



A REPORT

ON

**ADAPTATION POLICY BUNDLES FOR
TRANSPORTATION SECTOR**

Case city of Bangalore City

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1.1 INTRODUCTION

Urban floods are the main focus for the adaptation part of the project and so most of the policies have been formulated keeping urban flooding in mind. Climate change is inevitable, however, adaptive strategies help in strengthening the road network system and act as resilient measures against urban floods. Figure 1 shows the sequential steps followed in Policies formulation for Adaptation.

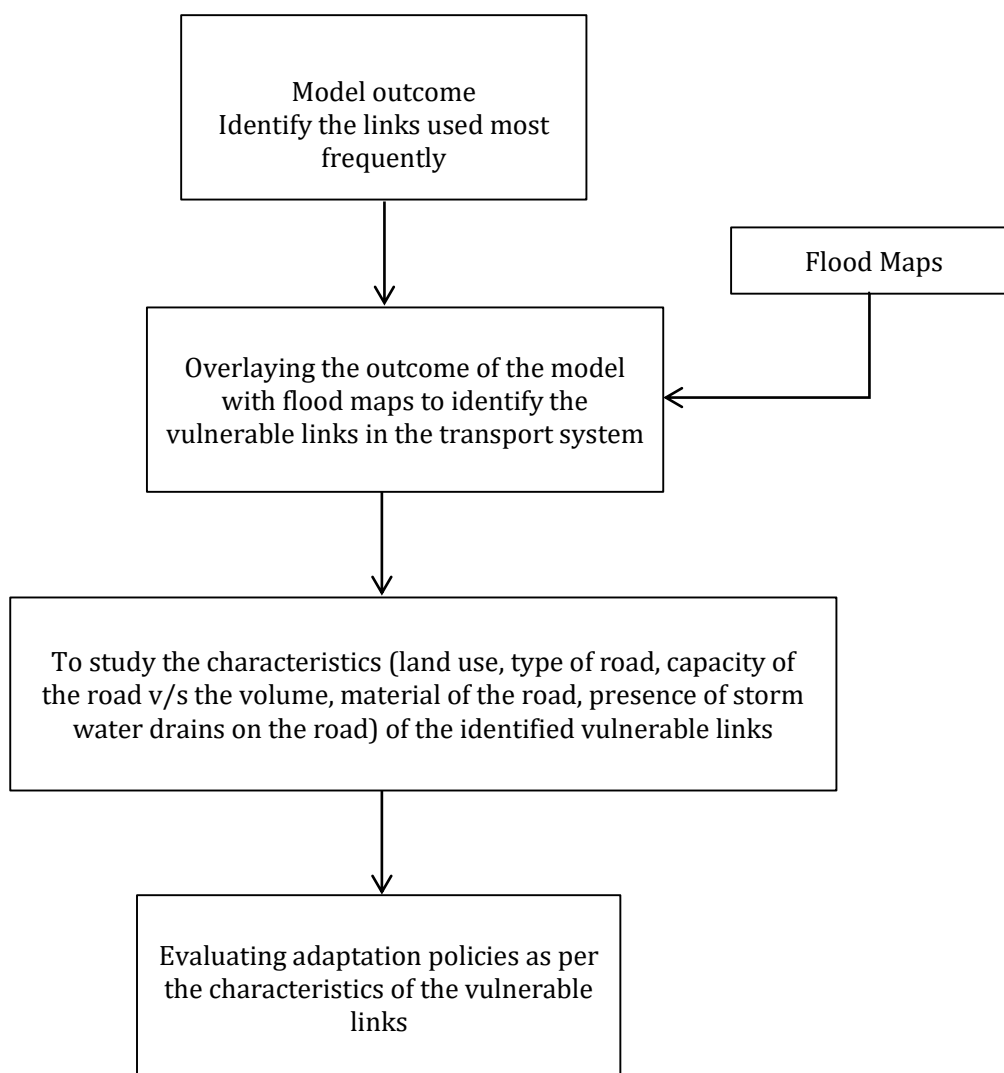


Figure 1: Policies formulation for Adaptation Flow Chart

The report is organised into three sections. In Section 1.2, the policy bundles are discussed in detail and also the impact of the policies on the TDM are presented. In Section 1.3, evaluation-ready description of the policies is made.

