Adaptation Policy Packages For Transport Sector
- Mumbai Metropolitan Region

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<tr>
<td>BEST</td>
<td>Brihanmumbai Electric Supply and Transport</td>
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<tr>
<td>BMC</td>
<td>Brihanmumbai Municipal Corporation</td>
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<tr>
<td>CIDCO</td>
<td>City and Industrial Development Corporation of Maharashtra Ltd</td>
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<td>CRZ</td>
<td>Coastal regulation Zone</td>
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<td>CTS</td>
<td>Comprehensive Transportation Study</td>
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<td>GoI</td>
<td>Government of India</td>
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<tr>
<td>MCGM</td>
<td>Municipal Corporation of Greater Mumbai</td>
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<td>MHADA</td>
<td>Maharashtra Housing and Area Development Authority</td>
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<tr>
<td>MIDC</td>
<td>Maharashtra Industrial Development Corporation</td>
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<tr>
<td>MMR</td>
<td>Mumbai Metropolitan Region</td>
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<td>MMRDA</td>
<td>Mumbai Metropolitan Regional Development Authority</td>
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<tr>
<td>MSAAPC</td>
<td>Maharashtra State Action Plan for Climate Change</td>
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<td>MoUD</td>
<td>Ministry of Urban Development</td>
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<tr>
<td>PMCCC</td>
<td>Prime Minister’s Council for Climate Change</td>
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<tr>
<td>RoR</td>
<td>Rest of the Region</td>
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<tr>
<td>TDM</td>
<td>Travel Demand Model</td>
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<tr>
<td>TERI</td>
<td>The Energy Research Institute</td>
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<td>ULB</td>
<td>Urban Local Body</td>
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1. Introduction:
Mumbai is ranked as one of the top 10 most vulnerable coastal cities in the world (R. J. Nicholls, 2008). In this study, we try to formulate policy packages for undertaking climate change adaptation strategies in the transport sector of Mumbai Metropolitan Region. The report is structured in three sections.

Section 1 is the introduction to Mumbai’s demography, transport and climate systems. It elaborates on the need for adaptation in the transport sector and the vulnerability of large slum population to extreme climatic events in MMR.

Section 2 presents the review of the literature on the climate change adaptation strategies for transport sector well researched and documented across the world.

Section 3 emphasises on the chosen policy packages from the literature suitable in the context of MMR, the methodologies to incorporate them in the Travel Demand Model and evaluate their impacts.

1.1 About Mumbai:
Since its conception, Mumbai (formerly known as Bombay) has been one of the major trading centres in Indian peninsula due to its strategic territorial advantages. By the middle of 18th century, it received huge reflux of migrant population from across India and continues to remain one of the most populous cities of the world. In 1872, Mumbai was reshaped by the reclamation of seven islands to form a single large landmass which has expanded rapidly in neighbouring geographies. Starting with 1 Municipal Corporation (Greater Mumbai), 13 Municipal Councils, 24 Census Towns and 1166 villages in 1981, the numbers grew and MMR, as we know today, has a total of 8 municipal corporations, 9 municipal councils, 35 census towns and 994 villages in MMR. It has a geographical spread of 4355 sq. km and a population of about more than 23.13 million with almost 92% of the population in MMR is urban population (Census 2011). The sex ratio of female to male in Mumbai Urban Agglomeration was found lower with the figure of 863 females against national urban average of 926 females per 1000 males.

Economic growth is one of the key driving forces for a growth of a city. Being the finance capital of India, Mumbai aspires to be the global finance sector. The GDDP of MMR has been steadily increasing with a CAGR of 14.92% as per Economic Survey of Maharashtra 2011. However, 41.3% of Mumbai households i.e 54% of the population lives in slums occupying only 6% of total land (Census 2011).

1.2 Transport System:
MMR is historically heavily dependent on public transport and walking as a mode of transport. Over 40% of workers in MMR reach their workplace on foot resulting in almost 52% of the total trips per day using walking as a primary mode of transport.

