DOI: 10.5821/siiu.10153

STRATEGIES AND APPROACHES PERTINENT TO PUBLIC SPACE FOR ADDRESSING FLOODS

An Assessment from Coastal Urban Slums in India

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ABSTRACT

Climate change and disasters are fast emerging as the most defining challenge of the 21st century as global risk. Changes in many extreme weather and climate events have been observed and linked with human influences, including an increase in extreme high sea levels and an increase in the number of heavy precipitation events. About 70 percent of the coastlines worldwide are projected to experience sea level change within 20 percent of the global mean. India, a developing country of global south and a major global contributor, is among the first ten countries in climate risk index. The country is witnessing average sea level rise of 1.7 mm/ year with rising sea projections in coastal cities. Further, India host a large percentage of urban population living in slums. Dharavi slum, Asia's biggest slum, located in the centre of Mumbai along the coast, host a population of more than a million in just 2.1 square kilometre. Slums are located at land which is usually unsuitable for formal development, being the low lying marshy areas along the river basins or coastal mangroves. As a direct cause, the physical location of the slums in developing world, makes them at a greater risk of flooding. Urban slums of metropolitan Mumbai, Kolkata and Surat in India, along with many others, are vulnerable to flooding. The present policy framework lack in providing for climate resilience and has thus compelled the slum dwellers to adapt to the risk of flooding with local community based measures involving public space retrofits.

The paper assess these adaptation measures and strategies from different coastal urban slums in India and aims to create a theoretical framework of measures and elements. Case study analysis approach is used to generate for adaptation strategies and presented in the parameters (type – time – role – intent and scale of adaptation). Results showcases a framework of adaptive and mitigation measures pertinent to local participation

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and public space retrofits for coastal urban slums. It enables the generation of a typology, lexicon of measures and elements, a toolkit to face extreme floods. Community mobilization with public space retrofits open new possibilities for addressing future floods and in gaining resilience.

Keywords: Adaptation, coping strategies, flood resilience in slums, public space retrofits.

Thematic block: Public space and urban project in the contemporary metropolis.

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1. INTRODUCTION

Climate change and disasters are fast emerging as the most defining challenges as global risks with higher impacts on neglected areas of the cities. The rate of sea level rise since the mid nineteen century has been larger than the mean rate during the previous two millennia (IPCC, 2014, p.2, 4). Changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions (IPCC, 2014, p.7). Flooding in coastal cities around the world is due to higher precipitation or sea water rise. It is the most common hazard, can be generally defined as the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. A particular flood can result from many combinations of meteorological, hydrological and human factors (Matos Silva, 2016, p.81). Flooding in urban areas is not just related to heavy rainfall and extreme climatic events; it is also related to changes in the built-up areas themselves. Urbanisation aggravates flooding by restricting where floods waters can go, by covering large parts of the ground with roofs, roads and pavements, by obstructing sections of natural channels, and by building drains that ensure that water moves to rivers more rapidly than it did under natural conditions. Such situations frequently arise where poor people build their shelters on low-lying flood plains, over swamps or above the tidewater on the coast (Unjust Waters, 2006, p.3). The impact of climate change are imposed on these people-driven local land surface modifications. The 2003 World Development Report notes the pronounced difficulties the poor face when disaster strikes. People in low-income countries are four times as likely as people in high-income countries to die in a natural disaster... Poor people and poor communities are frequently the primary victims of natural disasters, in part because they are priced out of the more disaster-proof areas and live in crowded, makeshift houses... poor families are hit particularly hard because injury, disability, and loss of life directly affect their main asset, their labour. Disasters also destroy poor households' natural, physical, and social assets, and disrupt social assistance programmes (Satterthwaite, Dodman, 2010, p.206).

Further, the developing countries such as India are facing the problem of increasing urban slums. In metropolitan cities like Mumbai, the percentage of slum population is high reaching 54 percent (Census of India, 2001). Slums are located at land which is usually unsuitable for formal development, being low-lying marshy areas along the river basins or coastal mangroves. The physical location and inability to prevent and absorb excess water makes them at a greater risk of flooding. For India, tackling the challenges of climate

