canals, and other water bodies that used to drain or retain water during heavy rainfall events.According to theReport of Government U.K. Foresight Future Flooding, (2004) Increasing total rainfall and rainfall intensity will result in a greater load on the drainage and sewerage systems. In addition, improper maintenance, aging etc. causes many problems (UK, 2004). Changes in land use in many of these emerging megacities have exacerbated hydrological processes and resulting flood events according to Ali *et al.,* 2011.

Also,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 as added by (Weber, A., 2019). Further, the definition can be separated into three individualcomponents: 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 (Prathipati et al. (2019) and NDMA (2010).

Cities are usually planned according to transport needs and generation of economy and it is often much later that issue of environment and natural systems are addressed. This approach needs to be rectified in order to save our cities from getting into a pattern of development that can cause increased environmental damage. Adding to the impact of uncontrolled urbanization are the factors of climate change and increasing amount of natural disasters (Kollarath & Sheriff, 2019).

Among the important cities of India, the average annual rainfall varies from 2932 mm in Goa and 2401 mm in Mumbai on the higher side, to 669 mm in Jaipur on the lower side. The rainfall pattern and temporal duration is almost

similar in all these cities, which receive the maximum rainfall from the south-west monsoons. The average rainfall for the month of July in Mumbai is 868 mm and this far exceeds the annual average rainfall of 611 mm in London (NDMA, 2010). Urban flooding which is a result of increase of impervious surfaces is another major concern in Bangalore. Unplanned urbanization has significantly changed the nature of catchment areas. This in turn increases the quantity and speed of surface runoff and results in the phenomenon of flooding in urban areas. India has been one of the countries facing extreme rainfall events in the recent years such as the floods which recently affected the entire state of Kerala in 2018 as well annual instances of flooding occurring in major metropolises such as Chennai and Mumbai (Kollarath & Sheriff, 2019).

Here, as per the mentions that more than half of the world population lives in urban areas, and this is an increasing trend and Consequently, more people, assets, facilities, and goods are concentrated in cities and exposed to floods by Barbaro et al. (2021).Flooding in urban areas is on the rise as a result of increasing watershed urbanization. As people migrate to urban centers this creates a compounded effect where the need for housing and the expansion of the physical work place to accommodate new jobs forces cities to develop beyond sustainable development levels (Biemer and Schardein Jr. 1998; Cohen 2006).The population pressures which have resulted in the encroachment of floodplains and unplanned urbanization is a major reason for urban floods (Kollarath & Sheriff, 2019). Lack of proper solid waste management and illegal dumping of bigger populations also decrease the drainage capacity of natural canals. Land subsidence is also increasing at alarming rates in many megacities due to the unplanned extraction of groundwater (The World Bank, 2011).

Economic betterment is the root cause of the global phenomenon of rural to urban migration (Cohen, 2003). This mass movement of populations has been a vital part of the urbanization process from ancient times and continues till now (Lall, Selod, & Shalizi, 2006). Accepting the challenges of accommodating the increased population as part of the global urbanization process, cities are turning to megacities. A strong association is seen between population growth and land cover change (Dewan & Yamaguchi, 2009) while this urban expansion and growth lacks proper planning in necessary infrastructural development (Akanda & Hossain, 2012).Accelerated urbanization poses challenges for cities to keep pace with expanding utilities and urban services (Cohen 2006) such as water and sewer as fast as developers can build them.

Cities like Chennai, Mumbai, Kolkata, Delhi, are already over-populated now. On the other side, Bangluru, Hyderabad and Ahmedabad like cities have also joined the race. The vicious cycle of development of "urban infrastructure" in already over populated cities is attracting more people from rural areas to urban areas who are looking to get settled. Overpopulated cities need infrastructure and better infrastructure attracts more people! The urban infrastructure projects like Metro Rail, Bus Rapid Transit System (BRTS), and Ahmedabad-Mumbai High speed Rail Corridor, Colleges, Universities and Better Medical Facilities is attracting more and more people every year to Ahmedabad. As a result Ahmedabad and Gandhinagar are becoming twin cities now. Hence, it is very hard to provide clean civic amenities with multiple contractors. The amenities are constructed to fulfill the immediate need of the cities with no long term vision. And as the population increases the amenities like roads, sever lines and storm water drainage lines requires an upgradation. 'Lack of coordination' between the agencies and malpractices by contractor's results in uneven levels (impervious surfaces) of roads in the city.

Urban flooding research has been an expanding field as a result of an increase in urban flooding events in cities due to the costs incurred from flood clean up (Hsu, Chen, and Chang 2000; Mark et al. 2004; Schmitt, Thomas, and Ettrich

2004). As cities become more urbanized and the sewer networks expanded urban flooding research is essential to urban planners to help mitigate the costs of urban flooding and help develop sustainable urban planning methods that could help reduce the negative impacts on local ecosystem (Paul and Meyer 2001).

In this paper, thepolicy advises has been given for Ahmedabad citywhereurban flooding is slowly becoming a major issue due to improper management and increasing migration. This paper aims to highlight the main issues of urban flooding in local areas which is not only the rainfall and climate change, it also based on the human factors which needs to be managed in proper ways.

Many researchers have published their research work on urban flooding and we review some of such publications with the focus on causes and attempts to establish a direct link with floods. This paper will argue that although the role of climate change in the increased incidence of floods is not very clear based on present records (Z. Kundzewicz et al., 2012a), there is a possibility for climate change to worsen the issue. This paper takes the position that popular use of engineering approach alone to address flooding issues in urban areas in developing countries are the only sustainable and adaptive approach and is indeed an immediate solution.

Sustainable Development Goals

The programme established by the United Nations, known as Sustainable Development Goals or SDGs, are a set of 17 goals which pledge to “Leave no one behind”. These goals and their targets were formed in the year 2015, which have detailed focus to deal with threats of climate change and reduce its impacts. Further, these goals could be achieved through continuous resource management, which results in helping the economies to prosper and create peace and equality. These 17 goals have indicators that a particular goal focuses on, more importantly, all the goals are interconnected that shows the completeness of the steps taken for a change (UNDP, 2020b).

SDG11: Sustainable Cities and Communities

- The SDG-11 focuses on Making cities and human settlements inclusive, safe, resilient and sustainable. It focuses on making the cities resilient to the extreme events arising due to climate change. This paper is about improving the basic infrastructure and mismanagement which causes urban flooding.

SDG13: Climate Action

- The SDG-13 focuses on Taking urgent action to combat climate change and its impacts. Our paper also focuses on improvement in the impervious surfaces and basic civic amenities so that the flood waters reach the nearby rivers.

SDG15: Life on Land

SDG-15 focuses on Protecting, restoration and promotes sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. The resurfacing and relaying of roads increases the heights of the roads making cities impervious. The Concrete stones or grit stones which are used in resurfacing of the roads come from mining in the mountains. Road resurfacing is actually causing destruction of mountain ecosystems. So, here addition of SDG 15 is only to highlight the issue that we are losing our mountainous ecosystems because of resurfacing of roads. The process of urbanization itself increases the total amount of impervious surfaces such as asphalt, concrete, structures and buildings. Most urban surfaces produce an increased amount of surface water runoff by reducing rate of infiltration as compared to other surface materials such as soil, grass, and other naturally

occurring surfaces and materials (Espey. Morgan, and Masch 1966; Arnold, Boison, and Patton 1982; Brabec, Schulte and Richards 2002).