Suburban local trains form the lifeline of Mumbai’s North-South transport. The average trip length of train commuters is very high, almost 24km owing to the unaffordability and restricted supply of housing in and around Central Business District of MCGM. Mumbai suburban railway network covers over about 400 km route network (280 km of Central Railway and 120 km of Western Railway) with 7 million average weekday passenger trips catering at extremely low fares.

In MMR, buses carry 26% mode share of public transport (except walk trips) which attributes to 3.55 million trips if feeder service is not considered. Brihanmumbai Electric Supply and Transport (BEST) along with other municipal public transport undertakings hold a fleet strength of 7544 buses on 5700 routes. In
2005, contract carriers increased from 7396 to 10633 and school buses increased from 912 to 1248. The growth of stage carriers, private contract carriers and school buses in MMR indicates that the public buses are losing their share of public transport. (LEA associates, Comprehensive Transportation Study, TRANSFORM, 2008)

Intermediate Public Transport like autos and taxis play an important role in accommodating travel demands and providing access to trains and buses. Within Greater Mumbai, island city has the highest percentage of cars while eastern suburbs have the lowest. It is observed that during 1996-2005, the proportion of cars is decreasing in the Greater Mumbai whereas it is increasing in Rest of the Region.

On the front of external travel, about 16% of the total freight movement is through-traffic, for in MMR. Mumbai Port and Jawahar Nehru Port are two of the 12 major ports in India. Though Maharashtra is the main hinterland for these ports, Mumbai itself accounts for almost 28% of total traffic originating from the ports. As the railways are already overcrowded by passenger traffic, most of the port evacuation happens by road.

1.3 Climate System.
Situated at the foothills of Sahyadri and on the coast of Arabian Sea West and Thane creek (East), both these factors substantially affect the climate of Mumbai. The average annual rainfall is usually around 2000mm whereas the average minimum and maximum temperatures are around 22°C- 23°C and 30°C and 31°C respectively. Much of Mumbai’s area is close to sea level.

It is well documented how the impacts of climate change will result in sea level rise across the globe. It will severely affect the low elevation coastal cities as they inhabit almost 13 percent of world’s population. Mumbai has already witnessed erratic climate variations. On 26th July 2005, Mumbai (Santa Cruz Meteorological Centre) recorded 944 mm rainfall in 24 hrs, a 1 in 100 years event, resulting in massive flooding and heavy storms in the MMR. Roads and railway lines at many places were under water for more than 24 hours. The rail and road traffic came to a halt. The airport was also closed on account of water logging and climatic reasons.

To understand the vulnerability of Mumbai to climate variability, (Nicola Ranger, 2010) attempted to quantify the flood hazards in Mumbai in terms of future precipitation projections for the 2080s taken from the PRECIS model; a high-resolution regional climate model based on HadCM3. The Fig 2. demonstrates that by the 2080s, the intensity of extreme rainfall could be increased at all return periods. For the shorter return period (more frequent) events, the increase is particularly strong. For example, the intensity of a 2–5 year return period event is almost close to double for the scenario under consideration i.e. SRES A2 scenario.
The analysis indicates that the return period of 944mm rainfall in a day i.e. of July 2005 scale is reduced to around 1-in-90 years in 2080 under this scenario. This analysis does exhibit several limitations and is based on only one climate model, these results indicate Mumbai’s high sensitivity to flood risks in future.

![Graph showing return period of daily maximum rainfall at Santa Cruz historically and in the 2080s (under a high-end scenario).](image)

*Figure 2 Estimates of the return period of daily maximum rainfall at Santa Cruz historically and in the 2080s (under a high-end scenario). (Nicola Ranger, 2010)*

It is difficult to attribute the increase in temperature in a region to specifically climate change, as there can be various factors causing a temperature increase in a complex urban environment like Urban Heat Island and LU&LUC. However, the graph made by analysis in Environmental Status Report (TERI, 2015) clearly indicates the shifting averages of the minimum as well as maximum temperatures in Mumbai region. It could be observed that post-1990s, MMR is experiencing new higher averages for both minimum as well as maximum temperature.