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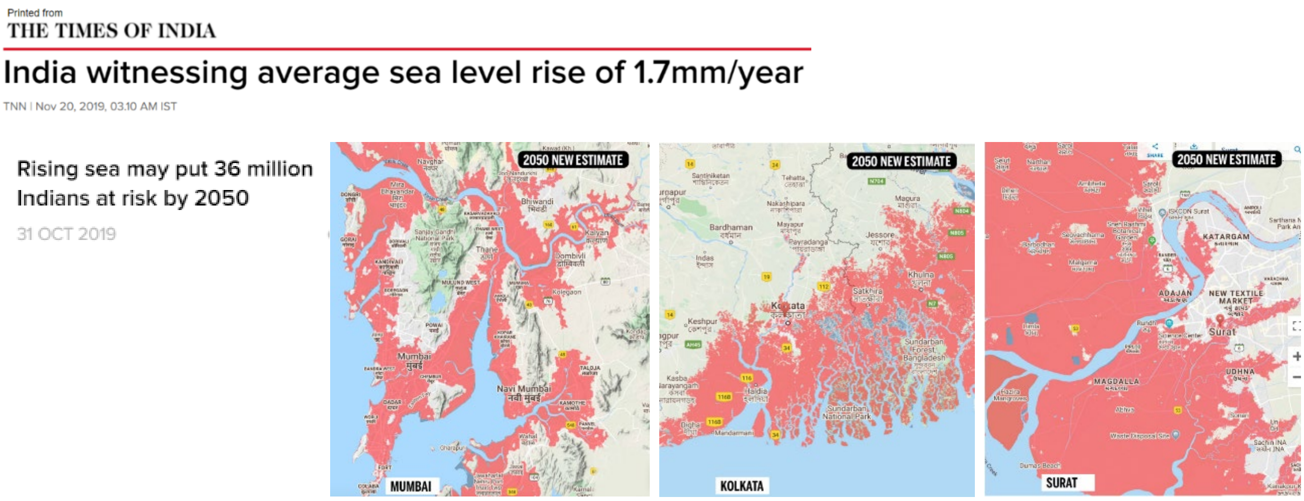
change and flooding posits particular significance as being a major global contributor. India is among the first ten countries in climate risk index of 2018. Through flood events and the response of slum dwellers suggests that adaptation measures needs more integration of local participation through vernacular coping strategies.

2. **LITERATURE REVIEW**

India is witnessing average sea level rise of 1.7 mm/year with projection of putting 36 million Indians at risk by 2050 (Times of India, 2019). The coastal cities of Mumbai, Kolkata and Surat are victims of climate change and host a numerous urban slums along the river basins and coasts facing recurring floods. These cities are vulnerable to recurring floods due to common reasons being faulty zoning regulations and planning, flash floods, cyclones and reduction of green infrastructure and destruction of wetlands. It is no wonder that contemporary Kolkata's regular flooding, or the projected submergence of parts of Mumbai by 2050, was a century in the making (Bhattacharyya, 2020).



[Fig.1 Rising sea water in coastal cities of India published in Times of India, November, 2019. Derived from https://timesofindia.indiatimes.com/india/india-witnessing-average-sea-level-rise-of-1-7mm/year/articleshow/72134279.cms and https://timesofindia.indiatimes.com/india/rising-sea-may-put-36-million-indians-at-risk-by-2050/articleshow/71834444.cms]

2.1 THE CASE OF MUMBAI

Mumbai was originally an archipelago of seven islands. Bombay, the old name of the city, meaning good bay, expresses a deep connection between the city and the water, built on the foundation of continuously altered and reclaimed natural and urban landscapes, an outcome of colonial exploitation, geo-political agendas and

DOI: 10.5821/siiu.10153

global competitiveness. Mumbai is a sanctuary for immigrants and urban slums forms a significant element of urban landscape.

> “Throughout the making of Mumbai, reclamation – in the sense of land creation, recovery, repossession, renovation and recuperation – has been (and remains) the driver of states of change” (Shannon, 2009, p.9).

Slum settlements house approximately 55 percent of Mumbai's population and are mostly located in low lying areas close to marshes and other marginal places (O'Hare et al. 1998). These slums are frequently flooded during monsoon season. Formal flood mitigation strategies adopted by the city authorities do not reduce risks for people living in informal settlements (Chatterjee, 2010, p.344). This compelled the local slum dwellers to adopt vernacular adaptation strategies. The heaviest rain was seen on 26th of July, 2005. Floods in Mumbai are said to be caused by heavy rains accompanied with high tides (Kadave et al. 2016, p.224).

[Fig.2 High tide hits the shore in Mumbai published in Times of India, High tide alert: Mumbaikars warned against venturing near sea, June, 2013 derived from https://timesofindia.indiatimes.com/city/mumbai/High-tide-alert-Mumbaikars-warned-against-venturing-near-sea/articleshow/36484560.cms]

The database of flood instances between the year 2000 and 2008 shows an average of 76 instances of flooding annually in the island city (Mumbai - District), 57 instances in the Eastern suburbs and 129 flooding instances in the Western suburbs. Historically, Mumbai has been receiving an annual rainfall of about 220 cm during the monsoon season between June and September. Since 2004, the average annual rainfall has been more than 240 cm. Heavy precipitation and resultant flash floods are regular event in Mumbai (Patankar, 2015). The reasons for flooding in Mumbai are extracted and listed in table - 1. The primary reason of flooded water logged areas in Mumbai stems from the reclamation between the original seven separate islands as

