A REPORT

ON

MITIGATION POLICY BUNDLES FOR TRANSPORTATION SECTOR

A case of Bangalore City

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1. Introduction

Climate change is a mammoth challenge which all the countries face today and the transportation sector is one of the largest contributors to its cause. This study attempts to reduce the contribution of the transport sector by mitigating the causes.

Mitigation is '*the action of reducing the severity or seriousness of something*'. The mitigation policies aim to reduce the total vehicular emissions by reducing the total vehicular kilometres travelled. Climate change is inevitable, and its impact is severe and is being felt worldwide. Therefore, it becomes necessary to take steps to tackle the issue climate change.

This report is a compilation of the Delphi Method utilised to formulate final mitigation policy bundles. It also includes the evaluation ready description of the final policies.

2. Methodology

A total of four sets of policy bundles were prepared and presented to various stakeholders from different government and private organizations. A feedback was obtained at the end, where the responses of each respondent were anonymous. To arrive on a consensus about the most efficient policy bundle, Delphi method was used.

The feedbacks from the stakeholders were evaluated by adding their scores (votes) and the results were mailed to the stakeholders in case they wanted to make amends. Subsequently, a final set of score/vote for each policy bundle was obtained.

2.1 Scoring Method

Each stakeholder could either agree or disagree with the policies in the bundles by giving them a score or 1 or -1 respectively. The total score of each policy was calculated by adding the scores of all individual stakeholders. The score reflects how many stakeholders support the policy. Further, to narrow down results, at least 75 percent stakeholders must have supported it. Policies attaining less than 75 percent votes were disqualified.