FOCUSING ON STUDY AREA

Ahmedabad is the largest and most populous city of Gujarat and located at 23.03° N 72.58° E in north-central Gujarat at the banks of Sabarmati River and covers 505 km2 areas. The average elevation of the city is 53 meter (174 ft. above sea level). The Ahmedabad is divided by the two physically distinct eastern and western regions. It is divided into 9 zones central, east, north, north-west, south, southwest, west zone (solanki & bhavsar, 2023). With the inclusion of Gajjar *et al.,* 2021 that the city has witnessed many phases of development in over 600 years of its existence. The core area showcases a vibrant living heritage built form with the reminiscence of the fortified city. The strategic location and better connectivity with other parts of the states open door for the migration towards the city. Post- independence the river banks became sites for squatter settlements and slums and the city's sewage often overflowed into the river. But the major problem was the seasonal flooding that created chaos for the city and particularly for the slums, Patel said.

As following to the Gajjar et al., 2021, he also mentioned that the city has gone through the transformation of land-use change with the growing demand of population and migration pattern from rural to urban setup. The gradual inclusion of fringe areas in the city administrative boundary required authority to prepare new development plans. This development plan process focused for physical land-use planning reflecting the advantages as well as disadvantages (Gajjar et al., 2021). The average annual rainfall of Ahmedabad is about 782 mm, yet there is a considerable variation every year. The Monsoon occurs generally during the months from June to September. The average humidity is about 60 % with a maximum of 80% to 90% during the rainy season. Also, Solanki & bhavsar (2023) mentioned that the city is on flat terrain and western zone contains some low lying area as well so water logging problems are happen during monsoon. Change of land use is not only a physical process of transforming one land use to another but also is linked to the alteration of the social, political, economic, and cultural orientation of any society (Pangaribowo, 2018).

AHM- Background Study

Ahmedabad is the first heritage city of the country and one of the smart cities of India. This city was founded on 26th February, 1411**.** Walled city Ahmedabad is a hilly area as per the geographical situation. At that time, when the city of Ahmedabad was established, canals were built for the drainage of rainwater in the city, which are still in operation today. About 15 to 18 canals in the old city area are directly connected to the Sabarmati river, the rainwater gets quickly disposed off. The rain drainage system was built during the British era and is still functioning today. Old Ahmedabad city is rich with a pol system; all the pols have wells to collect rainwater. The rainwater goes directly into the well. Even today, most households in the old city have a percolating well for underground water storage.

According to some reports the sewage and drainage systems of the walled city of Ahmedabad were established as early as the 1880s. The city until then also had surface drainage based on terrain slopes. The traditional street patterns were laid as per slopes on the eastern bank of the river. Due to good gradient till date dependency on pumping is low while the flows are well managed by natural slopes. New drainage and sewer systems follow roads which do not necessarily follow the slopes.

Rao Bahadur Ranchodlal Chotalal, the first Bhartiya president of the municipality, initiated this work. Around 1885-86, engineers from Britain as well as locals were involved in the first blueprints and laying the network. Apart from

natural terrain, the generous size and custom-made design of the network in the walled city areas is very robust and makes it safe against clogging.

A city develops gradually, but planning should be done to avoid civic issues. It is the duty and work of urban planners to do mapping for gutter lines and social mapping of the city properly. Its corporation's engineering department's duty is to work comprehensively in recognising topography and elevations of different areas. The city's lakes play an important role in water drainage and the AMC should utilize the more than 50 lakes that the city has, they work as a sponge city.

This city was founded on 26th February, 1411; the drainage system is as old as this city. People have not faced such issues for 611 years. Gravitational slopes are used as roads and houses are built on the sides. The old city has sewage hollow poles with arrows that show us the underground sewers are draining in which directions. These poles also help to detox the toxic fuels.

But now in monsoon times, developed Ahmedabad city faces severe water-logging issues; the city suffers water-clogging for more than 12 hours even after 3 to 4 inches of rain. On the other side, the old streets of heritage city Ahmedabad clear within half an hour even after heavy rain.

Lakes & Ponds of Ahmedabad

As Asaval was a historic settlement adjacent to the Sabarmati River (Shastri, 1964). Sabarmati was a seasonal river and could not be depended upon for year - round needs. Hence, the city planning historically incorporated water at the center of development in the form of Vavs. The old houses in the city used Tankas or underground tanks to collect rainwater from the roof. All around the Ahmedabad region, there were Tekros or higher mounds where settlements were present and Talavadis or ponds were generally located near these settlements (Tayyibji, 2016). The ponds of Ahmedabad were linked through open channels and collected rainwater from catchment areas. There is no dependence on conventional mechanisms of Talavadis, vavs, and Tankas today. Gradually, the sustainable practices of rainwater harvesting and stormwater management decreased and are of no use today.

In 1999, AUDA identified 630 lakes in its jurisdiction of which 79 lakes were notified as urban lakes (Bal et al., 2011). Due to rapid and uncoordinated urbanization, lakes are being engulfed by cities in Ahmedabad and the number of lakes has reduced from 630 to 122 over years the period of 20 years (Desai, 2020).

However, Reddy & Char, (2006) says that in Ahmedabad, since several water bodies are shallow and did not retain natural water for 10 years, they got excluded from being called a lake. And as they were not designated as lakes, the area was open for development and construction. The lake of Jodhpur village doesn't exist today and is one such example which has been completely filled up and construction has been done by the authorities.

The lakes of Ahmedabad usually become dry due to loss of catchment and disruption in their hydrological cycle. Three important points should be considered while gathering information about loss of water bodies in Ahmedabad viz. – i) appropriation of lake land for other purposes by the authorities; ii) grant of Building Permission under TP Scheme by the authorities itself; and iii) growth of Informal Settlements on the lake lands by poor.

Some observations and points considered on case to case basis are:

- The neighborhood center at Ghatlodiya; waterworks and garden at Vasna later developed as EWS housing; E.W.S. housing proposed and later developed as Ahmedabad Haat at Bodakdev were partially or completely built over a water body (TPVD, 2020).
- Multistoried apartments and other structures were constructed on the lake land in Ghatlodiya under (T.P.S. Ghatlodiya 2) and at Champal Talavadi under (T.P.S. Naroda 1).
- The lakes of Vasna, Chandola, Vastrapur, Memnagar, Thaltej, Isanpur and Asarwa were all infringed upon by informal settlements. The Lakhudi Talavadi in Navrangpura had been completely encroached upon by slums. The land had been earmarked as a garden and playground in the earlier Town - Planning Scheme (J.S. Rajpurohit vs. State of Gujarat, 2014).

On the other hand the city faces the issues of climate change, increasing temperatures, urban water clogging, wastewater management, water pollution, etc. To address these issues, the local government authority has come up with an initiative of interlinking lakes in the city in 2004 (Anand, 2014).