1.2 POLICY BUNDLES

The policy bundles for adaptation are listed in the table below.

Table 1: Adaptation Policy Bundles

Policy Bundles
BUNDLE 1
1.2.1.1 Replacement of impermeable road surface with permeable material in all vulnerable areas
1.2.1.2 Slum relocation and rehabilitation
1.2.1.3 Drainage in vulnerable road sections to be parallel to the slope of the area
1.2.1.4 Purchase or acquire land to conserve the vulnerable areas
1.2.1.5 Construction of redundant infrastructure
BUNDLE 2
1.2.2.1 Sending alerts via apps and messages about alternative route from hazard prone network
1.2.2.2 Rerouting people in case of unfortunate activity
1.2.2.3 Restricting development in low lying or vulnerable areas
1.2.2.4 Slum relocation and rehabilitation
BUNDLE 3
1.2.3.1 Replacement of impermeable surfaces with permeable material in all vulnerable areas
1.2.3.2 Integrate land use development and transportation planning
1.2.3.3 Drainage in vulnerable road sections to be parallel to the slope of the area
1.2.3.4 Road closure during extreme weather conditions

Each policy bundle has a certain number of policies amalgamated together to bring out specific results after implementation. These sub-policies affect the travel demand modelling at various stages. A particular policy from a policy bundle might have an impact on more than one stage of the Travel Demand Model (TDM). In the following sections, the above policies are discussed in detail and also the impact of the policies on the TDM are explained for each policy bundle separately.

The policies of each policy bundle have been explained in detailed below:

Policy Bundle 1: Vulnerable Areas

1.2.1.1 Replacement of impermeable road surface with permeable material in all vulnerable areas

Vulnerable areas or low lying areas and areas which either have no or inefficient storm water drains. Rainwater gets accumulated in the low lying areas, thereby, blocking the road, resulting in higher vehicle hours travelled and higher vehicle kilometers travelled. On the other hand, roads with an obsolete or no storm water drainage system also gets clogged resulting in the same issues of delay.

As a strategy to overcome or at least increase the rate of water permeation into the road, the material of the roads in the vulnerable areas can be replaced with permeable materials. This will also help in reducing the surface run off.

This policy will have an impact on the Trip Assignment of the TDM. This is because if the material of the roads in vulnerable sections gets replaced by permeable material then the water clogging will reduce and thus people will be able to take the shortest routes to their destinations instead of either taking longer alternative routes if present or wait for the water to drain out.

1.2.1.2 Slum relocation and rehabilitation

Generally, slums are found in the low lying areas because these areas are cheaper or no development exists there. When urban floods occur, their neighbourhood gets flooded with water which further blocks the roads. Due to this, their mobility is hindered. Since other areas are unaffordable for these people, they continue to stay in such conditions. This policy aims to put an end to their grievances by relocating them to other areas which are not vulnerable to urban floods. This can be done by providing incentives to these people to shift to better quality spaces.

Since the slums will be relocated to a new place, this will affect the number of trips being produced and attracted to zones. This policy thus impacts the productions and attractions to each zone in the demand model.

1.2.1.3 Drainage in vulnerable road sections to be parallel to the slope of the area

The slope of the pipelines in a storm water drainage system must be parallel to the slope of the area because there is no additional force that makes the water flow. The slope of the drain helps the water to flow from the tertiary pipelines to the trunk line. In case the slope is not parallel, the water might stop flowing in the pipelines and thus lead to ineffectiveness of the drainage system to seep water off the roads.

This policy will also impact the Trip Assignment as people can take alternate and shorter routes due to the reduction in the level of vulnerability of the roads.