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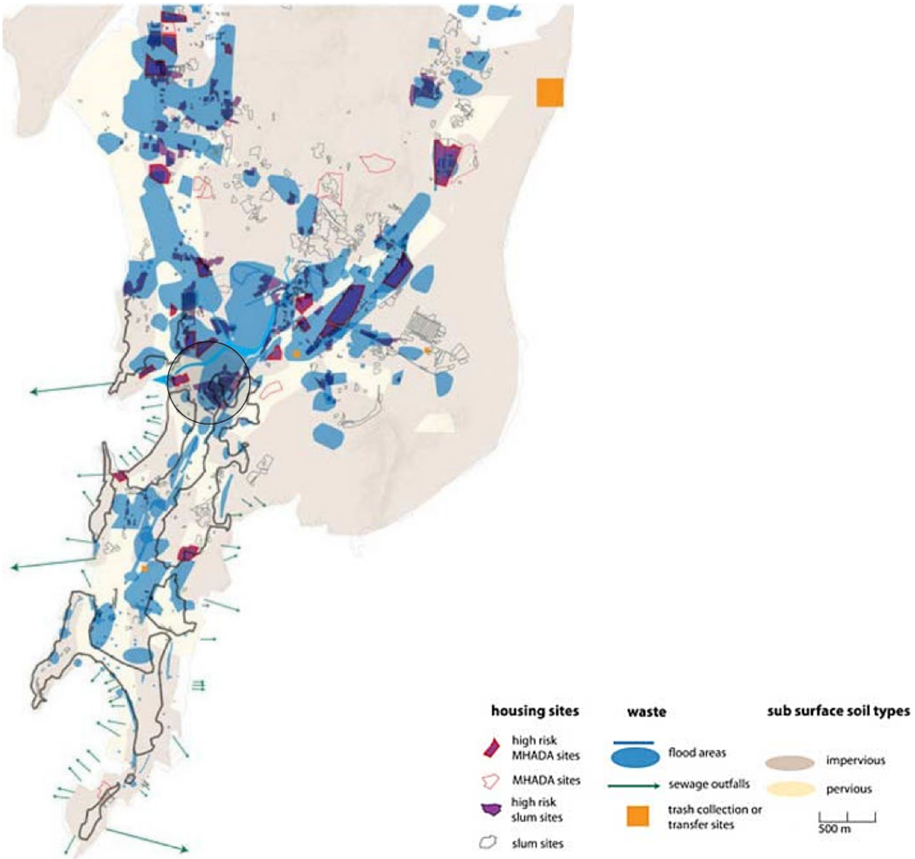
illustrated in Fig.3. Flooding happens where the drainage both man-made and natural are insufficient and clogged. There are many slums and MHADA sites around the Mithi River and Mahim creek that at high risk of flooding.

> “The strong setting places Mumbai in a category of large cities which have a particular relationship to landscape – similar in a certain sense to places such as Rio de Janeiro, Hong Kong, Cape Town and Barcelona. Nature and urbanity are in extremely close proximity, with both spectacular and problematic results” (Shannon, 2009, p.58).



[Fig. 3 Hydrographic Map of Mumbai: Water logged reclaimed areas between the original seven separate islands. Dharavi slum encircled. Derived from http://mapsof.net/uploads/static-maps/hydrographic_map_of_mumbai.jpg]

Further, the drainage system of Mumbai was constructed to handle rainfall at the rate of 25mm/hour. The city is actually subjected to approximately 100mm/hour which already stretches the existing capacity (Dharavi weekly, 2020). Further, encroachments and building on the city's natural drain has resulted in a catastrophic

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scenario. The storm water drainage for Mithi River catchment area has been disrupted due to the encroachment of hutments in large numbers, storage facilities, processing industries, workshops and other scrap yards situated along the banks that make it difficult to even delineate its path (NEERI, 2011). Lack of waste management resulting into clogged drains exacerbate flooding. The average depth of flooding in the surrounding compound, as reported by the households, is about 1.5 feet with the range of 0.5-4.5 feet and water remains between 0.5 to 8 hours depending on the area. 42% of the households have reported that flood waters enter their house every year during monsoon (Patankar, 2015, p.18).

[Fig.4 Mithi River along Dharavi slum in Mumbai published in The Wire, As Mumbai Rains Wreak Havoc: Slum Dwellers the Worst Affected, July, 2018 derived from https://thewire.in/government/as-mumbai-rains-wreck-havoc-slum-dwellers-the-worst-affected]

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[Fig.5 Mithi River along Dharavi slum in Mumbai published in DNA, Mumbai: BMC to pump big money on sewage, February, 2019 derived from https://www.dnaindia.com/mumbai/report-mumbai-bmc-to-pump-big-money-on-sewage-2718507]

[Fig.6 Choked drain in Mumbai published in Outlook India, September, 2014 derived from https://www.outlookindia.com/photos/single/96872]