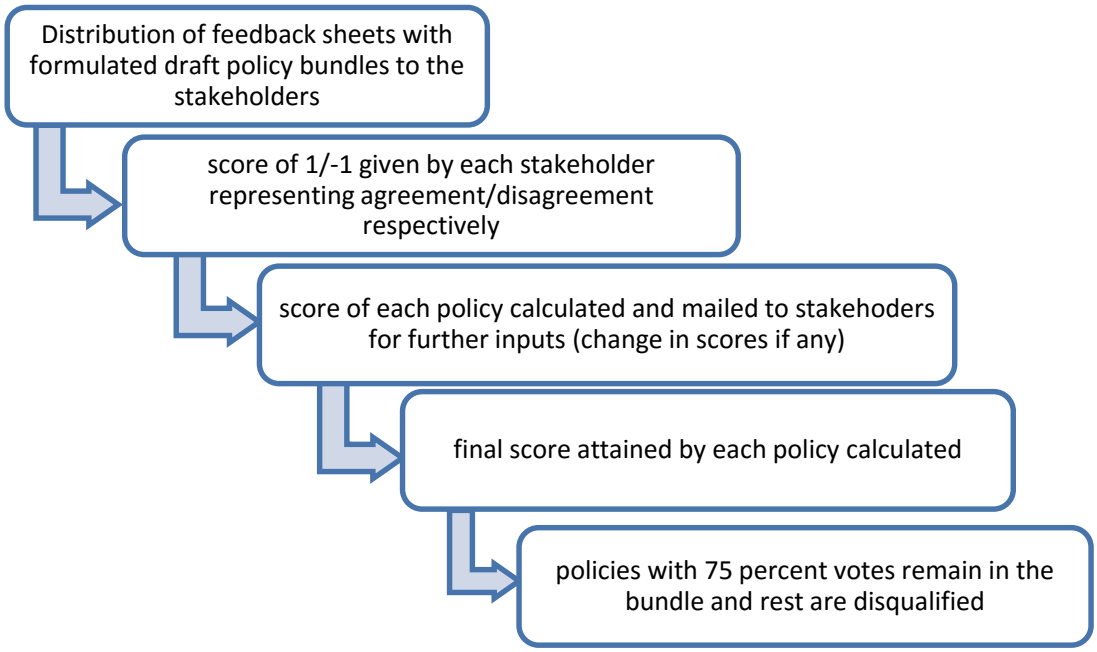

Figure 1: flow chart: Methodology adopted

3. Analysis

3.1 Policy Bundles

Policy bundles shown below (refer to figure1-4) are all different from one another. These bundles were presented to a total of 23 stakeholders/expert to get their inputs. For doing so, the Delphi method was utilized. The Delphi technique is classified into: the Classical Delphi - to establish facts; the Policy Delphi -to generate ideas; the Decision Delphi -to make decisions; and the Group Delphi -for group discussion. The method requires knowledgeable and expert contributors individually responding to questions and submitting the results to a central coordinator. The coordinator processes the contributions, looking for central and extreme tendencies, and their rationales. The results are then fed back to the respondents. The respondents are then asked to resubmit their views, assisted by the input provided by the coordinator. This process continues until the coordinator sees that a consensus has formed. The technique was intended to remove the bias that is possible when diverse groups of experts meet together. This method helps in structuring a group communication process that is particularly useful when there is little knowledge or uncertainty surrounding a complex area being investigated. One clear use of the Delphi technique is when the issue under investigation does not lend itself to precise analytical techniques, but can benefit greatly from subjective judgments on a collective basis.

Instruments									
Planning		**Regulatory**		**Economic**		**Information**		**Technology**	
P1	Increasing network coverage of Public Transit	R1	Limiting parking space	E1	Congestion Pricing	I1	Public information as to aid them in planning their trip.	T1	Improvement in standards for vehicle emission
P2	Defining car restricted zones	R2	High density mix building use along main transport corridors	E2	Pay to park	I2	Information and education	T2	Information and Communication Technology.
P3	High density mix building use along main transport corridors	R3	Congestion Pricing	E3	Fine for parking in no parking zone			T3	Low emission vehicles.
P4	Create walkable neighborhoods	R4	Encouraging car-pooling	E4	Taxes on vehicles with high emission				
P5	Park and ride	R5	Transfer Development Right (TDR)	E5	Heavy taxes on more than one car per household				
P6	Congestion Pricing	R6	Pay to park	E6	Increase in fuel cost				
P7	Cycling and Walking infrastructure	R7	Fine for parking in no parking zone	E7	Strict Vehicles inspection				
		R8	Taxes on vehicles with high emission	E8	Road Pricing				
		R9	Increase in fuel cost						
		R10	Strict Vehicles inspection						
		R11	High Occupancy Vehicle Lanes						
		R12	Slower speeds and ecological driving						

Figure 2: Policy Bundle 1

Instruments									
Planning		**Regulatory**		**Economic**		**Information**		**Technology**	
P1	Increasing network coverage of Public Transit	R1	Limiting parking space	E1	Congestion Pricing	I1	Public information as to aid them in planning their trip.	T1	Improvement in standards for vehicle emission
P2	Defining car restricted zones	R2	High density mix building use along main transport corridors	E2	Pay to park	I2	Information and education	T2	Information and Communication Technology.
P3	High density mix building use along main transport corridors	R3	Congestion Pricing	E3	Fine for parking in no parking zone			T3	Low emission vehicles.
P4	Create walkable neighborhoods	R4	Encouraging car-pooling	E4	Taxes on vehicles with high emission				
P5	Park and ride	R5	Transfer Development Right (TDR)	E5	Heavy taxes on more than one car per household				
P6	Congestion Pricing	R6	Pay to park	E6	Increase in fuel cost				
P7	Cycling and Walking infrastructure	R7	Fine for parking in no parking zone	E7	Strict Vehicles inspection				
		R8	Taxes on vehicles with high emission	E8	Road Pricing				
		R9	Increase in fuel cost						
		R10	Strict Vehicles inspection						
		R11	High Occupancy Vehicle Lanes						
		R12	Slower speeds and ecological driving						

Figure 3: Policy Bundle 2

Instruments									
Planning		**Regulatory**		**Economic**		**Information**		**Technology**	
P1	Increasing network coverage of Public Transit	R1	Limiting parking space	E1	Congestion Pricing	I1	Public information as to aid them in planning their trip.	T1	Improvement in standards for vehicle emission
P2	Defining car restricted zones	R2	High density mix building use along main transport corridors	E2	Pay to park	I2	Information and education	T2	Information and Communication Technology.
P3	High density mix building use along main transport corridors	R3	Congestion Pricing	E3	Fine for parking in no parking zone			T3	Low emission vehicles.
P4	Create walkable neighborhoods	R4	Encouraging car-pooling	E4	Taxes on vehicles with high emission				
P5	Park and ride	R5	Transfer Development Right (TDR)	E5	Heavy taxes on more than one car per household				
P6	Congestion Pricing	R6	Pay to park	E6	Increase in fuel cost				
P7	Cycling and Walking infrastructure	R7	Fine for parking in no parking zone	E7	Strict Vehicles inspection				
		R8	Taxes on vehicles with high emission	E8	Road Pricing				
		R9	Increase in fuel cost						
		R10	Strict Vehicles inspection						
		R11	High Occupancy Vehicle Lanes						
		R12	Slower speeds and ecological driving						