1.2.1.4: Construction of redundant infrastructure

It is always better to have redundancy in the road network. During the times of unfortunate events like flooding, if a certain section of people are connected with only one single road and it gets flooded, then that particular section is cut off from their usual activities. In such situations it is always good to have another road link that can connect to a location where there is no flooding. This policy will have an impact in producing trips which is in trip generation and route assignment.

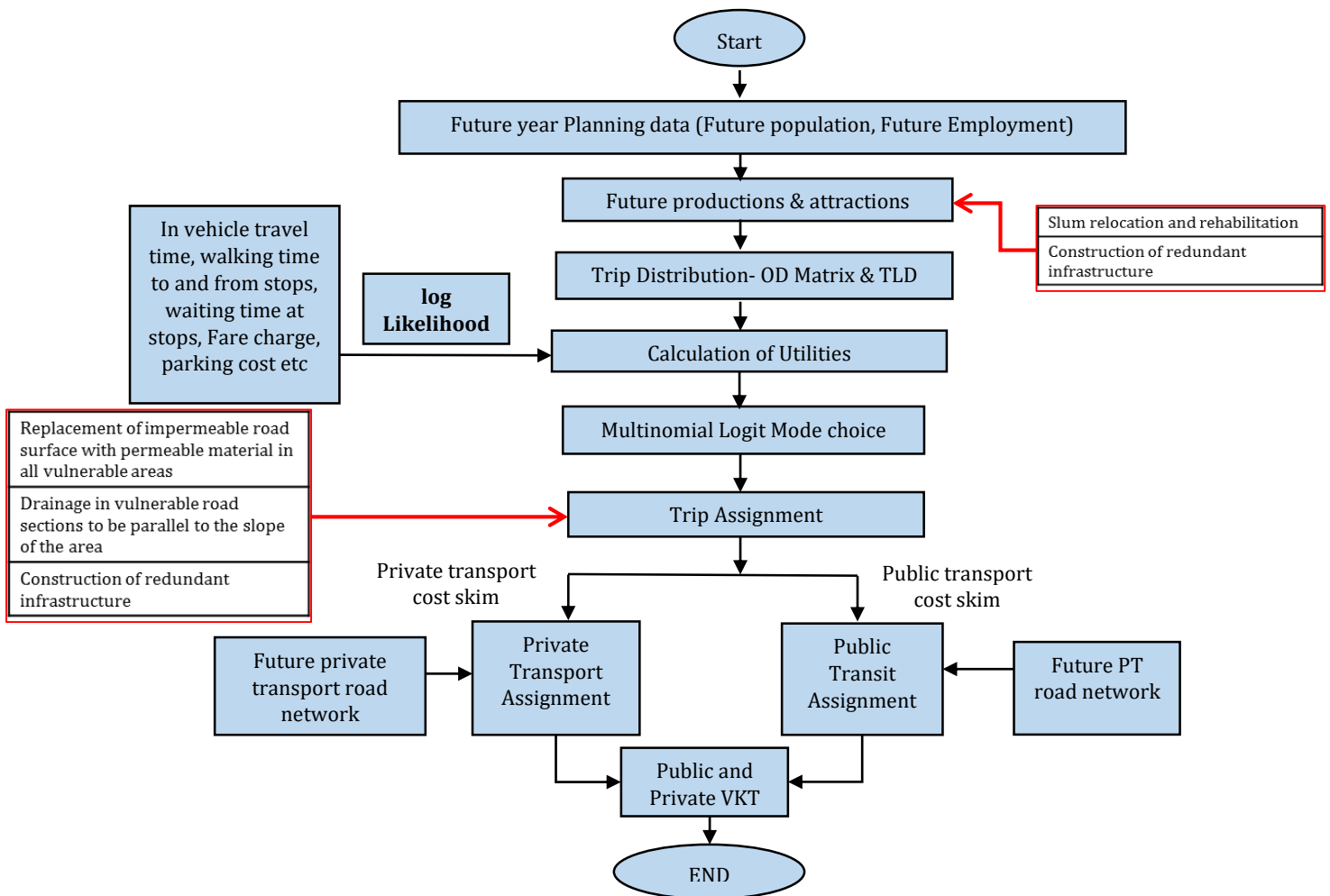


Figure 2: Impact of policy bundle 1 in Four stage modelling

Figure 2 highlights the areas where the policy bundle 1 influences the four stage modelling.

