GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

EVALUATING CLIMATE CHANGE MITIGATION & ADAPTATION POLICIES FOR URBAN TRANSPORTATION IN INDIA

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4th November 2022

15th Urban Mobility India Conference & Expo2022

IISc Sustainable Transportation Lab (IST Lab)

OUTCOME FROM INTER-DISCIPLINARY AND COLLABORATIVE RESEARCH

Indo-Norway Project CLIMATRANS

Climate Change Mitigation & Adaptation Policies from transport sector for Indian Cities

Partners – IISc Bangalore, IIT Bombay, SPA Delhi, TERI, TOI, MET, Norway

Funded by: Norway Research Council

Research Scholars: **Harsha Vajjarapu & Hemanthini Allirani**

HOW TO ADDRESS?

Climate Change

Mitigation

Efforts to reduce or prevent greenhouse gas emissions

Adaptation

Changes made in the system to reduce the adverse effects of climate change

Urban Flooding

(IPCC WGIII 5AR, 2014)

“Transportation planning should no more be just about removing congestion points and reducing V/C ratio but should also be about reducing total vehicles kilometre travelled (VKT) by motorized mode and reduced dependence on fossil fuels.”

”Eventually it should lead to more liveable Indian cities”

- ***A strong “Systems approach to developing mitigation strategies.***
- ***They should also solve core transportation problems as well.***
- ***Fundamental strategy should be to reduce no. of motorized vehicles, reduce total motorized VKT, and fix India’s energy mix to renewable sources***

OBJECTIVES

To develop mitigation strategies for the base year and the horizon years 2030 & 2050 for transportation sector which are aimed at reducing the GHG emissions, local pollutants and traffic congestion from a baseline condition.

To identify the transportation infrastructure that is vulnerable to climate change and assess the impacts of climate change on the transportation infrastructure

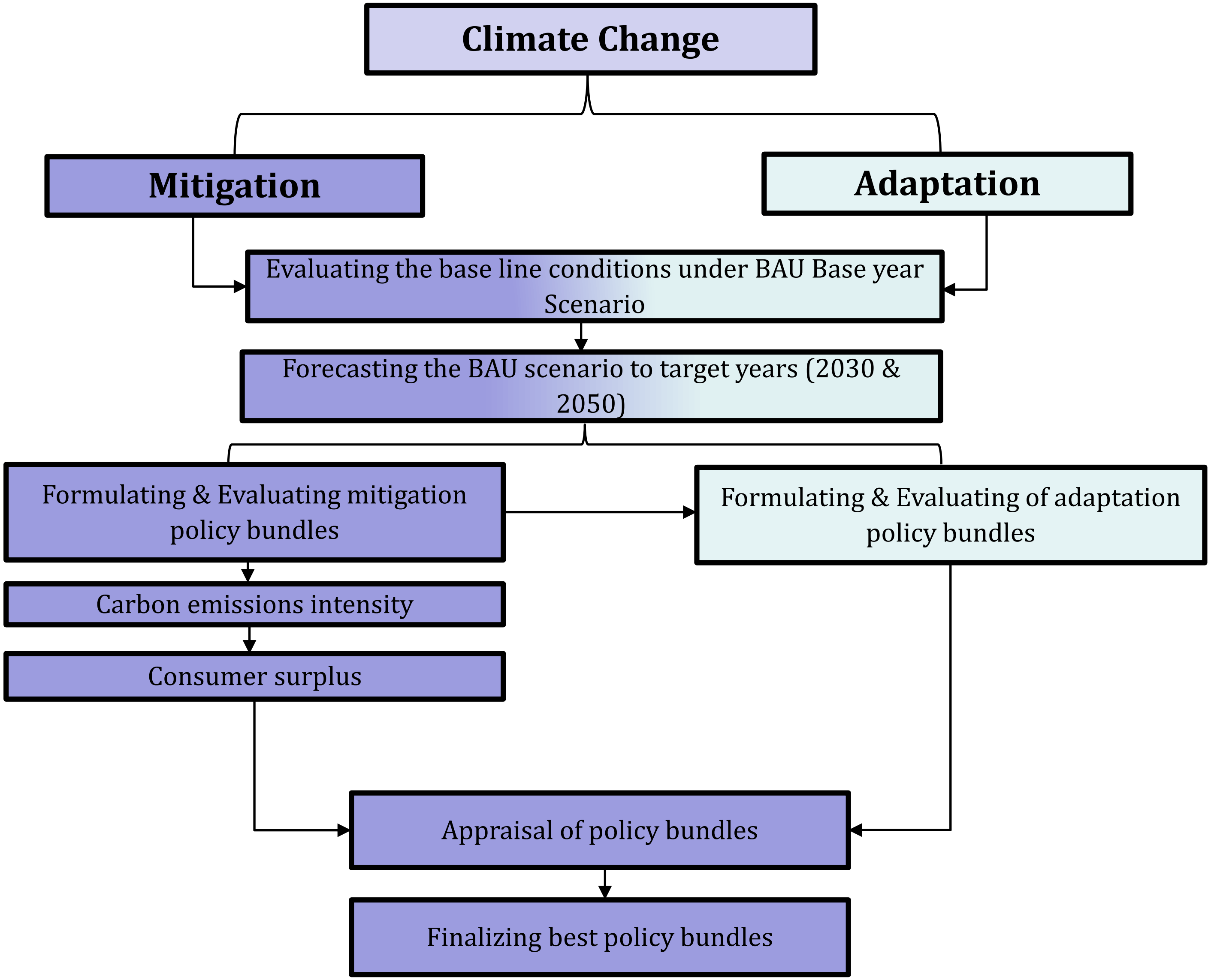
To develop adaptation strategies for the base year and the horizon years 2030 & 2050 to evaluate the vulnerability, scope & extent, severity of each flood event caused by climate change to transportation sector