![Graph showing average annual rainfall anomaly.](image)

*Figure 3 Average Annual Rainfall Anomaly, (TERI, Assessing Climate Change Vulnerability and Adaptation Strategies for Maharashtra: Maharashtra State Adaptation Action Plan on Climate Change (MSAAPC), 2014)*

1.4 Need for adaptation in the transport sector in Mumbai:
Mumbai has a population of over 12 million people. Maharashtra State Action Plan for Climate Change (MSAPCC) (TERI, 2014) mentions that geographically, it is a coastal city and some parts are below high tide level. It projects that there will be a 68-73% projected increase in minimum temperature and 10-14 % projected increase in extreme rainfall in Mumbai in 2030 as compared to baseline (1971-2000) by the end of the 21st century. It also estimates that Maharashtra’s coastline can experience about 24 cm to 66 cm of sea level rise by the end of the 21st century.
(TERI, 2014) also carried out district wise vulnerability assessment for MSAAPC. Table 1 presents the different values for each of the variables for the districts of Mumbai and Mumbai suburban which are part of the vulnerability index. The red colored represents either maximum or minimum values among all the districts. For the two out of three important variables in the table, the districts of Mumbai and Mumbai sub-urban give either maximum or minimum values among all the districts in Maharashtra. It can be inferred that there is high exposure of these districts to climate change.

<table>
<thead>
<tr>
<th>EXPOSURE INDICATORS (In The 2030s)</th>
<th>MUMBAI</th>
<th>MUMBAI (Suburban)</th>
<th>MAXIMUM</th>
<th>MINIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme rainfall</td>
<td>12.95</td>
<td>10.95*</td>
<td>28.32</td>
<td>10.95</td>
</tr>
<tr>
<td>Heat index</td>
<td>66.2</td>
<td>57.382</td>
<td>66.21</td>
<td>44.7795</td>
</tr>
<tr>
<td>Rainfall percentage change</td>
<td>18.727</td>
<td>20.565</td>
<td>36.77</td>
<td>10.777</td>
</tr>
</tbody>
</table>

Mumbai has a complex geography as many areas of the city like Bandstand, Cuffe Parade, Mahim Creek, Backbay and Bandra Kurla Complex have been reclaimed. As an urban area, Mumbai is majorly concretized, resulting in very low percolation of ground water. Several natural wetlands within the city are either reclaimed or clogged due to the dumping of waste or construction debris. Apart from being only a few meters above sea level, it has four rivers flowing through it, thus increases its vulnerability to flooding. Direct impacts from sea level rise include inundation, coastal erosion, land loss, increased storm flooding and damage. All these will have a direct impact on people’s livelihood causing displacement (IPCC ARC3).

It is important to adapt Mumbai transport infrastructure and make it resilient to the risks and threats posed by climate change. Mumbai is the finance capital of India. Its strategic location, high population density and economic growth also result in a higher potential for damages. Transportation infrastructure is long-lived capital intensive investments which provide critical functions in post-disaster period. Fast recovery of transportation facilities directly impacts disaster resilience of the area (Channing Arndt, 2012). Also, (Fan, 2002) emphasized that the impacts of public investments in roads and the broader infrastructure are multi-fold with high economic returns. The better the conditions of the roads to serve
the functions of transport mobility and connectivity, the better are the chances of the country to prosper at faster rates. Fig. 6 illustrates the depth of flooding in MMR region during July 2005 floods. The regions flooded for more than 3 m have suffered severe loss of property (Chitale, 2006).

1.5 Slum population distribution in Mumbai:
As per Census 2011, Total no. of Slums in Mumbai city numbers 1,135,514 in which population of 5,206,473 resides. This is around 41.84% of total population of Mumbai city. Dharavi, one of the largest slums in the world is spread across 520 acres and is a home to about 1 million population. MMR suffers extensively due to the extreme gaps in demand and supply of basic facilities like water, sanitation, health services, education etc. Unchecked land prices and unaffordable housing has forced the poor to live in informal settlements. Socio-economic indicators of the slum population indicate that it is the most vulnerable section of the Mumbai population (O'Hare, 1998).
Approximately 55% of Mumbai’s population resides in slums. They are mostly located in low-lying areas close vulnerable places like marshes. (O’Hare, 1998). Fig 7 shows that their location wrt. flood prone areas. These informal settlements routinely get flooded during monsoon season. The slum dwellers often seem to have devised mechanism and their own methods to deal with the risks of loss and distribution of risks during and after such flood events (UDRI, 2017).