Under this initiative, 44 lakes in western Ahmedabad were identified for development with the provision of interlinking, out of which, 8 lakes were interconnected in the first phase. The planning approach of interlinking lakes is a techno-planning solution to the urban waterclogging issue (Anand, 2014). The lakes were connected through an underground laid piped network to increase the catchment of stormwater and decrease water logging in urban areas and the linked network has an outflow in the Sabarmati River. Neighbourhoods that were vulnerable to urban flooding before 2004 have reportedly reduced after increasing the catchment area of stormwater flowing into the interlinked lakes (Anand, (2014), AMC, (2021)).

AUDA had envisioned the project to solve the dual water-related issues of Western Ahmedabad - flooding and water security (Patel S., 2020). The project's vision was also to leverage development in the region and develop the city as a 'Lake City' with vibrant public spaces around lakes for enhanced livability (Thakker, 2020).

Three objectives were defined for the project: i) to resolve the issues of waterlogging and strengthen flood resilience through lake interlinking; ii) to ensure water security for Western Ahmedabad through lake rejuvenation and groundwater recharge, and iii) to improve the livability or quality of life of Western Ahmedabad through the creation of green and recreational spaces s (AUDA, 2020) (Jagani, 2004) (Bal, Anthonie, & Jaap, 2011) (Thakker, 2020).

The project had two major components - Lake Redevelopment and Lake Interlinking. The interventions were to be implemented either on the lake land or in its vicinity. The interventions included - development of sewerage network in the lake vicinity; construction of public toilets and water standposts; development of the stormwater network in the lake vicinity; construction and widening of roads according to the TPS in lake precincts; rehabilitation and resettlement of informal settlements; reclamation of land for recreational purposes; deepening and desilting of lakes; construction of percolation wells; architectural landscape & development of recreational spaces and dry season recharge with Narmada water (AUDA, 2020). The Interlinking of Lakes is aimed at harnessing the combined potential of the lakes as a collective system for water augmentation and flood mitigation (Thakker, 2020).

However, water experts have criticized the approach as it involves unsustainable practices like altering the natural lake edge, using materials like concrete, land grabbing around the lake for recreational activities, etc. (Desai, 2020).

But even after the linking of lakes to the river the problem of urban flooding is not solved and by redeveloping the lakes with cements, it's the wrong practice. Earlier the lakes were characterized by its vast open spaces and the sandy soil which absorbed the rainfalls but now it has been replaced by cemented layers. The walls constructed around the lakes after redevelopment dosent allow the water from the roads to enter the lakes. The same issue is with the river fron constructed on the Sabarmati River; that is the water from the streets doesn't enter the river directly.

RESULTS & DISCUSSION

We believe that migration from rural areas to urban areas is a major cause of unplanned development. Corruption is another major issue which results in mindless resurfacing and aggradation of the roads. The construction of Compound walls and dividers stops the natural flow of water towards the rivers and lakes. There are many judgments of courts which are against resurfacing of the roads without scrapping the upper layer of a road. The contractors and corporations do not follow the guidelines of Indian Roads Congress and the judgments of the courts. Lack of proper cleanliness also causes localized flooding during the monsoons. We also believe that multi contractor policy is also a major cause of impervious surfaces in a city.

Migration

Pull Migration and Push Migration from Rural Areas to urban areas increases population in the Metro cities in India. Lack of good infrastructure projects in the remote places pushes people to settle in the urban cities like Ahmedabad for better facilities like healthcare, education and good life style which they do not get in remote places. These densely populated urban clusters push the government to construct more roads, bridges and metro rails which again pulls more population from rural areas to these urban clusters. It's a cycle. The migration waves will never stop if the government will not create new urban clusters in other parts of the state. In other words, the states in India need more metro cities or the government should start spending in the rural infrastructure sector.

Urbanization

Consequences of urbanization include the reduction in the infiltration element of the hydrologic cycle, which would increase the peak run-off discharge. Another concern of urbanization is the loss of many minor and medium wetlands. These wetlands worked as detention basins and resulted in decrease in the peak discharge. And hence it has reduced the detention effect.

Urbanization also results in channelization of drainage systems where previously natural drainage systems are made drainage efficient by concrete lining, forward "slopes made more uniform", curves and other obstructions removed to ensure a smooth and quick discharge of stormwater generated runoff (Liu, 2015; Raghunath, 2006) (Asiedu J.B., 2020).

"These changes" results in large volumes of stormwater runoff being generated (Raghunath, 2006), which the urban landscape is not able to contain, resulting in floods. (Asiedu J.B., 2020).

Unplanned growth and Failure of Infrastructure

We believe that the growth of the cities like Ahmedabad, Gandhinagar and adjoining areas is because of lack of urban infrastructure in the rural areas. Lack of uniform development policy of the towns in the state and lack of focus of administration on smaller towns and smaller cities pushes the people to migrate to better areas with better urban infrastructural facilities. It is actually impossible to predict the number of people migrating to a city plus the

mismanagement due to thousands of Contactors results in the failure of basic infrastructure. We also believe that small satellite towns like Mehsana Dhansura, Modasa, Talod, Himmatnagar, Viramgam, Dholka, Kapadvanj, Dehgam, Mansa, Prantij should be developed as smart towns and should be connected by high frequency urban transport infrastructure. These towns will help in easing the population density in Ahmedabad and Gandhinagar. These satellite towns can provide cheaper options of` housing to people who can travel to work in Ahmedabad. We believe that if there were more satellite towns around Mumbai which were connected by high frequency local trains then Dharavi would not have existed!

The "Compound Wall Effect"

As mentioned in the report of Chennai Floods 2015- A Rapid Assessment (2016), the compound walls and the road dividers restrict the natural flow of water in the cities. This accumulation of water due to compound walls is multiplied if the roads are elevated with chocked drainage inlets by debris or silt.

Plate 1

Figure 1

We can see in the above photographs that the drains got blocked because of resurfacing, and then in the monsoons the wall got damaged because of the water pressure from the other side.

Usually compound walls are built for safety in the cities around all the residential and commercial properties which restrict the natural flow of the water and causes water logging or Urban Flooding. These compound walls alter the local overland flow paths and sometimes even block the local channels because of inadequate provision of culverts. This in turn changes the local flooding pattern, protecting some areas while flooding the others. During major rainfall events many of these compound walls collapse because they are not usually designed to take water pressure from one side. In several cases, the compound wall and roads have affected the natural flow and the lack of adequate cross drainage has led too much of localized flooding and water logging, by Mujumdar, et al., (2016).

Road Elevation Issue and Road Resurfacing Policy

In any city of the world, roads act as a primary drainage. The water should always flow from the adjoining properties to the roads and from roads to the storm water drainage lines. The storm water drainage lines should be connected directly to a river or the nearby lakes. And hence the road levels should be below the properties adjoining a road. If the roads are elevated then the rain water will flow into the houses/flats and other properties adjoining a road. In Ahmedabad, due to resurfacing, the roads get elevated every year. As a result of it, the societies/flats/bungalows get flooded every year during the monsoons.

Plate 2

Figure 2

Road Resurfacing is a very important point in terms of urban flooding. It should be banned by the municipalities as it increases the height of the roads if the milling or scrapping of the upper layer of an existing road is not done. The corporations cannot expect the people to reconstruct their houses or properties from plinth level if it goes down the adjoining road due to resurfacing.