Policy bundle 2: Information and Relocation

1.2.2.1 Sending alerts via apps and messages about alternative route from hazard prone network

To minimize the inconvenience caused due to the urban flooding, alerts via apps and messages about blocked roads and the alternate routes available could be sent to the city. This policy will impact the trip assignment and the trip production and attractions table.

Scenario 1: Traveler yet to start a trip received the alert. He might cancel his trip. This will lead to reduced productions and attractions.

Scenario 2: Traveler on route receives alerts about a blocked link further ahead on his route, he could be assigned a different route altogether to save time.

1.2.2 Rerouting people in case of unfortunate activity

In case of an unfortunate activity, people could be assigned different routes to their respective destination thus avoiding the flooded routes and saving the extra kilometres and hours travelled.

Therefore, this policy affects the trip assignment in the TDM.

1.2.3 Restricting development in low lying or vulnerable areas

The low lying or the vulnerable areas are usually at the outskirts of the town and prone to floods. As the areas are cheaper (with no restrictions by the municipality), some people construct homes and due to high economic demands at other places, they continue to stay in such conditions.

Through this policy, the development of residences will be restricted at such low lying and vulnerable areas and incentives can be provided for the people to shift near the city centers.

This policy will affect the trip generation phase of the model. This because of the change in the locations of certain groups the productions of the zones will change.

1.2.4 Slum relocation and rehabilitation

The impact of this policy is the same as policy no 1.2.1.2.