1.6 Plausible causes of urban flooding in Mumbai:
Frequent traffic disruptions due to water logging have become a norm in every monsoon season in Mumbai. There is a definitive relationship between rainfall and runoff caused due to both natural and man-made reasons which needs further attention in Mumbai. Following are some of the major causes of flood hazard in Mumbai.

1. Inadequate storm water, sewerage and solid waste disposal systems: Mumbai has many severe deficiencies in its storm water drainage systems which form the vital component of urban civic
management. Many gradients are flat, number, design and coverage of drains is inadequate and access for maintenance is difficult. Similar is the condition of sewerage systems. More than half of the city's population lives in unplanned, ill-managed slums which are the major cause of overburdened, inadequate sewerage system. Also, in many of the suburban areas, sewerage and storm water drainage are connected which need be segregated. (Envis Centre for Human Settlements, 2010)

2. High tide levels: The compounded impact of heavy rainfall and high tides often leads to water logging and floods (TERI, 2015).

3. Changes in natural and manmade landform- Reclamation, which originally started to link the seven islands, was eventually extended extensively into other parts of Mumbai to accommodate the ever-increasing population of Mumbai. The land reclaimed from the sea is developed and used by both large slum colonies and planned construction. However, some of this development has encroached upon the storm water drains, wetlands, floodplains and mangroves which were crucial buffer zones and provide exits for storm-water into the sea.

Figure 7 Loss of Wetlands and open lands, Land Use map of Mumbai 1973-2010 (Hossein Shofizadeh Moghadam, 2013)
2. Review of Adaptation measures in transportation sector across the world.

It is well known that transport system performs much worse under extreme events and adverse climatic variations. However, detailed attention was paid very recently to understand the specific impacts of climate change in the transport sector and understand the increased vulnerability of transportation assets to climate change predictions. (Channing Arndt, 2012). The risks are accentuated when the networks are large and population density is high, as in the case of Mumbai. As already mentioned, Mumbai’s transport sector has historically played an important role in the city's economic growth and will continue to do so. Increased risks and uncertainties due to climate change will demand more attention to be paid to adapt the transport sector and make it more climate-resilient. (Mark J. Koetse, 2012); (Rosenzweig, 2011); (Tiffany Finley, 2011); (Andrey and Mills., 2002); (Titus, 2002); (Wooler, 2004) have researched and documented various recommendations for adaptation strategies in transport sector across the globe. These recommendations can be categorised to community-based, infrastructure based or institution based approaches to adaptation strategies.

Community-Based Approach- This approach acknowledges the reality that the impacts of climate change affect the poor and marginalised population disproportionately. There is a definitive difference in the socio-economic status of urban dwellers which exposes them to the hazards in different ways. The poor experience variety of existing vulnerabilities which are exasperated due to climate change. Therefore, additional efforts must be taken to build adaptation capacities for this section of the society.

This approach also draws support from the co-benefits approach. Co-benefits is the idea that development actions can sometimes bring climate gains—is at the core of our National Action Plan on Climate Change (PMCCC, 2009) (Navroz K Dubash, 2013). The Mumbai city draws a large number of migrants from all over the country and has one of the largest slum population in the world. There are historical reasons related to how the settlement happened in the city 1960s onwards and how the city is economical, socially and culturally structured. Social discrimination against migrants, lower caste, former mill workers and Muslim minority, the groups that are marginalised tend to inhabit the more vulnerable, flood-prone areas owing to their social networks, lack of assets (especially land) etc. Demography, literacy, gender issue might not be directly related to climate change adaptation but they do increase the existing vulnerability and access to transport networks.

Infrastructural Approach- This approach aims to quantify the infrastructure exposed to the risk of climate change to aid climate resilient planning and develop a climate vulnerability assessment for infrastructure services. It notes that the degree to which a city is vulnerable to climate hazards depends not only on the frequency and intensity of climate-related events but also on the local capacity to respond to them by design upgradations, better O&M, technical improvements etc. However, sometimes soft infrastructure like eco-sensitive areas are given less priority than hard infrastructures like roads, bridges or airports.