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[Fig.7 Reclamation at Mithi River bank by BMC for metro project resulting in reduction of river width published in The Asian Age, December, 2017 derived from https://www.asianage.com/metros/mumbai/181217/activists-warn-of-flooding-due-to-mithi-width-cut.html]

Climate change adaptation is a learning continuous adjustment process aimed at reducing vulnerabilities (Matos Silva, 2016, p.59) and the response of slum dwellers towards flooding is considered significant in generating coping strategies and adaptation measures. Throughout history, people and societies have adjusted to and coped with climate, climate variability and extremes, with varying degrees of success (IPCC, 2014, p.54). Living in harmony with water and vernacular adaptation has become a requisite in slum neighbourhoods. Chatterjee discussed the response of slum dwellers and learnings from flood event in 2005. It is observed (Chatterjee, 2010) that formal flood mitigation and adaptation strategies adopted by city authorities do not reduce the risks for urban poor. Neither relocation of urban slums is the solution due to strong network of livelihoods and social organization. Slum dwellers do whatever little they could to deal with the intensity of the monsoons. This includes using of plastic sheets to cover windows and over the roofs or relocation to safe higher floors. Furthermore, the raising of the floors and the veranda can help prepare for the monsoon rains. With the limited ability, the households, both poor and non-poor, undertake various measures every year on the onset of monsoon through their own initiative and funding (Patankar, 2015, p. 21). Furthermore, cleaning house surroundings, canals, sewer drains and repairing roofs are most common recurrent measures. Women in Versova's urban fishing village spread risk by using insurance, engaging in community-based fishing, and diversifying their livelihoods in the face of growing coastal erosion (Banti et al. 2016). Mumbai lacks sectoral or city-scale planned adaptation projects or policies. While the city has a coastal

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zone management plan in place since 2015, climate risks are not explicitly considered. (Sharma, Chauhan, 2011).

[Fig.8 Flood adaptation by construction of barrier wall: A man clearing water outside from the flooded house in Mumbai published in DNA, Water-logging was below one feet – BMC says, Despite low-lying areas deep under water on first day of monsoon, corporation sees satisfied with its 'measures taken', June, 2018 derived from https://www.dnaindia.com/mumbai/report-dna-rain-check-water-logging-was-below-one-feet-bmc-says-2623761]

[Fig.9 Flood adaptation of walled-in Vakola Nala, a major tributary of the Mithi River in Mumbai: Kirtane, ORF 2010]

[Fig.10 Sheetal Talao, one of the few surviving ponds in the catchment of Mithi River: Kirtane, ORF, 2010]

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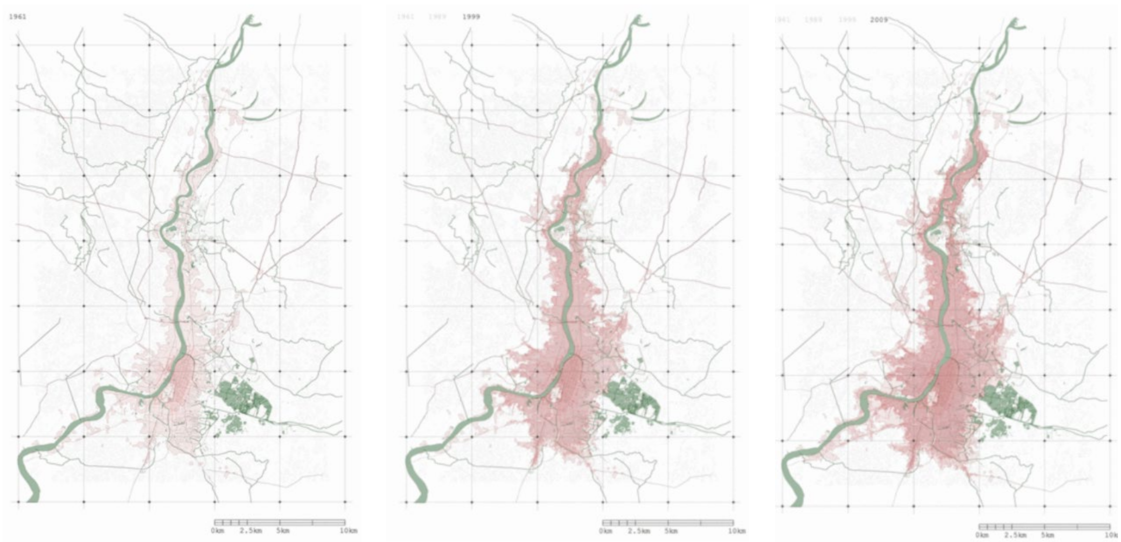
2.2 THE CASE OF THE CITY IN THE SWAMPS: KOLKATA AND THE SUNDARBANS

Kolkata is located 145 km away from the coastline, but is considered as a coastal mega-city because of the direct effect of marine processes and deltaic settings (Sekovski et al. 2012). The modern city of Kolkata was developed on land recovered from the wetlands following the Dutch model of cities built along the Rhine River despite geographical challenge similar to those in Kolkata (Rumbach, 2014). The city is also known as the city in the swamps (Murphey, 1964).