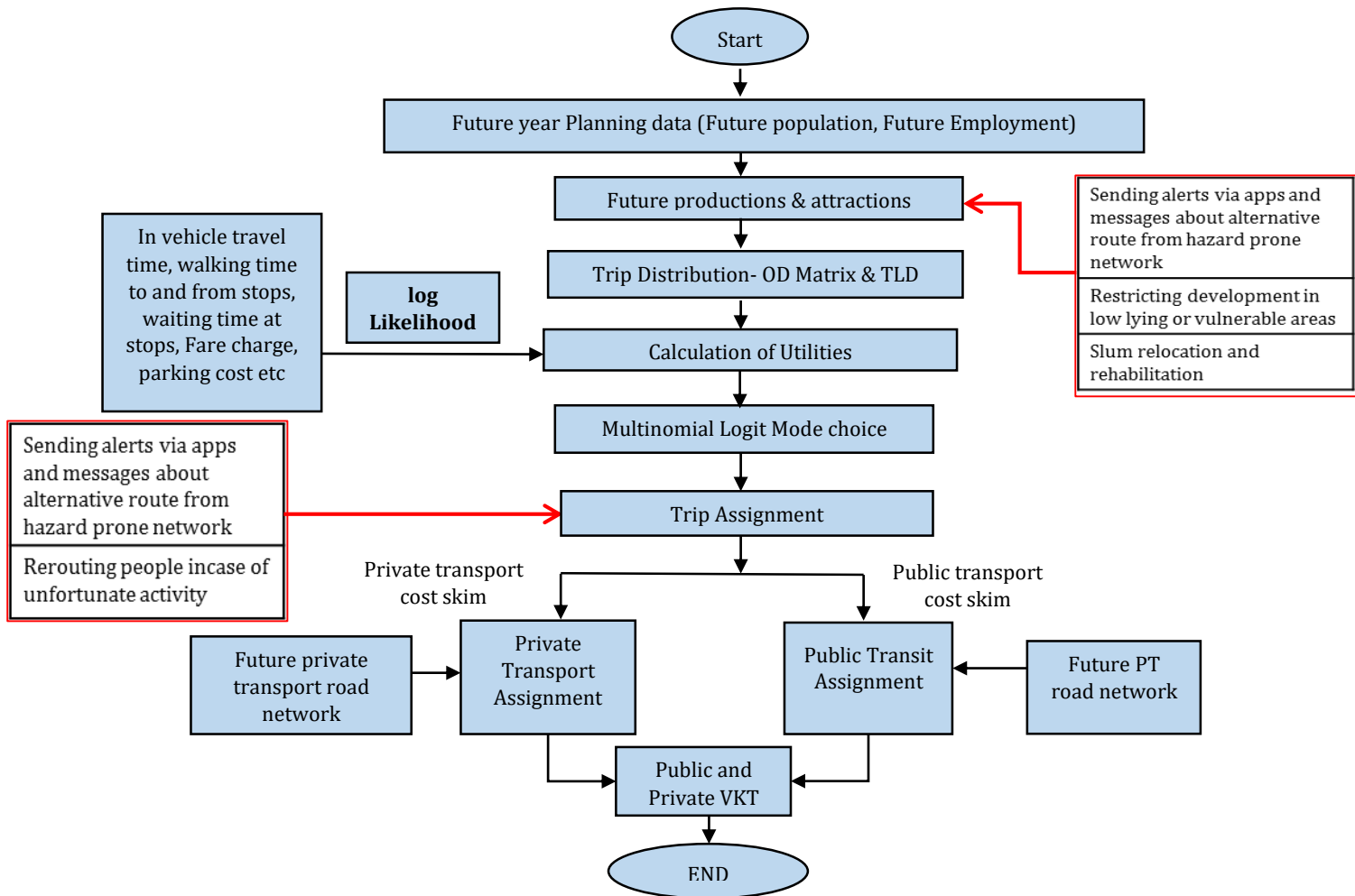


Figure 3: Impact of policy bundle 2 in Four stage modelling

Figure 3 highlights the areas where the policy bundle 2 influences the four stage modelling

Policy Bundle 3: Infrastructure development

1.2.1 Replacement of impermeable road surface with permeable material in all vulnerable areas

The details of this policy and its impact are discussed in Section 1.2.1.1.

1.2.2 Integrate land use development and transportation planning

This policy aims to reduce the trip lengths so that people can shift from private to public or non-motorized transport systems. In India, a lot of departments do not work in cohesion. As a result, a land use map is never in congruence with the transportation network. This policy aims to fix the issue by integrating the land use planning and transport planning. Transit Oriented Development is one such development that can be done for this policy.

This policy will mainly affect trip generation and distribution of the model. Since it deals with land use, it will impact the productions and the attractions. Since integration will lead to smaller neighborhood, the origin and the destinations might change as well. This will impact the trip distribution in the model.

1.2.3 Drainage in vulnerable road sections to be parallel to the slope of the area

The details of this policy and its impact are discussed in Section 1.2.1.3.

1.2.4 Road closure during extreme weather conditions

In case of road closure due to urban floods in a particular link, the trip assignment will be affected since a different route will have to be assigned for the trip. Thus, this policy affects the trip assignment of the TDM.