Problem with Drainage System

In recent times, floods have occurred in Greater Ahmedabad in 2001, 2003, 2005, 2006, 2008, 2010 and 2013 (solanki & bhavsar, 2023). The drainage system has been found wanting because of several reasons. These include: (i) reduction in the vent way caused by the construction of bridges, (ii) sand bar formation at the mouths of rivers, (iii) clogging of the drains due to indiscriminate dumping of solid waste and construction debris, (iv) inadequate design capacity, (v) lack of connectivity of storm sewers with macro drainage, and (vi) encroachments. While successive governments have focused on dredging of rivers and desilting of major drains, maintenance of minor drains is neglected due to scarcity of funds as well as public apathy. In this context it is important to bring out the effect of bad solid waste management on the condition of drainage channels, both major and minor (Mujumdar, et al., (2016)).

Plate 3

Figure 3

In the above photos we can clearly see the chocked drainage inlets and the resurfaced roads around the drainage inlets and broken inlets too.

Chocking of Drainage Lines by Sand/Mud/Silt

The roads of Ahmedabad are full of construction sand, mud and dust. Lack of focus of the authorities and mismanagement is the root cause of this silt which gets accumulated in the drainage lines. Corruption, Lack of coordination, lack of training of cleaning Personnel, lack of modern cleaning-equipments, primitive cleaning techniques is also responsible for the chocking of the drainage lines by silt. Because of Illegal encroachments and illegal constructions, the roads are not constructed wall to wall. Wall to wall road construction reduces the issue of silt on the roads. The roads should only be constructed after clearing the illegal encroachments and illegal constructions.

According to Jha, 2018, Incessant construction over the natural drainage pathways in the town without taking into account the soil type of the area has led to making once flood free zones into flood prone areas. Moreover, the improper and delay in linking the drainage systems plus the improper solid waste management combine to give clogged drains, accumulation of silt all increasing the water levels in the rivers.

Plate 4

Figure 4

Improper disposal of solid waste, including domestic, commercial and industrial waste and dumping of construction debris into the drains also contributes significantly to reducing their capacities (NDMA, 2010).

Plate 5

Figure 5

The cleaning of the silt before and during the monsoons is done by the workers but is not collected and transported to safer places. Instead it is kept by the workers lying on the roads which again gets mixed with rains and flows inside the drainage lines and chocks the same.

Improper or no Solid Waste Management

Improper solid Waste Management or lack of cleanliness of the streets chocks the Storm water drainage lines during the monsoons. Strict banning of single use plastic and single use paper cups and other single use disposables can be of a great help. Regular trimming of trees, Door to door waste collection, segregation of waste at source, proper manual and machine cleaning of the roads really reduce the threat of water logging in the monsoons. We also believe that the drainage lines should be designed such that they can be cleaned manually by just removing the lids or the covers.

Plate 6

Figure 6

We believe that the corporations should create guidelines for the required number of sweepers/cleaners per ten thousand or one lakh people residing in an area. The cleaning of the roads and solid waste management plus the capping of the existing dumping site should be done by a single company only. Complete privatization with single contractor policy is the only solution to the improper solid waste management.

Mixing of Solid Waste in Flood Waters Causing Blockage of Drains

The garbage collection in the city is done by Municipal Corporations in major areas. Lack of dustbins, lack of collection of waste and lack of civic sense compels people to throw their wastes anywhere. The ‘garbage heaps’ near the houses or besides the roads increases vulnerability to floods of the people in area when flood occurs as open garbage and sewage flows into the streets and inside houses.

Plate 7

Figure 7

Solid waste disposal and its proper management have significant effects on drainage performance. Most towns and cities have open surface drains besides the road, into which there is unauthorized public disposal of waste. Solid waste increases hydraulic roughness, causes blockage and generally reduces flow capacity. Besides, most of these drains carry large quantities of sewerage all year round, effectively resulting in decreased capacity being available for rain-water to flow. In addition, blocked drains may create insect breeding sites and encourage disease transmission. These drains need to be cleaned on a regular basis to permit free flow of water. There may also be instances of pipe bursts, etc. (NDMA, 2010).

Vector and Water Borne Diseases

As Waterlogging occurs during the monsoons also increases the health vulnerability of people in areas during monsoons. Drainage lines which exists but not in function become the breeding grounds for mosquitos during monsoons. Mixing of faecal matter in the flood water due to open defecation also increases a threat of diseases during the monsoons.

Multi Contractor Policy

Multi contract policy creates chaos in construction of urban infrastructure. If a road is constructed by a contractor and other contractor constructs the footpath, and a third contractor installs a storm water drainage line and the installation of light-poles is laid by some other contractor then there will be chaos and lack of coordination in the construction of roads and other such amenities. In our opinion, all the work should be given to a single company. The issue of coordination and liability is resolved if all the works are done by a single company. The Greenfield project of Dholera is one such example of Single Contract policy. According to the Website of Ahmedabad Municipal Corporation, there are 859 contractors registered with AMC. We believe that it is impossible to coordinate with multiple contractors and is the root cause of impervious surfaces.

https://ahmedabadcity.gov.in/portal/AppCmnAttachServlet?ActionFlag=ViewFromStoragePath&AttachID=5869

Other Issues

Potholes

Usually the corporations do resurfacing of the roads instead of doing patch work. People also like driving on resurfaced surfaces. Generally tenders are given to contractors who are lowest bidders. Bribes are also given to win tenders. To maximize profit, the contractors construct poor quality surfaces. These practices results in poor quality of roads. The contractors who are into resurfacing, also wants poor quality roads so that they get work of 'resurfacing'. It is a vicious circle. These practices causes increase in the height of the roads. Patch working jobs doesn't pays and is considered as a tedious job.

Loss of public and private property

Construction of poor quality roads by the contractors itself is a 'loss of public property'. The poor quality roads get washed away in the monsoons resulting in potholes. As a result, corporations do resurfacing of the roads post monsoons without scrapping of the top layer. The resurfacing practices results in increase in the height of the roads. During monsoons, because of these increased surfaces, it causes localized flooding resulting in loss of public and private property.

Traffic Jams

The water logged roads create long traffic jams. In our view, there must be a small design team of a single contractor which initially maps the drainage lines. The corporations should also use Digital Elevation models and map areas having water logging issues in the monsoons. The issue of water logging should be addressed by altering road designs by the contractor. Long traffic jams can easily be addressed if the construction of the roads is done smartly.

JUDGEMENTS

Judgment of Chennai High Court

In the case of D.Sridharan VS The Principal Secretary to Government, Municipal Administration and Water Supply Department, Secretariat, Chennai of the High court of Judicate at Madras dated 19/7/2019, the Honourable Justice S. Manikumar and the Honourable Justice Subramonium Prasad observed and stated that While re-laying the roads, it is quite essential that the road is in existence and damaged, should be scrapped (scrapping of the upper layer) and after the scrapping process, new upper surface should be laid. This would ensure that the road is laid evenly and survives for a

longer duration. According to the petitioner, this is the practice that is generally followed in different parts of the State of Tamil Nadu.