Institutional approach- It looks at the adaptation deficit from the side of institution failings and suggests strategies based on these deficits. It basically focuses on the institutional issues like inadequate drainage and sewer lines, high slum population, lack of coordination between transportation department and land use planning department, inadequate design standards or zoning regulations (Land Use zones/ Coastal Zones) etc. Further, it pinpoints two issues- one, the lack of financial capacity to maintain and renovate infrastructure. Two, the lack of institutional capacity to efficiently use manpower and resources (Hunt & Watkiss, 2009).
Following is the list of some of these adaptation strategies compiled from the literature across the world for transport sector grouped in three different categories focusing firstly on identification of vulnerable infrastructure; secondly on development of climate-resilient infrastructure based on understanding of impacts of climate change and thirdly on building adaptive capacity to maintain and manage the existing and new infrastructure.

**Vulnerability assessment of transport infrastructure:**

1. Mapping of vulnerable transport infrastructure assets at facility and network level
2. Mapping of critical infrastructure with high impact zones
3. Economic and non-economic cost estimation of climate change impacts on transportation infrastructure
4. Assessing direct and indirect impact of resilient transportation on poor and vulnerable population

**Climate Resilient Infrastructure Development:**

1. Retrofitting and protecting existing infrastructure
2. Building climate-proof new infrastructure

**Impacts of Climate Change on Transportation Infrastructure:**

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Impact on Transport Infrastructure</th>
<th>Adaptation policy</th>
<th>References</th>
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<tbody>
<tr>
<td>Temperature</td>
<td>Affects speed and modal choice</td>
<td>- Laying of more heat resistant materials such as asphalt for roads &lt;br&gt;- More heat resistant metals for rail and bridge connections &lt;br&gt;- Better maintenance and operation</td>
<td>(Mills, 2002), (Hoo, 2002)</td>
</tr>
<tr>
<td>Floods</td>
<td>Congestion, delays and accidents</td>
<td>- Construction of dykes and barriers &lt;br&gt;- Clean and well-designed drainage systems &lt;br&gt;- Better forecasting facilities &lt;br&gt;- Availability of sufficient road cleaning equipment &lt;br&gt;- Provision of enough slope/gradient &lt;br&gt;- Availability of alternate routes and modes of transport &lt;br&gt;- Construction of porous asphalt roads</td>
<td>(Kinsella Y, 2005), (InfrastructureCanada, 2006)</td>
</tr>
<tr>
<td>Increased Frequency and intensity of extreme events</td>
<td>Cancelled routes, damage to vehicles, accidents</td>
<td>- Better designing standards for storm water drainage &lt;br&gt;- High clearance for bridges &lt;br&gt;- Continuous pumping &lt;br&gt;- Better evacuation facilities by competent disaster management team</td>
<td>(Kinsella Y, 2005), (Mills, 2002)</td>
</tr>
</tbody>
</table>
Sea level rise | the threat to coastal construction, inundation, land loss | - Heavy pump use
- Construction of sea barriers, walls, dykes
- Elevation of coastal roads to move traffic to higher ground | (Kinsella Y, 2005), (InfrastructureCanada, 2006), (Titus, 2002)

Adaptive capacity:

IPCC defines adaptive capacity as “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences”. Adaptive capacity in the transportation sector will mean incorporating the impacts, risks and uncertainties associated with climate change in the planning process itself.

1. Dynamic Adaptive Planning to produce an adaptive plan for long-term management (Marjolijn Haasnoota, 2012)
2. Setting and implementation of early warning systems
3. Coastal Zone Regulation and Management
4. Additional communication between transportation engineers and climate scientists to incorporate climate scenarios in designing coastal highways
5. Prediction of high priority and quick recovery routes
6. Regular review and modification of O&M practices
7. Transportation Asset Management (TAM) to incorporate weather and climate-related risks in decision making regarding service life, condition etc. in Life Cycle Assessment of transportation through concerted research and data collection.
8. Better stakeholder management and information flow between weather and traffic control departments.
9. Better information network through news, radio and smartphones on flooded networks and alternate routes.