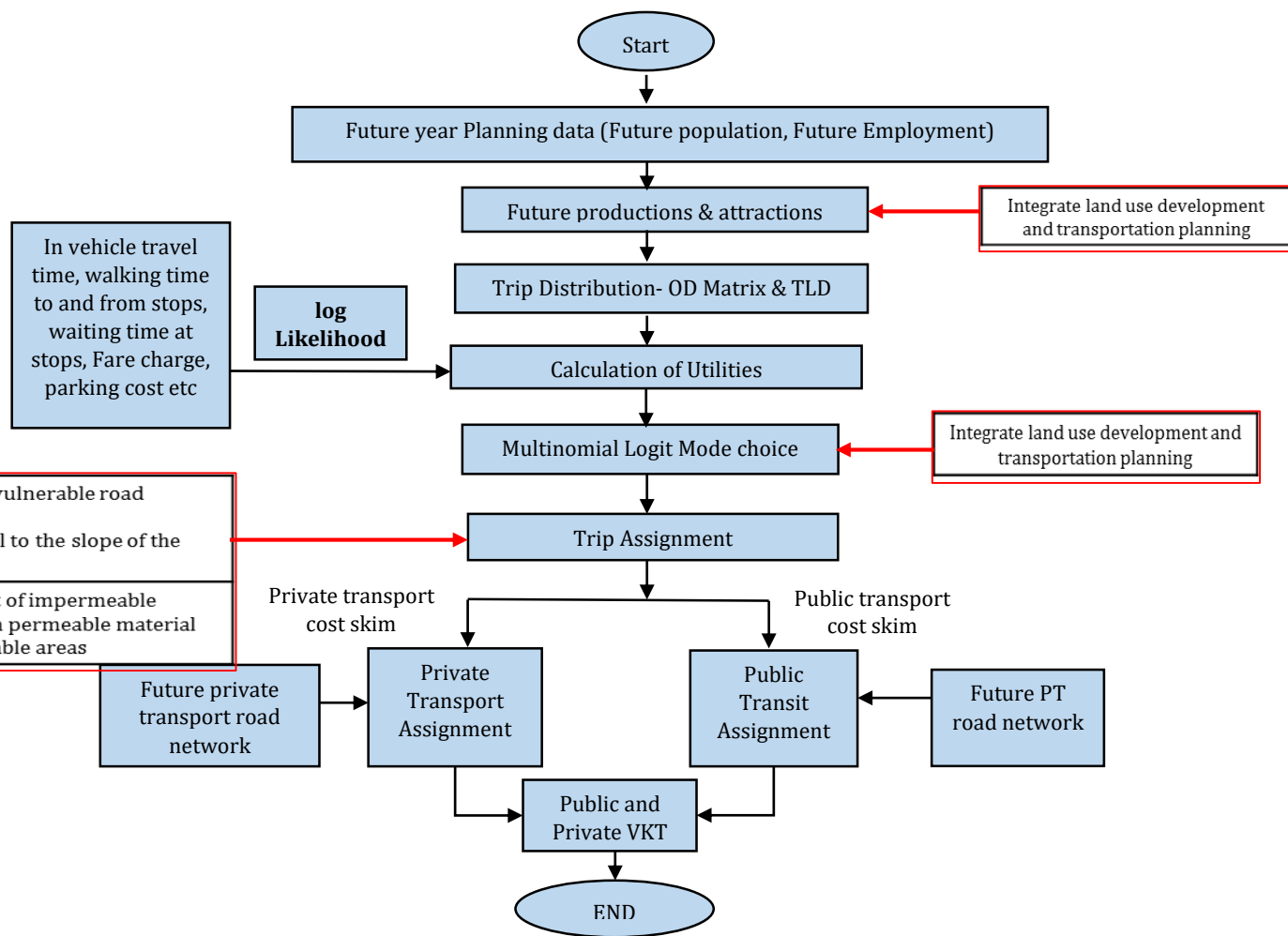


Figure 4: Impact of policy bundle 3 in Four stage modelling

Figure 4 highlights the areas where the policy bundle 2 influences the four stage modelling

1.3 EVALUATION READY DESCRIPTION OF POLICIES

The bundles mentioned in Section 1.2 have some policies common across the bundles. Evaluation of each of these policies is described below. A table with the details of the costs involved in the policy implementation and the performance indicators that evaluate the policy is presented.

1. Replacement of impermeable road surface with permeable material in all vulnerable areas:

Costs	Indicators	
	Before Policy	After Policy
	Cancelled Trips	Reduction in Cancelled Trips
Construction cost	VHT	Reduction in VHT
Maintenance cost	Road Maintenance	Reduction in Road Maintenance
	Parking lot damages	Reduction in Parking lot damages

*VHT-Vehicular Hours Travelled

In order to evaluate the policies, an assessment should be made with the performance indicators. For this policy, the vulnerable road links to flooding will be found out using the spatial analysis. The pavement at such segments where the flooding is more will be replaced by a permeable material which can drain off the flood. This helps in reducing the flooding on the road because there is not stagnation of water on the road. Before implementing the policy some indicator values should be estimated.