Figure 4: Policy Bundle 3

Instruments									
Planning		**Regulatory**		**Economic**		**Information**		**Technology**	
P1	Increasing network coverage of Public Transit	R1	Limiting parking space	E1	Congestion Pricing	I1	Public information as to aid them in planning their trip.	T1	Improvement in standards for vehicle emission
P2	Defining car restricted zones	R2	High density mix building use along main transport corridors	E2	Pay to park	I2	Information and education	T2	Information and Communication Technology.
P3	High density mix building use along main transport corridors	R3	Congestion Pricing	E3	Fine for parking in no parking zone			T3	Low emission vehicles.
P4	Create walkable neighborhoods	R4	Encouraging car-pooling	E4	Taxes on vehicles with high emission				
P5	Park and ride	R5	Transfer Development Right (TDR)	E5	Heavy taxes on more than one car per household				
P6	Congestion Pricing	R6	Pay to park	E6	Increase in fuel cost				
P7	Cycling and Walking infrastructure	R7	Fine for parking in no parking zone	E7	Strict Vehicles inspection				
		R8	Taxes on vehicles with high emission	E8	Road Pricing				
		R9	Increase in fuel cost						
		R10	Strict Vehicles inspection						
		R11	High Occupancy Vehicle Lanes						
		R12	Slower speeds and ecological driving						

Figure 5: Policy Bundle 4

Instruments									
Planning		Regulatory		Economic		Information		Technology	
P1	Increasing network coverage of Public Transit	R1	Limiting parking space	E1	Congestion Pricing	I1	Public information as to aid them in planning their trip.	T1	Improvement in standards for vehicle emission
P2	Defining car restricted zones	R2	High density mix building use along main transport corridors	E2	Pay to park	I2	Information and education	T2	Information and Communication Technology.
P3	High density mix building use along main transport corridors	R3	Congestion Pricing	E3	Fine for parking in no parking zone			T3	Low emission vehicles.
P4	Create walkable neighborhoods	R4	Encouraging car-pooling	E4	Taxes on vehicles with high emission				
P5	Park and ride	R5	Transfer Development Right (TDR)	E5	Heavy taxes on more than one car per household				
P6	Congestion Pricing	R6	Pay to park	E6	Increase in fuel cost				
P7	Cycling and Walking infrastructure	R7	Fine for parking in no parking zone	E7	Strict Vehicles inspection				
		R8	Taxes on vehicles with high emission	E8	Road Pricing				
		R9	Increase in fuel cost						
		R10	Strict Vehicles inspection						
		R11	High Occupancy Vehicle Lanes						
		R12	Slower speeds and ecological driving						

Figure 6: Policy Bundle 5

4. Additions/Changes in policy bundles

Some new policies were added to the bundles by the stakeholders and they have been listed below.

Policy Bundle 1

Planning

- good condition of roads
- Exclusive bus lane
- Public transport infrastructure to be more inclusive (age)
- Encourage car pooling
- park and ride only for cycles and two wheelers
- IPT

Regulatory

- Old Vehicle Scraping Policy
- Using hybrid
- Scraping of old vehicles

Economic

- Include two wheelers in heavy taxes for more than one two wheeler

Information

- Conduct seminar and workshop to prevent emission

Technology

- Quality fuel to vehicle
- Electric Vehicles
- Solar Panel charging stations
- scrape BSII, BSIII vehicles

Policy Bundle 2

Planning

- Restrict heavy vehicles for certain time of the day

Regulatory

- scraping of old vehicles
- parking rates higher in public places and lower in metro parking

Policy Bundle 3

Regulatory

- Subsidy for low emission vehicles

Technology

- subsidy for green vehicles
- Clean fuel vehicles (biodiesel and bioethanol)
- hybrid and electric vehicles
- promoting green infrastructure

Policy Bundle 4

Planning

- Feeder from metro to railway

Regulatory

- Pay to Park (4 wheelers)

Economic

- Subsidise electrical vehicles

5. Final Policy Bundles

After adopting the criteria to derive final policy bundles, the following policy bundles were finalised and are shown in **Table*1***.