3. Selected Policy Packages for Mumbai Metropolitan Region:
Though the review of literature on climate change adaptation policies for transport sector across the world provide a plethora of options to be implemented in Mumbai, the city-specific restraints like lack of data, institutional capacity, scale of implementation, regional political agendas and feasibility of incorporating the policies in Travel Demand Model for MMR compel us to choose following policy packages to proceed one step ahead in the direction of adopting sustainable policies for climate change adaptation in transport sector in MMR.
The loss due to the failure of the transport network in direct economic terms is difficult to calculate as associated the scale of physical damage, delays caused, loss of life or investments involved are all different in different cases. Critical infrastructure is ‘any facility/system which is essential for the functioning of the society and their breakdown/failure will cost significant damage to the society’ as defined by NIDM, India. It is important to identify them and undertake necessary vulnerability reduction measures like high pump use, early warning systems, elevated roads and porous asphalt pavement as a starting point.

(Schulz, 2007) presented a methodology to identify critical transport infrastructure. For this, the number of passenger vehicles on a link will be taken as a reference for the damage potential. The link with the highest number of vehicles would, therefore, entail the highest consequences if interrupted. Similar analysis will be carried out for rail, bus, metro networks with highest ridership links. Fig 8 demonstrates the conceptual methodology of incorporating the above-mentioned strategies in Travel Demand Model as it will influence the modal split and trip assignment in the horizon year.
3.2 Urban flooding/ water logging

As mentioned earlier, MMR suffers from urban flooding and water logging problem every year due to a variety of reasons like heavy rainfall, high tide level, high built up area etc. The main objective of this policy package is to focus on avoiding urban flooding and associated losses.

Restricted use of low lying areas- The areas with flood plains experience severe risk of flooding should be delineated and restricted for use under certain conditions. The owner and the use should be made aware of the risks. The areas should have low FSI and special taxation of developers especially of drainage is not designed for worst-case scenarios (Envis Centre for Human Settlements, 2010).

Avoid Destruction of Eco-sensitive zones- In the 1990s, the mangroves around Mumbai covered around 37 km² (3700 ha) but since then in the last decade, Mumbai has almost lost 40% of its mangroves largely because of reclamation for housing, slums, sewage treatment and garbage dumps. Had Mumbai’s Mithi river and Mahim creek mangroves not been destroyed by builders, fewer people would have died and the property damage would have been dramatically less (Soonabai Pirojsha Godrej Marine Ecology Centre, 2013). (Mark Everard, 2014) has graphically illustrated the storm protection due to mangroves during the tsunami and is also recognised in other literature.

Mangrove destruction is an offence under The Environment (Protection) Act, 1986, which declares a Coastal Regulation Zone (CRZ) in which debris dumping, land reclamation and bunding are restricted to protect the coastal environment. A preliminary report on mangrove destruction on private land revealed a total of 115 cases between April 1, 2016, and March 31, 2017, of which 74 cases were recorded between January and April this year and 21 cases were filed. The report also states that since 2013, the city has seen 354 cases of mangrove destruction with 131 first-information-reports (FIRs) being filed, but no arrests or convictions in any of the cases (Hindustan Times, 24th Apr 2017).

In coastal areas, the conservation or restoration of habitats (e.g., mangroves, wetlands, and deltas) can provide effective measures against storm surge, saline intrusion, and coastal erosion by using their physical characteristics, biodiversity, and the ecosystem services they provide as a means for adaptation (Borsje et al., 2011; Jones et al., 2012; Cheong et al., 2013; Duarte et al., 2013b).

Similar destruction of eco-sensitive mangroves is feared during the construction of new coastal road/western freeway and Navi Mumbai airport. The CRZ notification is amended in the case of coastal road to
allow unhindered land reclamation for 186 hectares and the hacking of mangroves. Though precautionary measures like replanting of mangroves have been suggested by MoEF before notifying the amendment, their feasibility is under question.