[Fig.11 Urban growth of Kolkata 1961 – 2017: Orff et al. 2017]

The swamps are turned into profit generating infrastructural projects with massive swamp reclamation from the early decades of the twentieth century. Fig. 11 illustrates the urban growth of the city along the Hooghly River from 1961 to 2017. Kolkata's urbanization process is inextricably linked to the larger regional ecosystem of the Sundarbans, a UNESCO World Heritage site (Orff et al. 2017). Sundarbans, largest tidal mangrove forest provide for protective shield against cyclones and tsunamis are constantly endangered from coastal erosion, sea level rise and salinization. Urban poor living along the Hooghly River or the coast face recurring floods.

The ambitious spaces and mud deposits on the western banks, the salt marshes on the eastern fringes of the Hooghly River were transformed into projects to address the need of urbanization and expanding city. The region is undergoing land subsidence and this can be a boosting mechanism for future floods in the region (Chatterjee, 2010). The multivalent uses of marshes, ponds and canals were ignored. The city is subjected to

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extreme precipitation during monsoons with an annual rainfall of around 160 cm and flooded due to the flat terrain, drainage outfalls being tide-dominated. Some recommended adaptation measures (Dasgupta et al. 2013) are de-siltation of the existing sewers and construction of new sewers, improvement of storm water drainage system and renovation of the outfall canal system. Fig. 12 illustrates the local flood adaptation by slum dwellers by building defence mechanism using sandbags along the wetlands.

[Fig.12 Flood prevention by building bunds using sandbags published in The Print, Drive to Sundarbans sees paddy lands turned into fishing ponds by cyclone Amphan, May, 2020 derived from https://theprint.in/india/drive-to-sundarbans-sees-paddy-lands-turned-into-fishing-ponds-by-cyclone-amphan/428701/]

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[Fig.13 Flood defend measures of building barrier and elevated houses in deltaic region of Kolkata published in Café Dissensus Everyday, Ten years after Cyclone Aila, inhabitants of Sundarbans still waiting for rehabilitation, August, 2018 derived from https://cafedissensusblog.com/2018/08/02/ten-years-after-cyclone-aila-inhabitants-of-sundarbans-are-still-waiting-for-rehabilitation/]

2.3 THE CASE OF SURAT

Surat is located on the bank of Tapi River which along the west coast in India. The expansion of the city boundaries to include the Dumas coastal area has also made Surat a coastal city. The city hosts around 406 slums, many of these located on tidal creeks and along the river and other drainage channels (Bhat et al. 2013). Annual rainfall ranges from 100 to 120 cm with around 90 percent of rainfall between June and September. As Surat is located near the mouth of the river, high tides reach the western part of the city, with a tidal range of five to six metres, and during the rainy season, high tides often inundate settlements located along several tidal creeks (Bhat et al. 2013). The colonial history of the city provide for events of flooding prior to the instrumental records. The inner wall of the city, constructed in British era in 16th century, performed as a flood protection structure with gates which were closed during the floods. Based upon the geomorphology of the city, it can be divided into a coastal zone and an alluvial area. The coastal zone is composed of marshy shoreline with an extensive tidal flat stretch intercepted by estuaries. The alluvial area is marked by alluvial

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deposits from the Tapi River (Patel et al. 2017). Five major flood events are reported since 1979, the flood event of 2006 being devastating. The primary reason of flooding being extreme precipitation and release of water from Ukai Dam. The listed anthropogenic factors (Jariwala, Samtani, 2012) being land reclamation on the banks of creeks, construction of bridges and suspended solids and non-degradable substances in city effluents. The results of flood assessment and the extent of inundation in the low lying areas (Patel et al. 2017) indicates that 75-77 percent area of the city was inundated during the flood. Also, much of the city and its surrounds are less than 10 metres above mean sea level. Direct risk from sea level rise affects around 5000 households located along tidal creeks (Bhat et al. 2013). Flood reduction plan for Surat (Agnihotri, Patel, 2008) suggests measures highlighting the need of flood water detention ponds and diversion of water to other rivers. Surat's Resilience Strategy is a forerunner in urban adaptation planning and implementation and showcases how effective water management through strategic municipal action can provide environmental and health co-benefits (Rietveld et al. 2016).