Table1
Final Policy Bundles for Mitigation

Policy Bundles
Bundle 1
Increasing network coverage of Public Transit Cycling and Walking infrastructure Taxes on vehicles with high emission Strict Vehicles inspection/ Improvement in standards for vehicle emission
Bundle 2
Taxes on vehicles with high emission Strict Vehicles inspection/ Improvement in standards for vehicle emission Increase in fuel cost
Bundle 3
Increasing network coverage of Public Transit Defining car restricted zones High density mix building use along main transport corridors Park and ride Congestion Pricing Cycling and Walking infrastructure Encouraging car-pooling and High Occupancy Lanes

4. Policy Bundles and their impact on the TDM

Each policy has an impact on certain stages in the Travel Demand Model and this has been shown in the following section:

Policy Bundle 1

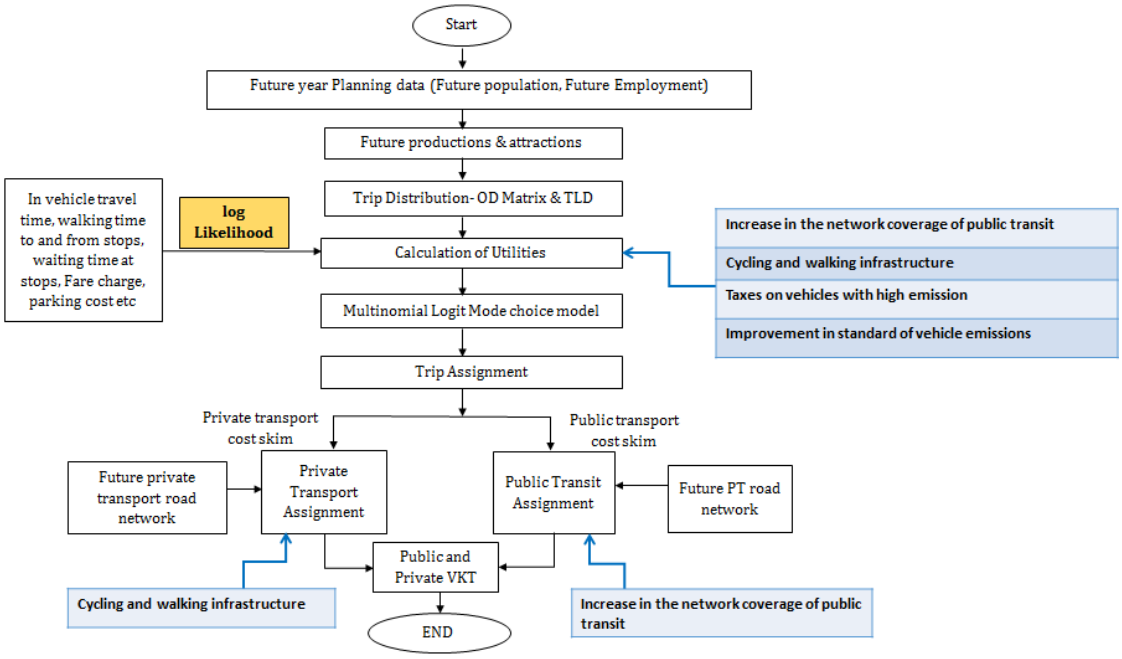

Figure 7: Impact of Policy Bundle 1 in four stage TDM

Policy Bundle 2

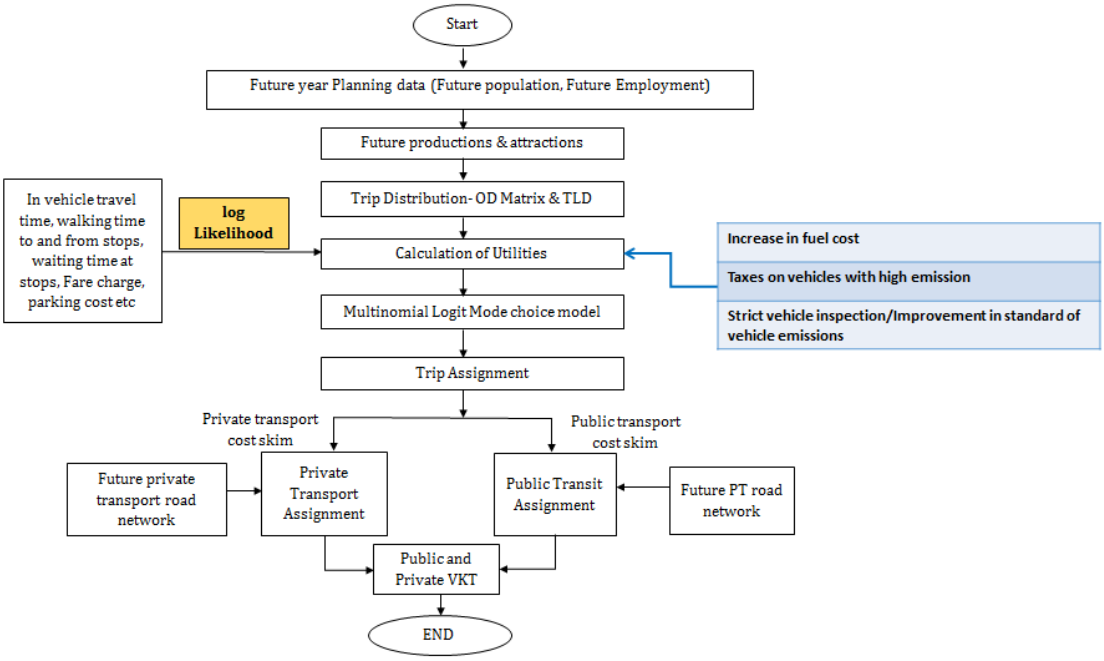

Figure 8: Impact of Policy Bundle 2 in four stage TDM

Policy Bundle 3

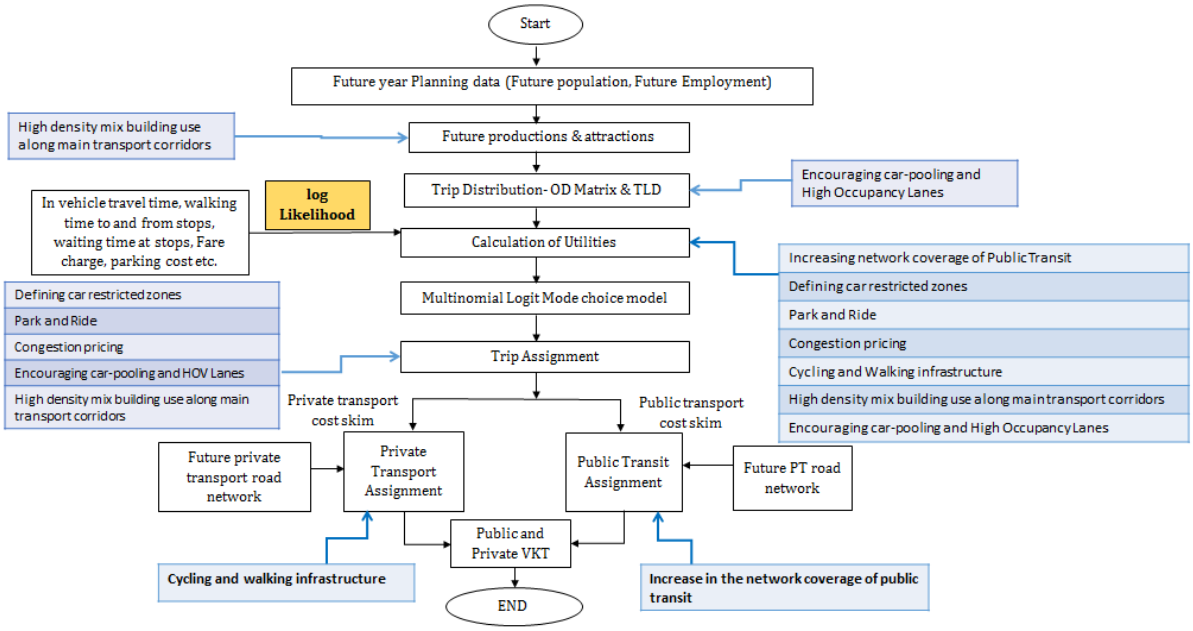

Figure 9: Impact of Policy Bundle 3 in four stage TDM

5. Evaluation Ready Description of Policy Bundles

The final policy bundles are selected based on Delphi survey which will be evaluated separately to estimate the reduction in VKT thus leading to a decrease in emissions. The evaluation of policy will be done using the travel demand model. Difference in input variables in each step of the model affected by the implementation of this policy will used in the evaluation of the corresponding policy bundle.