_Flood Rescue Centres_ - Currently, the flood rescue responsibility in the city lies with the fire brigade department. There is a necessity of added capacity and training for more efficient rescue and evacuation process. Also, the Chitale fact-finding committee that was set up after July 2005 floods suggested additional transport vehicles to be deployed and alternate routes made available for them from fire stations to flooded areas. Fig 9 suggests that there is a need for more proliferation of fire stations to cover more vulnerable areas in the city.

The Fig. 10 illustrates the location of fire stations vs the location of vulnerable areas in MCGM. Similar maps will be prepared for MMR to assign trips from fire stations to flood-prone zones where the depth of water logging was more than 2 m in July 2005 floods. Also, we can demark the transport networks present in the eco-sensitive mangrove areas and find alternative routes for the same. Fig. 10 demonstrates a conceptual methodology to incorporate the strategies to avoid urban flooding/ water logging in the Travel
Demand Model. The strategies will impact the horizon year transport network as it will influence the origin-destination of trips, trip assignment and trip distribution.

**Figure 10 Methodology to incorporate Policy Package 2 in TDM**

3.3 Community-based adaptation

**Policy Package 3**

**Slum Rehabilitation and Relocation** -
Maharashtra State New Housing Policy & Action Plan, 2015 (GoM, 2005) lays out Strategy for Continuous Creation of Land Bank and Making Housing Affordable in urban areas. It has set a target to create 11 lakh homes in the MMR and 8 lakh homes outside MMR by 2022 by rehabilitation, relocation, redevelopment and Greenfield project development of slums through continuous creation of land banks on private and govt. lands. For this a master plan of the lands in the Government Land Bank by pooling the lands available...
with ULBs, MIDC, CIDCO, MHADA and MMRDA etc. is to be prepared by MHADA. This map can help understand the relocation and distribution of slum population in the future scenarios.

Slum Rehabilitation Authority (SRA) also envisages to make Mumbai 'Slum-free' by up gradation, rehabilitation and redevelopment of slums and prepare maps for the same. The slum act will also be amended for evacuation of slum dwellers in condition if 50% of the slum dwellers have moved out. Various other acquisition policies will be undertaken. Access to these maps will be attempted to understand the movement of slum population from current vulnerable areas to less vulnerable, affordable housing areas in future.

Early warning systems for hazard prone areas-
There will be increased submergence of land in coastal cities due to sea level rise which causes loss of life and property. (National Disaster Management Authority, 2010) recognises this threat but also mentions that the sea-level rise is now inevitable. The only adaptation strategy is to build effective flood defence. For example, the Municipal Corporation of Greater Mumbai (MCGM) is now in the process of installing floodgates in combination with high-discharge pumps at eight of the hitherto ungated sea outlets.

There was no reliable real-time rainfall forecast mechanism at that time of July 2005 floods. IMD was unable to issue flood warnings in advance due to the lack of equipment like tipping bucket rain gauges, etc. Disaster managers lacked the support of technology to know the spatial or temporal variation of rainfall in real-time. Therefore, MCGM and IITB installed 35 automatic weather stations (rain gauges) in June 2006. More such installation of the state-of-the-art technology for early warning of heavy rainfall or high waves etc. needs to be undertaken. This promotes disaster preparedness and avoid large loss and damages of life and property.

Such attempts at slum relocation and rehabilitation will alter the spatial distribution of planning parameters (population and employment). It will also have an influence on the trip distribution and assignment.

Study Area Zoning
Horizon Year Transport Network
Horizon Year Population and Employment
Travel Demand from Traffic Surveys

Trip Ends, TLFD, Skimmed Matrix (Shortest Path), Travel Demand Matrix

Trip Generation
Trip Distribution
Modal Split
Trip Assignment

Community-Based Adaptation

Horizon Year Link Flows and V/C

Vehicle Kms Travelled (VKT)
Volume/ Capacity ratio (V/C)

Inputs
Output

Figure 11 Methodology to incorporate policy package 3 in TDM
References


Titus, J. (2002). Does Sea Level Rise Matter to Transportation Along the Atlantic Coast?. The potential impacts of climate change on transportation, 135.


TERI. (2015). Environmental Status Report for MMR. MMRDA.