[Fig.14 Existing Tapi River edge in Surat: Tapi Riverfront Development and Rejuvenation Project, Final Concept Master Plan Report, 2019, p.40]

[Fig.15 Existing Tapi River edge in Surat: Tapi Riverfront Development and Rejuvenation Project, Final Concept Master Plan Report, 2019, p.44]

DOI: 10.5821/siiu.10153

[Fig.16 Existing retaining wall and edge scenario at River Tapi in Surat: Tapi Riverfront Development and Rejuvenation Project, Final Concept Master Plan Report, 2019, p.12, 46]

3. METHODOLOGY

Urban slums of metropolitan Mumbai, Kolkata and Surat in India are assessed for the reasons of flooding: meteorological, hydrological and anthropogenic reasons, and adaptation measures by urban poor pertinent to public space. These three cities are located along the Indian coast, Mumbai and Surat at the west coast and Kolkata at the east coast. The adaptation strategies are extracted through observations and interpretations from reality to provide for a framework set in flood adaptation parameters. The adaptation parameters in different types: infrastructural, behavioural, institutional and ecological, that provide for adaptation in different time of a flood event: reactive, anticipatory or concurrent in nature. Further, categorized into the role as defend, engage or store mechanisms, along with the intent and scale of each measure. The parameters are derived from the previous established classification of flood adaptation.

The measures that provide for protection as defend from flooding comprises the capabilities to reduce the vulnerability and risk towards flooding. The measures that relate to engage the water entail the capacity to store and turn the treat from excess water into an opportunity. It is observed from the case examples that the stored water is seen to be used for aquaculture, washing of cloths, bathing etc. by the slum communities. The adaptation parameters are described in table 1. The parameters of categorization can be more diverse. Only the parameters of type – time – role – intent and scale are considered within the scope of this paper, to categorize the measures and analyze the study cases.

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Table 1. Description of flood adaptation parameters. Derived from previous established classification in scope of this paper.

Parameters	Categorization	Description
Type	Infrastructural	Infrastructural measures involve coverage of basic physical infrastructure such as sewer lines, water channels, drains, green permeable spaces etc. Also include re-structuring and improving the aging infrastructure or waste landscapes. Such measures are adopted at all scales.
	Behavioral	Such measures depend on individual or community choices.
	Ecological	These are eco-system based measures. Typically natural soft measures of protection.
	Institutional	Involve formal mandate in long term climate change mitigation and adaptation planning in form of action plans fragmented in different agencies and programs.
Scale	Individual	Measures adopted at household level. These primarily depend upon behavioral factor and individual capability to adapt. Such measures plays vital role in risk reduction for urban slum dwellers.
	Neighborhood	These measures provide for risk reduction at community level. Slum settlements hold inviolable social networks and measures with local community level participation are vital in risk reduction for urban slums.
	City	Formal government action plans and interventions largely provide for adaptation measures at city level.
Time	Reactive	These are autonomous actions that evolve as circumstances change during a flood event
	Anticipatory	These measures are performed and based upon the presumption of a future flooding event in time and magnitude. The anticipation of an event can be in long term projections or short term.
	Concurrent	These measures are performed on continuous regular basis irrespective of the flood event.
Role	Defend	The protection strategy is based upon defending (protecting from) the impacts of flooding.
	Engage	This involve the water with measures and elements to live in harmony with water resulting in risk reduction.
	Store	Such measures and elements entail the infrastructural capacity to store water and also provide for reduction in surface runoff. The storage mechanism/ infrastructure can be over (open/ closed) or below the ground surface. The stored water can be filtered, cleaned and transfer back for other purposes.
Intent	Autonomous	Autonomous measures are individual independent measures based on behavior and desire/ necessity towards flood adaptation. Such measures are not imposed from formal government action plans.
	Strategic/ Planned	Strategic/ Planned measures and elements are imposed and enforced as action plans resulting from long term strategic assessment. The intent of desire and freedom is absent.

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Table 2. Framework of measures and elements for flood adaptation. Derived from case examples.