The bundles mentioned have some policies common across the bundles. Evaluation of each of the policy is described below.

1. Increasing network coverage of Public Transit

The network coverage of public transit has an effect on the ridership. By increasing network coverage, there will be an increase in the accessibility, which in turn increases the ridership. The ridership increase might be due to new commuters or the ones who shifted from private vehicles. Thus, this policy affects the mode share of public transport. Quantitative changes in the following variables are expected:

- Travel cost
- In vehicle travel time

- Out of vehicle travel time (Public Transit)

By superimposing BMRDA road network and BMTC bus routes in GIS, the areas with no network coverage to public transport can be identified. Then, the public network will be extended in these areas to achieve higher ridership.

2. Defining car restricted zones

Defining car restricted zones will help in the reduction of cars attracted to certain selected zones. With the implementation of this policy, commuters travelling via cars will have a choice to either park their vehicle outside those zones and take public transit or, use NMT. This will result in changing their modes of travel and thus it will impact the mode choice stage in the TDM. Also, this policy might have an impact on the trip assignment as commuters might choose alternative routes. The following variables are subject to change:

- Travel cost
- In vehicle travel time (MV)
- In vehicle travel time (Cycle)
- Out of vehicle travel time (Public Transit)

For implementing the policy highly congested areas are identified in Bangalore. The identified locations are:

a) K R Market
b) Shivaji nagar
c) Shanti nagar
d) Madiwala
e) Koramangala
f) M G Road
g) Whitefield
h) Malleswaram

The identified locations are highly congested and have a mixed land-use. Car restriction in these areas with combined implementation of other policies from the bundle will help in reduction of vehicle number and thus emission.

3. High density mix building use along main transport corridors

The aim of this policy is to decrease the trip length and encourage use of public transit by introducing high density mix building use along the transport corridors. In order to evaluate this policy, the zonal attractions will be changed. Also, it will impact the TDM at the mode choice stage as the average trip lengths will decrease and the commuters might

have more utility for other modes of travel. Therefore, this policy impacts the Trip Distribution, Mode share and Trip Assignment. The following variables are subject to change:

- Trip attraction
- Travel cost
- In vehicle travel time
- Out of vehicle travel time (Public Transit)

Development has to be focused in areas adjacent to bus stations, metro stations and near railway stations where public transport accessibility will be high. There is high probability of commuters using public transportation. Also some commuters might shift from private to public transportation. Locations selected for the policy implementations are:

a) M G Road
b) Metro stations
c) Traffic Transit Management Centres
d) Madiwala
e) Ring roads (Inner and outer)
f) Bannerghatta road
g) Hosur road
h) Mysore road
i) Chord road
j) Intermediate ring road

4. Park and Ride

The city of Bangalore currently has two operational metro lines and the rest is under construction. Metro Rail will have a significant impact on the reducing emissions as it is a mass rapid transit system. Therefore, it becomes essential to provide certain amenities which attract people to choose it as a mode of commute, parking in one of such amenities. People who are willing to commute via metro can park their vehicles at the parking facility near the metro station. This ensures last mile connectivity in the absence of para-transit (like auto-rickshaws). The objective of this policy is to increase the mode share of Metro Rail in future years to reduce vehicular emissions.

This policy has an impact on the Mode Share and Trip Assignment in the TDM and the following variables will be used to evaluate its impact:

- In-vehicle time (MV)
- Out-vehicle time (Public Transit)
- Travel cost (fuel cost, parking cost, fare for metro)

Park and Ride shall be applicable to implement at the major Transfer Metro Stations and Traffic Transit Management Centres (TTMCs).

5. Congestion Pricing

The policy aims to reduce the number of vehicular trip being generated. In zones like CBD where people go to work and shop, congestion is the maximum. A congestion price of Rs.10.50 per km (T. M., et al., 2013) will add to the travel cost of the trip and will impact the utility of that mode for individuals which would reflect in the mode share. They might prefer using public transit to commute.