- Cancelled trips will be estimated by looking at the number of vehicles that are going to pass through a heavily flooded link. This indicator value will be estimated before and after the implementation of the policy.
- Since the flooding levels have reduced, the speed of the vehicles will increase. These increased speeds will be an input in the TDM and using the distance between centroids the travel times can be estimated. After the route assignment is completed vehicle hours travelled will be one of the outputs which can also be checked before and after the implementation of the policy
- Road maintenance and parking lot damages are infrastructure related cost indicators and they can be estimated using the current market prices. The cost for maintaining the road per km will be estimated before and after the policy implementation. Similarly for the parking lot damages also the damage cost per meter will be estimated before and after the implementation of policy.

The values of the indicators before and after the policy implementation will be compared to check if the policy is effective or not.

2. Slum relocation and rehabilitation:

Costs	Indicators	
	Before Policy	After Policy
Demolition cost	VHT	Reduction in VHT
Relocation cost	VKT	Reduction in VKT
Rehabilitation cost	Household Level damages	Reduction in HH level damages
Cost of compensation		

*VHT-Vehicular Hours Travelled VKT-Vehicular Kilometers Travelled

There are various costs involved in this policy which are shown in the table above. The performance indicators for this policy will be vehicle hours travelled (VHT), vehicle kilometers travelled (VKT), household (HH) level damages. The poor sections of people have vulnerable houses that are prone to damage during floods. The damage costs should be estimated before and after the relocation of the slums. If there is a reduction in the household level damage cost, then the policy is effective. With the change in the location of the slum, there will be a change in the distance of their travel. The relocation and rehabilitation should be done in such a way that there will less VHT and VKT.

3. Drainage in vulnerable road sections to be parallel to the slope of the area:

Costs	Indicators	
	Before Policy	After Policy
	Cancelled Trips	Reduction in Cancelled Trips
Construction cost	VHT	Reduction in VHT
Maintenance cost	Road Maintenance	Reduction in Road Network Damages
	Congestion level	Reduction in congestion

*VHT-Vehicular Hours Travelled VKT-Vehicular Kilometers Travelled

The slope of the drainage should be designed parallel to the camber of the road so that the water from the road can easily drain into the drainage. This helps in reducing the level of flood on the road which reduces the VHT, damages to road and also vehicles. The reduction in flood also reduces the cancelled trips and congestion. The change in the Congestion level can be estimated by observing the difference between the volume of vehicles at a particular section of the road before and after implementation of policy. VHT, Cancelled trips, road maintenance can be calculated as mentioned earlier.

4. Purchase or acquire land to conserve the vulnerable areas:

Costs	Indicator	
	Before Policy	After Policy
Maintenance cost, TDR cost	VKT, VHT, HH level damage reduction	Reduction in VKT, VHT, HH damages

*VHT-Vehicular Hours Travelled VKT-Vehicular Kilometers Travelled HH-HouseHold

The government should purchase vulnerable land from the people who are willing to sell them and conserve the areas with very less or in fact no development. This involves in maintenance cost of the vulnerable land and transfer development right costs. Because of conserving such areas there will be a difference in trips produced and attracted. Also, there will be changes in VHT and VKT because of change in the land use and change in the distances depending the location of the vulnerable area. For example, consider a location that is so vulnerable to flooding that even a small amount of rain causes heavy flood. The road network link that is passing through this vulnerable areas will be removed from the road network map. This is will lead to change in the travel distance and time. Because there is less development in such vulnerable areas the HH level damages will be reduced.