Coastal Cities	Flood Events	Reasons of Flooding	Measure and Elements pertinent to public space in urban slums	Adaptation Parameters				
				Type	Time	Role	Intent	Scale
Mumbai	2005	**Meteorological Reasons**	Raising of plinths in individual dwelling units	Infrastructural	Anticipatory	Defend	Autonomous	Individual
		Monsoon heavy rains						
	76 events between 2000 – 2008	**Hydrological Reasons**						
		Coastal high tides	Plastic sheet to cover windows and over the roofs.	Infrastructural	Anticipatory Reactive	Defend	Autonomous	Individual
		Rising sea levels	Temporary relocation to upper floors in individual dwelling	Behavioural	Reactive	Defend	Autonomous	Individual
		Flat gradients and mud flats causing excessive siltation						
		Anthropogenic Reasons						
		Extensive reclamation	Temporary relocation to higher public space like community grounds, squares etc.	Behavioural	Reactive	Defend	Autonomous	Neighbourhood
		Faulty zoning regulations Inadequate rainwater drainage system	Restoration of natural drains	Ecological Infrastructural Institutional	Anticipatory Concurrent	Engage	Strategic	Neighbourhood City
		Faltering drainage systems	Cleaning and clearing of bottlenecks in Mithi River	Ecological Infrastructural Institutional	Concurrent	Engage	Planned Strategic	City
		Encroachments over Mumbai's natural drain	Removal of encroachments and establishing recreational parks as buffer zones	Ecological Infrastructural Institutional	Concurrent	Defend Engage Store	Strategic	City
		Reduction in river catchment areas	Construction of river embankments	Infrastructural	Anticipatory Concurrent	Defend	Strategic	Neighbourhood City
		Bandra – Worli sea link	Cleaning of community drains	Infrastructural Institutional	Anticipatory Concurrent	Engage	Autonomous	Neighbourhood
		Change of path of natural rivers (Mithi River due to Airport)	Revival/ restoration of traditional water bodies (Ex. wells and water ponds, blue – green infrastructure action plan)	Ecological Infrastructural Institutional	Concurrent	Engage Store	Strategic	City
		Lack of waste management resulting into clogged drains	Community based fishing	Behavioural	Concurrent	Engage	Autonomous	Individual
				Ecological				Neighbourhood
		Lack of open grounds in slum neighbourhoods to allow water seepage	Diversifying the livelihoods (Ex. aquaculture)	Behavioural Ecological	Concurrent	Engage	Autonomous	Individual Neighbourhood
			Building temporary barriers	Infrastructural	Anticipatory Concurrent	Defend	Autonomous Strategic	Individual Neighbourhood
		Destruction of mangroves and marshes due to mushrooming slums	Dewatering pumps to drain floodwater	Behavioural Institutional	Reactive	Engage	Autonomous	Individual Neighbourhood
		Deforestation of forests in Mumbai	Shoreline stabilization and protection (Ex. concrete tripods)	Infrastructural	Concurrent	Defend	Strategic	City
		Destruction of wetlands due to reclamation of land for infrastructural projects	Constructing barriers across the door fronts (Ex. Sandbag walls)	Infrastructural	Anticipatory	Defend	Autonomous	Individual
			Construction of flood defences and dikes	Infrastructural Institutional	Anticipatory Concurrent	Defend	Strategic	Neighbourhood City
		Reclamation of water-logged areas between the original seven separate islands	Dredging of rivers	Infrastructural Ecological	Concurrent	Engage	Planned	Neighbourhood City
			Water diversion for laundry grounds (Ex. Dhobi Ghat)	Infrastructural	Anticipatory Concurrent	Engage Store	Planned Strategic	Neighbourhood
		Loss of holding ponds						
		Depletion of flood plain due to encroachments						
Kolkata	1956	**Meteorological Reasons**	De-siltation of existing sewers	Ecological Infrastructural Institutional	Concurrent	Engage	Strategic	City
	1959	Monsoon heavy rains and cyclones						
	1978	**Hydrological Reasons**						
	1995	Natural subsidence	Construction of new sewers	Infrastructural Institutional	Anticipatory Concurrent	Engage	Planned Strategic	Neighbourhood City
	1999 2000 2016	Flat terrain with drainage outfalls being tide dominated						
		Anthropogenic Reasons	Improvement of storm water drainage system	Infrastructural Institutional	Anticipatory Concurrent	Engage	Planned Strategic	Neighbourhood City
			Renovation of outfall canal system	Ecological	Concurrent	Engage	Strategic	City

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		Reclamation from wetlands and swamps		Infrastructural Institutional				
		Inadequate drainage system from British era	Pumping out excess water	Behavioural	Reactive	Engage	Autonomous	Individual Neighbourhood
			Wetland edging	Infrastructural Ecological	Concurrent	Defend	Strategic	Neighbourhood City
		Lower conveyance capacities of sewer system	Extensive use of bamboo in building barriers, defend structures and raised platforms	Infrastructural	Anticipatory Concurrent	Defend	Autonomous Strategic	Individual Neighbourhood
			Floating structures made of bamboo (Ex. floating flower market)	Infrastructural	Concurrent	Defend	Strategic	Neighbourhood
			Mangrove afforestation	Ecological	Concurrent	Defend	Strategic	City
			Solid waste filtration	Ecological Infrastructural Institutional	Concurrent	Engage	Planned Strategic	City
			Floating structures and bamboo boardwalks	Infrastructural	Anticipatory Concurrent	Defend	Planned	Neighbourhood City
			Elevated bunds	Infrastructural	Anticipatory Concurrent	Defend	Strategic	Neighbourhood City
			Bioswale path	Infrastructural Ecological	Concurrent	Engage Store	Strategic	Neighbourhood
			Floriculture	Behavioural Ecological	Concurrent	Engage	Strategic	Neighbourhood
Surat	1979 1990	**Meteorological Reasons**	Detention ponds	Infrastructural Ecological	Anticipatory Concurrent	Engage Store	Planned Strategic	Neighbourhood City
	1994 1998	Monsoon heavy rains and Storms	Diversion of excess water to other rivers	Infrastructural Ecological	Concurrent	Engage	Strategic	City
	2006	**Hydrological Reasons**	Raising plinth height	Infrastructural	Anticipatory	Defend	Autonomous	Individual
		Seawater intrusion through different creeks (Khadi floods)	Water management in river catchment area	Infrastructural Ecological	Concurrent	Engage Store	Planned Strategic	Neighbourhood City