This policy has an impact on the Mode Share and Trip Assignment in the TDM and the following variables will be used to evaluate its impact:

- In-vehicle travel time (MV)
- Out-vehicle travel time (public transit)
- In-vehicle travel time (walk)
- In-vehicle travel time (cycle)
- Travel cost (congestion price, fuel cost, fare)

Assumption: Congestion Pricing will be the same for all days in a week.

6. Cycling and walking infrastructure

This policy has an impact on the Mode Share in the TDM and the following variables will be used to evaluate its impact:

- In-vehicle travel time (MV)
- In-vehicle travel time (walk)
- In-vehicle travel time (cycle)
- Travel cost (congestion price, fuel cost, fare)

Assumption: With an improvement in the cycling and walking infrastructure, all the trips which are shorter than the acceptable trip length of 0.75 km and 1.66 km (T.M., et al., 2013) for walking and cycling respectively will shift to NMT.

This provision shall be tested at the entire sub-arterials road and collector roads of the city as the local roads are too narrow to provide the infrastructure.

7. Encouraging carpooling and High Occupancy Vehicle (HoV) Lanes

Carpooling can reduce the number of vehicles on a route with similar or same origin destinations. The policy will be tested on all sub-arterial & arterials roads and main transport corridors of Bangalore where HoV lanes can be provided. Faster movement would be ensure with the provision of HoV lanes.

The OD Matrix shall be utilised to find out the trips with same origin and destinations. The evaluation will be based on the assumption that all these individual trips will carpool. A separate OD will be prepared for the car-pooling vehicle and this will be preloaded onto the HoV lanes only. Then the trips would be assigned and the resulting VKTs will be calculated for this policy.

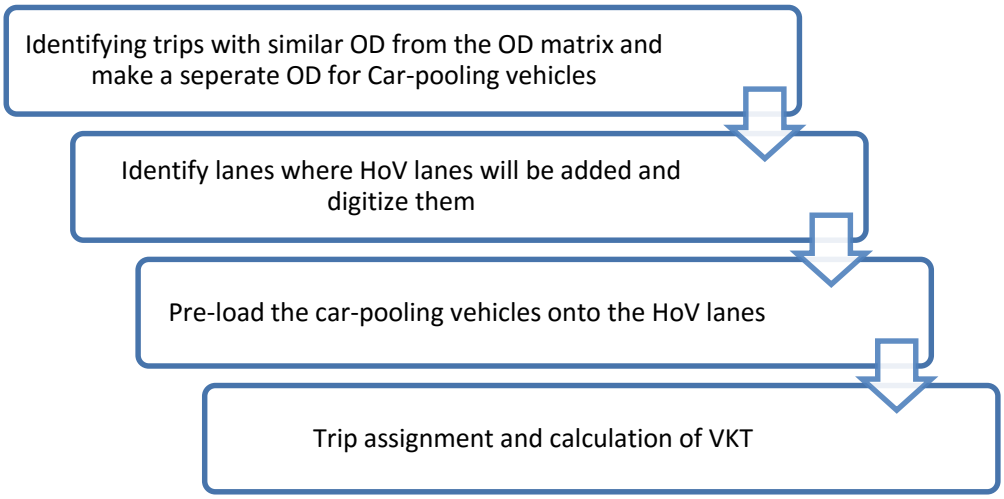

Figure 10: Process of evaluation of carpooling and HoV lanes

This policy has an impact on the Mode Share in the TDM and the following variables will be used to evaluate its impact:

- In-vehicle travel time (MV)
- Travel cost (congestion price, fuel cost, fare)

Assumption: all the individual trips having the same origin destination will carpool.

8. Higher emission standard

From the impedance matrix, the distances which less than the acceptable trip distance for NMT (cite) will be removed. The remaining values form the impedance matrix for private motorised vehicles.

Bangalore has a percentage of vehicles which are older than 15 years. From the impedance matrix, these old vehicles will be sliced. Out of the total old vehicles, it will be

assumed that 50 percent will be scrapped out and the remaining will upgrade to Bharat Stage VI. The OD matrix of these upgraded vehicles will then be assigned onto the road network and the VKTs will be obtained.

9. Taxes on vehicles with higher emissions

This policy aims to reduce the number of motorised vehicles with higher emissions by taxing them. This tax would be an addition in the Travel Cost variable in TDM model and would reflect in the mode share.

10. Increase in Fuel Cost

This policy will be evaluated by changing the fuel cost on the travel cost variable in the mode choice stage of the four stage model.

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