However, roads which are being re-laid by the respondents are increased in height by a minimum of 5 inches to 8 inches from their original height. It is submitted that increase in height is causing a serious concern to the petitioner and several other residents of this locality since the increase in height of the roads would result in the height of the roads to be higher than the houses and other constructions and sink, thereby causing difficulty of ingress and egress and also the risk of flooding during monsoon as the rain water would naturally enter the houses once their height becomes lower than the road. It is submitted that roads in this locality are not re-laid by following the established guidelines and the same is causing a huge hindrance to the residents of this locality.

R. Bala Chandar VS The Principal Secretary

In the case of R.Bala Chandar vs The Principal Secretary, on 9/3/2018, the honourable Court of Madras passed an order that before relaying the roads, the existing roads shall be scrapped and the height of the roads shall not be increased. The indiscriminate repair and relaying of roads without scrapping the existing roads has led to considerable increase in the height of roads, which, in turn, causes accumulation of water in nearby houses, with plinth level lower than the surface of the road. This causes inconvenience to house owners, who cannot be expected to raise the height of the plinth of their houses every time roads are relaid.

DISCUSSION

The debris and waste gets mixed in the first rains and enter into the drainage lines. It actually becomes difficult to clean the wet roads by the workers during monsoons if the roads are water logged. Water logging happens due to improper cleaning of the streets, compound walls, dividers and the resurfaced roads. Resurfacing without scrapping of the upper layer causes flooding. Poor quality roads constructed by multiple contractors causes potholes and gives a chance to these contractors for resurfacing of streets. These poor quality streets with potholes causes traffic jams in the water logged roads.

SUGGESTED INTERVENTIONS

Single Contractor Policy (SCP) and Urban Planning & Design Team

Single Contractor Policy (SCP) means the urban/city infrastructure is constructed by a single company instead of giving work to multiple contractors. SCP basically ensures easy coordination between many agencies. It ensures liability of the work done. It ensures a proper urban planning team which focuses on the issues and has permanent solutions.

In our opinion, the construction of city-infrastructure should be given to a single company. That company/contractor should have team of experts, urban planners, GIS specialists, Expert Surveyors or should have an experience in building a smart city in the past, like government is doing it in Dholera Greenfield smart city in Gujarat. The construction of Dholera has been given to Larsen & Toubro.

Banning Road Resurfacing (Without Milling)

Road resurfacing should be banned by the municipal corporations and Highway authorities. It actually increases the height of an existing road if the scrapping of the upper layer is not done. Ahmedabad has witnessed 3 to 5 feet of elevation at many places due to just resurfacing. Many old flats and societies have gone down from the road levels due to macro resurfacing of the roads. This creates issues with the existing/installed storm water drainage lines. And the rainwater flows

from the roads to the societies and adjoining properties. In fact Ahmedabad Municipal Corporation did not have a map of storm water drainage line while constructing BRTS corridor in the year 2009 and also bought metal detectors to locate gutter inlets covered by resurfaced roads and already installed drainage lines.

Localized flooding and water logging is quite common and widely prevalent every year, even during normal showers, due to aggradation of roads and lack of adequate cross drainage infrastructure. As per Indian Road Congress codes (IRC: 120-2015), the roads have to be milled before resurfacing. Although this is mandated by the corporation, this norm is usually flouted by the contractors and not strictly enforced.

All road re-levelling works or strengthening/overlay works will be carried out by milling the existing layers of the road and recycling of materials obtained as a result of the milling so that the road levels will be not be allowed to increase (NDMA, 2010).

Usage of Milling Machines

Milling Machines should be used before resurfacing of the roads. Resurfacing increases the height of the roads and hence urban flooding occurs. Scrapping of the upper layer of a bituminous road is important while resurfacing. A road milling machine helps in scraping the upper layer before constructing a new upper layer. This helps in maintaining the previous road levels and should be a standard practice. It is the duty of the Municipal Corporations to ensure that the road levels are always below the plinth levels of the adjacent properties. The rain water should not flow from roads to the adjacent properties.

Plate 8

Figure 8

Resurfacing policy actually promotes over mining of stone grits. Hence usage of milling machines reduces the issue of over mining for grit stones in the mountain regions. Usage of milling machines and reusing the same grit to construct the upper layer will reduce the mining activities resulting in saving the mountain ecosystems. We believe that mining for stone grit is a big environmental issue of the future. We advise the Corporations to adopt FDR technique in construction of the city roads. Full Depth Reclamation (FDR) is the method of recycling and is normally performed to a depth of 100 mm to 300 mm. The train of equipment consists of recycling machine hooked to a water tanker and steel drum roller with pad foot shell. The advantages of full depth reclamation are that most pavement distresses are treated, hauling costs are minimized, significant structural improvements can be made (especially in base), material disposal problems are eliminated, and ride quality is improved.

Preparation of Road Level Maps and Storm water Drainage Maps

In our opinion, a base year should be decided by the corporations to decide the road levels. Road level maps should be prepared by the corporations which should be kept for reference while construction of civic amenities and roads. In 2009, Ahmedabad Municipal Corporation bought metal detectors to find Manhole Covers which gets covered under the resurfaced roods. To solve this, Drainage maps should be prepared using mapping tools and mapping softwares. GIS and remote sensing techniques should be used to map such civic amenities. People can easily locate and open if there are Wall markings about such storm water lids/covers and can be of great help during monsoons. In our opinion, the corporations should use digital terrain models and Digital surface models. Storm water drainage Network maps should be created using GIS. Elevation of storm water drain, junctions and other appurtenances while construction of roads. Road and street networks along with their levels should be marked and the data of such levels should be considered every time a road is reconstructed. The corporations should do mapping of urban catch basins for each storm sewer and do wall markings to locate during heavy flooding. In our opinion the corporation should engage itself in the development of a local numerical Storm Water Management Model for Ahmedabad city instead of indulging itself in the coordination between the agencies. Flood plain modeling gives a clear idea about the flow of water during heavy rainy days or in heavy monsoon seasons. There must be constant upgradation of such flood plain models by GIS experts and it acts as an early warning system before an urban flood strikes a city.

Maintenance of Drainage System

One cannot over-emphasize the need for keeping all the storm water drains free from blockages due to indiscriminate dumping of solid waste into them. While keeping the major drains clean could be the responsibility of the urban local body, keeping the minor drains clean should be the responsibility of local population. It is not possible to make the entire drainage system work effectively, unless part of the ownership of the drainage system is taken by the local users. It may be worthwhile to encourage the formation of citizen groups which work in close coordination with government, as mentioned in the report of Chennai Floods 2015- A Rapid Assessment (2016).

Plate 9

Figure 9

The corporations and contractors should follow and adopt Indian Road Congress codes as best practices while construction of the civic amenities. IRC: 042-2014 is the basic guidelines for road drainage in India. The guidelines describes surface drainage, subsurface drainage, hydrological designs of roadside drains, hydraulic design of road drainage, roadside ditches and drains, cross drainage works and drainage of bridge deck and groundwater recharge from road drainage. We believe that guidelines are not followed because there are multiple contractors. Liability of following the IRC guidelines is fixed if there is a single company implementing it. IRC: 050-2013 is also very important in terms of Urban Drainage.