		Silting of river basins due to tides Sea level rise impacting coastal aquifers	Construction of protection wall (Ex. also in 16th century the inner wall was constructed as flood protection)	Infrastructural Institutional	Anticipatory Concurrent	Defend	Autonomous Planned Strategic	Individual Neighbourhood City
			Construction of balloon barrage system	Infrastructural Institutional	Reactive	Defend	Strategic	Neighbourhood City
		Anthropogenic Reasons	Improving wastewater and sanitation systems (Ex. Surat City Resilience Strategy)	Infrastructural Institutional	Concurrent	Engage	Strategic	Neighbourhood City
		Encroachment of flood plain (Ex. Hazira industrial complex project) Clogged and inadequate drainage systems Reclamation on banks of creeks Construction of bridges Suspended solids and non-degradable substances in city effluents Blockage of natural water flow patterns Faulty zoning regulations. Expansion in coastal zone. Sudden release of water at Ukai Dam, 100 km from the city (Ex. Floods of 1998, 2004 and 2006)	Cleaning drainage and sewer systems	Infrastructural Institutional	Concurrent	Engage	Strategic	Neighbourhood City
			Gabion wall construction	Infrastructural	Concurrent	Defend	Strategic	Neighbourhood City
			River alignment and creation of continuous public realm (Ex. Tapi Riverfront development and rejuvenation project)	Infrastructural Institutional Ecological	Concurrent	Engage Defend	Strategic	Neighbourhood City
			Barrage embankment	Infrastructural	Anticipatory Concurrent	Defend	Strategic	Neighbourhood City
			Refurbishment of existing bunds	Infrastructural	Anticipatory Concurrent	Defend	Strategic	Neighbourhood City
			Retaining wall	Infrastructural Institutional	Anticipatory Concurrent	Defend	Autonomous Strategic	Individual Neighbourhood City
			Permeable pavements	Infrastructural Institutional	Concurrent	Engage	Strategic	Neighbourhood

DOI: 10.5821/siiu.10129

4. RESULTS AND CONCLUSIONS

The impact of climate change are aggravated in urban coastal cities which is evident from the recent flood events in the assessed cities. The paper examines the adaptation measures and elements pertinent to physical public space for urban slums in three mega-cities in India. Very little has been done in regard to research and systematization of vernacular measures by urban poor. Formal measures provide less towards the risk and vulnerability of urban poor and in developing countries with higher percentage of slums, addressing floods depend on the ability of slum dweller to respond, physical factors such as protection from water leakages, efficiency of drainage systems and natural typological situations. The excess of water seen as a treat, is progressively being seen as an opportunity with learning how to live in constant adaptation. Adaptation at local level from slum dwellers is very crucial in the present scenario due to multiply causes and impacts of flooding. Reducing the risk and vulnerability depends on the water management in the river catchment area. It is observed, most adaptation projects and measures focused on water sector with infrastructural or institutional interventions. Only few considered interventions with nature-based solutions. Present adaptation actions are often reactive, sectoral, and risk-focused (C. Singh et al. 2021) and does not address the risk and vulnerability for slum settlements. Also, the adaptation measures varies in accordance with the geographic locations and regional identity of urban slums. The high application of bamboo in constructing defence barriers, raised platforms etc. is observed in the case of Kolkata whereas slums in Mumbai comprises strong community networks that provide for behavioural and institutional adaptation.

A more visionary and multidisciplinary approach for flood resilience with potential of urban green spaces, restoring blue and green infrastructure would be acknowledging the risk and vulnerability for urban slums. For instance, urban aquaculture is under-utilized measure, which provide for mitigation adaptation benefits. The framework of adaptation measures grounds for the composition of a systematized lexicon to render urban slums resilient to future floods. Though this assessment composed of only three cities, the study can be representative of other Indian coastal cities with similar environmental and demographic settings.

ACKNOWLEDGEMENT

The author would like to acknowledge the support provided by the Research Centre for Architecture, Urbanism and Design, CIAUD at Lisbon school of Architecture, University of Lisbon in development of this research paper. The support and guidance from professor Maria Cabral Matos Silva Aires Pereira at URBinLAB and professor Sérgio dos Santos Barreiros Proença at formaurbis LAB with CIAUD is overwhelming and necessary towards the on-going research. Also, I recognise the suggestions from Joana de Mesquita Lima at URBinLAB which aided the development of this paper.

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