5. Construction of Redundant infrastructure:

Costs	Indicator	
	Before Policy	After Policy
Construction cost	VHT	Reduction in VHT
Maintenance cost	Cancelled trips	Reduction in cancelled trips

There is always a necessity for a redundancy in the road network in the flood vulnerable areas. This will be estimated by finding out the more flooded zones and look out for road networks in

those particular zones that doesn't have a redundancy. The heavily flooded links can be found from the flood maps and extra links can be added to the road (which bypass the flooded links). This helps in reducing the vehicle hours travelled during flooding, and also reduces the cancellation of trips.

6. Sending alerts via apps and messages about alternative route from hazard prone network:

Costs	Indicator	
	Before Policy	After Policy
Employment generation and Infrastructure cost	Cancelled Trips	Reduction in Cancelled Trips
	VHT	Reduction in VHT
	Congestion level	Reduction in congestion

This policy involves various costs due to employment generation (to manage the process) and the investment cost in building the infrastructure (needed to send the alerts). In order to evaluate the policy, we will estimate the indicator values before implementing the policy. Trips that are on the heavily flooded links will get cancelled. Due to flooding the time taken to travel increases and the congestion also increases. After sending the alert about the flooding event at certain locations the commuter has a chance to change his route to another. In modelling, this will be done by changing the path of the vehicles (removing the flooded links from the road network) using route assignment method. An efficient non-flooding route with high speed can be provided.

7. Rerouting people in case of unfortunate activity:

Costs	Indicators	
	Before Policy	After Policy
Fuel Cost	VHT	Reduction in VHT
	Congestion	Reduction in Congestion

When a re-routing happens, an extra cost is added to the commuter for the fuel. To evaluate this policy the main indicators are the VHT and levels of congestion. In modelling, when the re-routing happens the links that are flooded will be removed from the road network. This allows the modeller to choose the next route with high speeds and less travel time. In this way we can estimate the reduction in VHT. Congestion will be evaluated by calculating the volume of vehicles on the road at a particular location before and after the implementation of policy.

8. Restricting development in low lying or vulnerable areas

Costs	Indicators	
	Before Policy	After Policy
Investment in Land TDR	Household level damages	Reduction in Household level damages
	VHT	Reduction in VHT

The low lying areas should be restricted from development in order to reduce the impacts of flooding. If a person owns the land he should be given the compensation to shift to another location. This process involves transfer development right costs. To evaluate this policy the low lying or the vulnerable areas to flooding are identified using the zone level flood maps. The households in these vulnerable areas will be shifted to another place either in the same zone or to a different zone. This will reduce the household level damages due to flooding. As the vulnerable areas are restricted from development, there will not be much activity in those areas and the vehicle hours travelled by the commuters who earlier used these areas will be reduced.

9. Integrate land use development and transportation planning

Cost	Indicators	
	Before Policy	After Policy
Cost of acquiring land	VKT	Reduction in VKT
Construction and maintenance cost	Congestion	Reduction in Congestion
Construction cost of road	VHT	Reduction in VHT

This policy is very helpful in both mitigation and adaptation. There are various costs involved in developing such infrastructure. They are cost of acquiring land, construction and maintenance costs and the construction cost of road. Before implementing the policy and constructing the required infrastructure, the indicators like VKT, congestion and VHT will be calculated. VKT and VHT will be estimated from the route choice method in four stage TDM. Congestion can be calculated by finding out the flow at a particular section of the road. Once the policy is implemented the same indicators values will be estimated to check the effectiveness of the policy. The number of trips that are within the acceptable trip distance for NMT will be separated from the OD matrix based on the shortest path matrix. Now we ll have three OD matrix which are NMT OD matrix, Public transport OD matrix, Motorized trips OD matrix. Zones with high productions and attractions will be provided with an increased public transport network to increase the coverage of public transport.

10. Road closure during extreme weather conditions

Costs	Indicators	
	Before Policy	After Policy
Investment in land TDR	VHT	Reduction in VHT

During extreme weather events the roads that are vulnerable to flooding should be closed to reduce the impacts of the flood. The road links that are flooded can be identified from the flood maps. Such links will be removed from the road network and the route assignment is done. This reduces the time taken to travel for the commuters because of the high speeds compared to the flooded roads.