Intensive Rainfall

As described by Asiedu (2020), that overwhelmingly intense rainfall is recognized as the number one cause of floods but this can be turned into a resource in developing countries where the rate of urbanization has outstrip the capacity of city authorities to provide basic facilities like portable water. Rainwater harvesting for reuse either for irrigation or for none-portable household chores like washing, flashing of toilette could be a more sustainable alternative. (Asiedu J. B.)

Imperviousness

Here, some authors had mentioned it as, the contribution of imperviousness to increased runoff generation and eventually floods cannot be overstated. An intervention which therefore targets impervious surfaces, specifically at the plot level such as roofwater harvesting can be effective in controlling the situation. Roof water has been identified as contributing to stormwater runoff that accumulates to cause floods in communities (Armitage, 2013, p. 25; Jha, 2012, p. 241; Sharma, 2016, p. 446)**.** Strategies should thus be developed to target roofwater management at the plot level; this way the volume of stormwater runoff from roofs that will join the street water will be reduced, making it far easier to manage (A working paper is underway to quantify the contribution of roofs to total runoff generation in urban areas) (Asiedu J. B., 2020).

Reduction in the Working of Municipal Corporations

In our opinion, Municipal corporations should only be engaged in collecting the taxes and clearing encroachments or illegal constructions. The government should give all the works of the corporation to a single company, so that liability of the work can be fixed. Dholera is one such example of Single Contractor policy. Single contractor policy also ensures the better coordination between the agencies.

Creating Twin Cities or Connecting Multi Towns by Urban Infrastructure

Ahmedabad is facing population density issue because other parts of the states are not getting developed at the pace at which Ahmedabad is getting developed. Inadequate infrastructure or no infrastructure usually forces people to migrate to the cities which have adequate infrastructure. If the Rajkot International Airport was built in Kalavad instead of the current site then residents of Upleta, Jamnagar, Rajkot, Gondal, Khambhadiya, Jetpur, Junagadh and Bhanwad could have easy access to the Rajkot international Airport.

Same way, if the Rapid Rail Transit System (RRTS) or Metro rail is constructed between Naliya, Bhuj, Anjar, Mundra, and Mandvi; and a Cargo Airport in Dahinsara then a new mega city could have been developed in the region which would restrict the people from migrating to other regions like Ahmedabad.

In our opinion, proper urban infrastructure development in Kutch and Saurastra Region can really ease the issue of population density in Ahmedabad instead of building Greenfield cities like Dholera near Ahmedabad.

Need to follow Pre- Monsoon Action Plan Strictly

'Pre-monsoon action plan' doesn't mean finding drainage-inlets using metal detectors during monsoons. Drainage cleaning at the time of monsoon is absolutely ineffective in preventing localized flooding. While following the pre monsoon action plan as to cleaning the drains, you found those workers to following this trend of finding covers of gutter and again scrapping that drain area to open up and cleaning.

Plate 10

Figure 10

The pre-monsoon plan of municipalities should include effective cleaning of the streets along with trimming of all the trees of an urban area. In the summer season when there are no rains, the municipal corporations should clean the storm water drainage lines at a higher pace and not at the time of monsoons. We believe that the local authorities should be engaged in desilting of all the major drains mapped should complete it during March month. Besides the pre-monsoon de-silting of drains, the periodicity of cleaning drains should be worked out, based on the local conditions. The roster of cleaning of such drains should be worked out and strictly followed.

All waste removed both from the major and the minor drains should not be allowed to remain outside the drain for drying. Instead, it should be collected and should be transported as soon as it is taken out. In exceptional cases, the silt may be allowed to dry for about 4 to 24 hours outside the drain before transporting the semi-solid silt for disposal. We also believe that the maintenance of all the drainage lines should be done round the clock and throughout the year instead of doing it just before the monsoons.

Stricter Norms on Roads and Compound Walls

While studying the effect of urbanization on the floods, major emphasis is usually laid on how the run-off and the peak flow magnitude increases due to decrease in the infiltration component. The workers also focuses on how the disappearance of water bodies, small and large, due to land use change, decreases the detention effect of the catchment. It is also important to understand, how encroachment of water ways reduces their flood carrying capacity and how poor solid waste management clogs the storm water drainage system. It has been learnt from Chennai floods that some minor processes can have significant effects, at least locally.

As discussed earlier, Continuous re-surfacing of roads (thereby increasing their elevation), construction of high and impervious road medians and ubiquitous presence of “compound walls” between adjacent real estate properties alter the over land flow paths with improper solid waste management, lack of proper cleaning of drainage limes cumulatively affect the location and the depth of inundation. They also prompt uncoordinated acts of local inundation control through breaching of bunds, breaking of compound walls and clogging of culverts.

River Interlinking Project

India is a country of rivers and is dependent on rains for agriculture. The interlinking of Indian rivers to transfer the floodwater from the surplus rivers to deficit areas is one of the most effective ways to increase the irrigation potential, for increasing the food grain production, mitigate floodwaters and reduce regional imbalances in the availability of water. It is believed that Sir Arthur cotton, a British irrigation engineer suggested the linking of the Ganga and Cauvery for navigational purposes and then the Vajpayee government started it again in the year 2002.

It is a well-known fact that the Brahmaputra, the northern tributaries of Ganga, Mahanadi, Godavari and west flowing rivers originating from the Western Ghats are surplus in water. If the government could build storage reservoirs near these rivers and connect them to other parts of the country then the surplus water can be easily diverted to the water scarce areas.

An excellent example of it is the transfer of surplus waters from Bhakra Nangal of Rabi, Baes and Satluj to Rajasthan right up to Jaisalmer through Indira Gandhi Nahar Pariyojana. The project has eliminated drought conditions and transformed deserted waste lands into agriculturally productive lands by bringing irrigation and vegetation to about 2 million hectare area. It is believed that the project has miraculously changed the living conditions and the socio-economic conditions of the people in these states.

River interlinking is important as India is a land of many rivers, mountains and people. We have a very large population which depends on rains for agriculture and domestic use as well. Sir Arthur Cotton, a \British irrigation engineer/expert pioneered the development of water resources in India from 1839 onwards, and had proposed a plan for interlinking of Indian rivers for inland navigation. A small portion of the plan was implemented but was abandoned later in favor of railways.

The proposal to link rivers in India was first given by Dr. K.L. Rao, the then Irrigation Minister Government of India in 1972. His idea was to link Ganga with Cauvery which was about 2640 km. Thereafter Captain Dastur in 1974 suggested the concept of Garland Canal. Then in 1982 NWDA was created to carry out the project, which included carrying out the survey and preparation of feasibility reports.

The Ministry of Water Resources (then known as Ministry of Irrigation) in the year 1980 formulated a National Perspective Plan for water resources development by transferring water from water surplus basins to water deficit basins/regions by inter-linking of rivers. We believe that it will increase navigational efficiency apart from controlling flood & eliminating chances of draught.

CONCLUSION

All the works of the AMC should be given to a single contractor. The corporations should ensure that the contractors follow the Indian Road Congress guidelines. There must be a base year of road levels decided by the corporations. Road level maps and local Digital Elevation Models should be prepared by the corporations. The corporations should also prepare Drainage line and Drainage inlet maps. There must be wall markings on the adjoining walls about drainage covers so that people can open it during flooding and heavy rains. There must be a design team of the contractor which resolves the issue of road levels and localized flooding issues as well as design faults. Increasing Population density and Migration multiplies the effect of extreme events like flooding. Hence, we also believe that small satellite towns should be developed

as smart towns and should be connected by high frequency urban transport infrastructure. These towns will help in easing the population density in Ahmedabad and Gandhinagar. There is a dire need of a well-planned mega city in Kutch region too. Similarly, Rajkot and Jamnagar should be developed as twin cities by creating infrastructure in Kalavad as Kalavad is equidistant from Jamnagar and Rajkot. We also suggest that the corporations should come out with an incentive scheme for people who do not construct compound walls. If the authorities follow the above mentioned points, judgments of the courts and guidelines of IRC then we believe that the impact of flooding will be minimized during the monsoons.

BIBILIOGRAPHY

1. *Dewan, A. M., & Yamaguchi, Y. (2009). Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005. Environmental Monitoring and Assessment, 150(1–4), 237*
2. *Kapinga.I.D. (2020) Adaptive design in Urban Flooding conditions case of Dar es Salaam- Tanzania. Master's Thesis, Miami University, Ohio.*
3. *Gupta, K. (2016, October 27). Interview: Dr. Kapil Gupta on Urban Floods. Press Information Bureau. Government of India. Special Services and Features.*
4. *National Disaster Management Guidelines: Management of Urban Flooding. A publication of the National Disaster Management Authority, Government of India. ISBN: 978-93-80440-09-5, September 2010, New Delhi.*
5. *Goswami B N, Venugopal V, Sengupta D, Madhusoodanan M S and Xavier P K 2006 Increasing trend of extreme rain events over India in a warming environment; Science 314 1442–1445.*
6. *Rajeevan M, Bhate J and Jaswal A K 2008 Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data; Geophys. Res. Lett. 35 L18707, doi: 10.1029/2008GL035143.*
7. *NDMA (2010). National Disaster Management Authority (NDMA). Government of India.*
8. *Hari Ilam Vazhuthi N. and Kumar A. (2020). Causes and Impacts of Urban Floods in Indian Cities: A Review. International Journal on Emerging Technologies, 11(4): 140–147.*
9. *Akanda, A. S., & Hossain, F. (2012). The climate-water-health nexus in emerging megacities. Eos, Transactions American Geophysical Union, 93(37), 353–354.*
10. *Nusrat, Farah, (2018) "Analyzing Urban Flood Disasters in Emerging Megacities Using EarthObservations". Open Access Master's Theses. Paper 1294. https://digitalcommons.uri.edu/theses/1294.*
11. *Dawson, R.; Speight, L.; Hall, J.; Djordjevic, S.; Savic, D.; Leandro, J. Attribution of flood risk in urban areas. J. Hydroinform. 2008, 10, 275–288. [CrossRef]*
12. *Dasgupta, Susmita, Asif Zaman, Subhendu Roy, Mainul Huq, Sarwar Jahan, and Ainun Nishat. 2015. Urban Flooding of Greater Dhaka in a Changing Climate: Building Local Resilience to Disaster Risk. Directions in Development. Washington, DC: World Bank. doi:10.1596/978-1-4648-0710-7. License: Creative Commons Attribution CC BY 3.0 IGO.*
13. *Government U.K. Foresight Future Flooding; Office of Science and Technology: London, UK, 2004.*

14. *Ali, M., Khan, S. J., Aslam, I., & Khan, Z. (2011). Simulation of the impacts of landuse change on surface runoff of Lai Nullah Basin in Islamabad, Pakistan. Landscape and Urban Planning, 102(4), 271–279.*
15. *WEBER, A. (2019, JAN 15). Policy Analyst. NRDC.*
16. *Prathipati, V. K., CV, N., & Konatham, P. (2019). Inconsistency in the frequency of rainfall events in the Indian summer monsoon season. International Journal of Climatology, 39(13), 4907-4923.*
17. *Kollarath, R. M., & Sheriff, V. A., (2019). Green Infrastructure Strategies As Counter Measures To Urban Flooding. Journal of Emerging Technologies and Innovative Research (JETIR), 6(4), 99-103.*
18. *Barbaro, G.; Miguez, M.G.; de Sousa, M.M.; Ribeiro da Cruz Franco, A.B.; de Magalhães, P.M.C.; Foti, G.; Valadão, M.R.; Occhiuto, I. Innovations in Best Practices: Approaches to Managing Urban Areas and Reducing Flood Risk in Reggio Calabria (Italy). Sustainability 2021, 13, 3463. https://doi.org/10.3390/su13063463.*
19. *Biemer, M. and H. J. Schardein Jr. 1998. Fifty Years of Service: A History of the first half-century of the Louisville and Jefferson County Metropolitan Sewer District. Published by The Louisville and Jefferson County Metropolitan Sewer District.*
20. *Cohen, B., and Sustainable Cities. 2006. Urbanization in Developing Countries: Current Trends, Future Projections, and Key Challenges for Sustainability. Technology in Society 28 (1-2): 63-80.*
21. *Cohen, J. E. (2003). Human population: the next half century. Science, 302(5648), 1172–1175.*
22. *Lall, S. V, Selod, H., & Shalizi, Z. (2006). Rural-urban migration in developing countries: A survey of theoretical predictions and empirical findings. The World Bank.*
23. *Solanki, S., & Bhavsar, V., (2023). Urban Flooding By Remote Sensing and GIS IN West Zone Ahmedabad. TIJER – International Research Journal, 10(3), 604-608.*
24. *Bimal Patel, 2011, Metropolis Indian CITIES: Managing Urban Growth Edited by Chris Johnson, pg- 95-106.*
25. *Bernard, J. ASIEDU, Reviewing the Arguments on floods in Urban Areas: A Look at the causes. Theoretical and Empirical Researches in Urban Management, Vol. 15, No. 1 (February 2020), pp. 24-41.*
26. *Pangaribowo, R. L. (2018). Dynamics of land-use change in urban area in West Jakarta. In IOP Conference Series: Earth and Environmental Science (Vol. 106, p. 12040). IOP Publishing.*
27. *Kaur, R., Gupta, K., (2022). Blue-Green Infrastructure (BGI) network in urban areas for sustainable storm water management: A geospatial approach. City and Environment Interactions 16, 100087.*
28. *Kundzewicz, Z., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Muir-Wood, R., . . . Sherstyukov, B. (2012a). Flood risk and Climate Change: Global and Regional Perspectives. Hydrological Services Journal, 59(1), 1–28. doi: 10.1080/02626667.2013.857411*
29. *Anand, A. (2014). Linking Urban Lakes: Assessment of Water Quality and its Environmental Impacts [Master's Thesis, Faculty ITC, University of Twente]. http://www.itc.nl/library/papers_2014/msc/upm/anand.pdf*

30. *Bal, M., Van Ast, J. A., & Bouma, J. J. (2011). Sustainability of water resource systems in India: role of value in urban lake governance in Ahmedabad. 13th Biennial Conference of the International Association for the Study of the Commons (IASC)., 1–30. http://hdl.handle.net/1765/26325*

31. *Bal, M. (2020, May 7). Consultation on Impact of Interlinking of Lakes Project in Ahmedabad. (U. Patel, & T. Bose, Interviewers)*

32. *Desai, D. (2020). From 630 to 122: Where did Ahmedabad's lakes disappear? Citizen Matters. https://citizenmatters.in/ahmedabad-vanishing-water-bodies-21853*

33. *Reddy, M. S., & Char, N. V. V. (2006). Management of lakes in India. Lakes and Reservoirs: Research and Management, 11(4), 227–237. https://doi.org/10.1111/j.1440-1770.2006.00311.x*

34. *AUDA. (2020, August 14). Interlinking of Lakes - AUDA. Ahmedabad, Gujarat, India.*

35. *Ahmedabad Municipal Corporation. (2020, June 18). Water Project and Water Production. Retrieved from Ahmedabad Municipal Corporation: https://ahmedabadcity.gov.in/portal/jsp/Static_pages/water_project.jsp*

36. *AMC. (2020). Data on Interlink Capacity.*

37. *AMC. (2020, November 11). Data on Lakes in Ahmedabad. Ahmedabad.*

38. *AUDA. (2020, July 20). About Us: AUDA. Retrieved from Ahmedabad Urban Development Authority: http://www.auda.org.in/*

39. *Tayyibji, R. (2016, May). ANCIENT STEPWELLS OF AHMEDABAD: A Conversation on Water and Heritage. Retrieved from Sutra Journal: http://www.sutrajournal.com/ancient-stepwells-of-ahmedabad-a conversation-on-water-and-heritage-by-riyaz-tayyibji*

40. *Thakker, H. (2020, July 13). Consultation on Impact of Interlinking of Lakes Project in Ahmedabad. (T. Bose, Interviewer)*

41. *Thakker, H. (2020, July 13). Consultation on Impact of Interlinking of Lakes Project in Ahmedabad. (U. Patel, & T. Bose, Interviewers)*

42. *Thakker, H. (2020, August 14). Planning and Implementation of Large Infrastructure Projects: Lake Interlinking Project - Ahmedabad Experience. (M. Iyer, Interviewer)*

43. *Jagani, A. (2004). Techno planning solution for water resources conservation through interlinking the lakes of peri-urban area: a case study of AUDA. Ahmedabad.*

44. *Patel, S. (2020, June 19). Consultation on Impact of Interlinking of Lakes Project in Ahmedabad. (U. Patel, & T. Bose, Interviewers).*

45. *Shastri, H. (1964). THE DATE OF THE FOUNDATION OF AHMEDABAD. Proceedings of the Indian History Congress (pp. 119-123). Indian History Congress.*

46. *TPVD. (2020, August 07). Home: TOWN PLANNING & VALUATION DEPARTMENT. Retrieved from TOWN PLANNING & VALUATION DEPARTMENT: https://tpvd.openprp.in/pro/main/modules/role_public/map/index.php*

47. *J.S. Rajpurohit vs. State of Gujarat, PIL/72/2014 (The High Court of Gujarat September 5, 2014).*
48. *Brabec, E., S. Schulte, and P. L. Richards. 2002. Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning. Journal of Planning Literature 16 (4): 499-514.*
49. *Espey, W. H., C. W. Morgan, and F. D. Masch. 1966. A study of some effects of urbanization on storm runoff from a small watershed. Texas Water Development Board Report 23, 110 p.*
50. *Arnold, C. L., P. J. Boison, and P. C. Patton. 1982. Sawmill Brook: An Example of Rapid Geomorphic Change Related to Urbanization. The Journal of Geology 90 (2): 155-166.*
51. *Kotecha, M., 2022. INTERLINKING LAKES Decision support tool for sustainable lake ecosystem, Ahmedabad, India. [Master's Thesis, University of Twente].*
52. *The World Bank. (2011). Indonesia -Jakarta Urgent Flood Mitigation Project (Jakarta Emergency Dredging Initiative). Retrieved from http://projects.worldbank.org/P111034/jakarta-urgent-flood-mitigationproject?lang=en*
53. *Srishti, J., 2018. Urban Floods- A Case Study of Araria, Bihar. [M.A. Dissertation, Ambedkar University].*
54. *Cohen, B., and Sustainable Cities. 2006. Urbanization in Developing Countries: Current Trends, Future Projections, and Key Challenges for Sustainability. Technology in Society 28 (1-2): 63-80.*
55. *Hsu, M. H., S. H. Chen, and T. J. Chang. 2000. Inundation Simulation for Urban Drainage Basin with Storm Sewer System. Journal of Hydrology – Amsterdam 234 (1-2): 21-37.*
56. *Mark, O., S. Weesakul, C. Apirumanekul, S. B. Aroonnet, and S. Djordjević. 2004. Potential and Limitations of 1D Modelling of Urban Flooding. Journal of Hydrology 299 (3/4).*
57. *Paul, M. J. and J. L. Meyer. 2001. Stream in the Urban Landscape. Annual Review of Ecology, Evolution, and Systematics. 32:333–65.*
58. *Schmitt, T. G., M. Thomas, and N. Ettrich. 2004. Analysis and modeling of flooding in urban drainage systems. Journal of Hydrology 299, 300–311.*
59. *Torgersen, G., et al., 2014. Addressing Flooding and SuDS when Improving Drainage and Sewerage Systems—A Comparative Study of Selected Scandinavian Cities. Water (6), 839-857. doi:10.3390/w6040839*
60. *Mujumdar, P.P. et al., 2016. Chennai Floods 2015 - A Rapid Assessment. Interdisciplinary Centre for Water Research. Indian Institute of Science, Bangalore.*
61. *Asiedu J. B., 2020. REVIEWING THE ARGUMENT ON FLOODS IN URBAN AREAS- A LOOK AT THE CAUSES, Theoretical and Empirical Researches in Urban Management, 15(1), pp. 24-41.*
62. *Armitage, N. V., Michael; Winter, Kevin; Spiegel, Andrew and Dunstan, Jessica. (2013). Alternative Technology for Stormwater Management Alternative Technology for Stormwater Management. Cape Town, Republic of South Africa: Water Research Commission, South Africa. p -25.*

63. *Jha, A. K. B., Robin and Lamond, Jessica (2012). p. 241. Cities and Flooding: A guide to integrated urban flood risk management for the 21st century Retrieved from https://www.gfdrr.org/sites/gfdrr/files/urbanfloods/urbanfloods.html doi:10.1596/978-0-8213-8866-2.*

64. *Sharma, A. K. C., Stephen; Gardner, Ted and Tjandraatmadjja, Grace. (2016). Rainwater tanks in Modern Cities: A Review of Current practices and Research. Journal of Water and Climate Change. p. 446.*

65. *Raghunath, H. M. (2006). Hydrolysis - Principles, Analysis and Design. New Dehli: New Age International (P) Limited, Publishers.*

66. *Liu, A. G., Ashantha and Egodawatta, Prasanna. (2015). Role of Rainfall and Catchment Characterisitics on Urban Stormwater Quality. Singerpore: Springer.*

67. *Sonali A. More, 2014. Interlinking of Rivers. International Journal on Arts, Management and Humanities 3(2): 14-20.*

68. *UNDP, (2020b). Goal 11: Sustainable Cities and Communities. Retrieved from United Nations Development Programme: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-11-sustainable-cities-and-communities.html.*