Improving the overall liveability of Bengaluru

LIVEABILITY

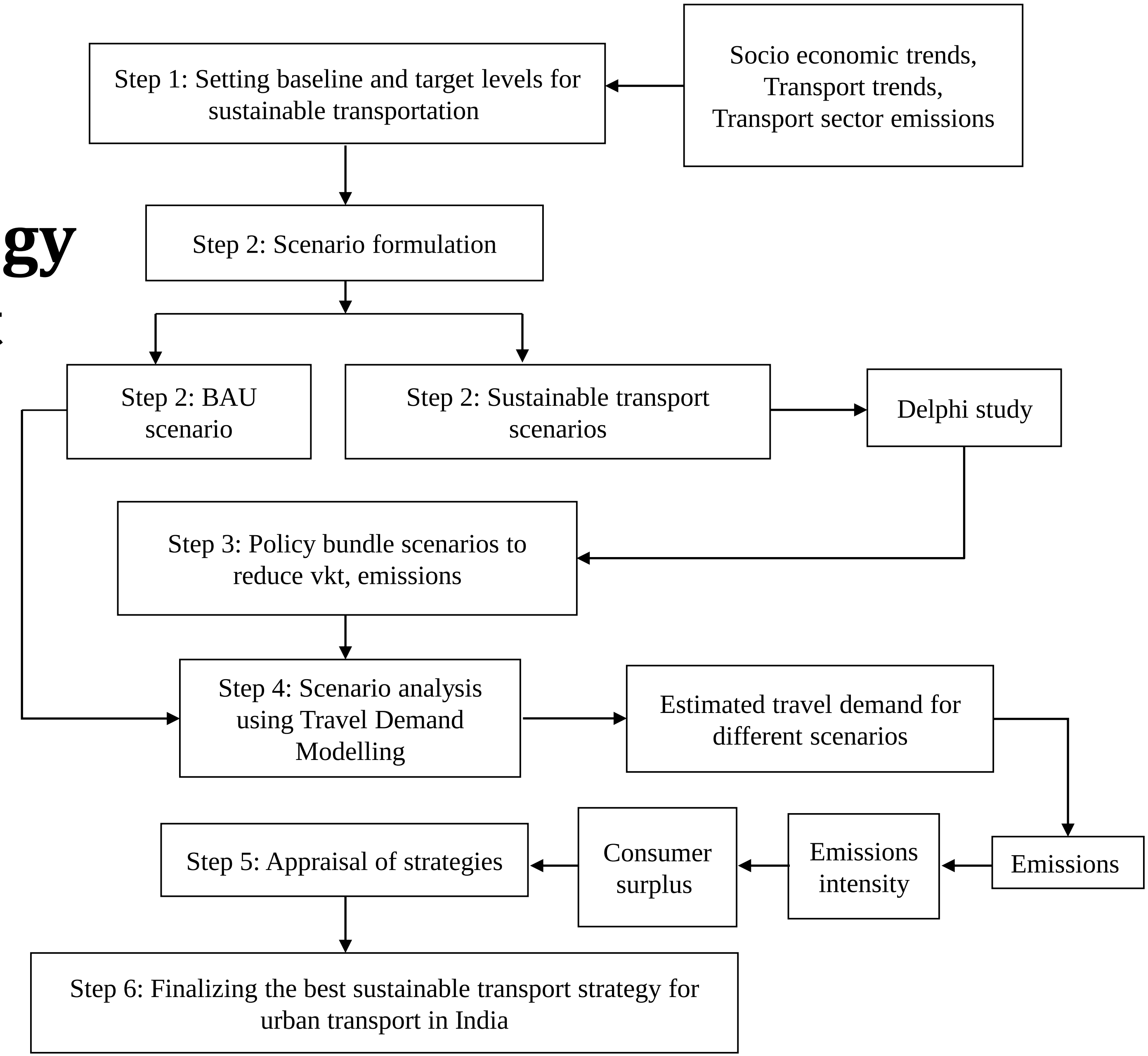
In this study, quantitative evaluation of sustainable transport mitigation and adaptation measures are carried out aimed to improve the liveability of Bengaluru in terms of;

- reduced traffic congestion (VKT)
- reduced exhaust emissions (PM, CO, NOX, HC etc.)
- reduced greenhouse gas emissions (CO2)
- reduced carbon emission intensity with respect to GDP growth
- increased consumer surplus of sustainable modes
- improved resiliency of transportation system



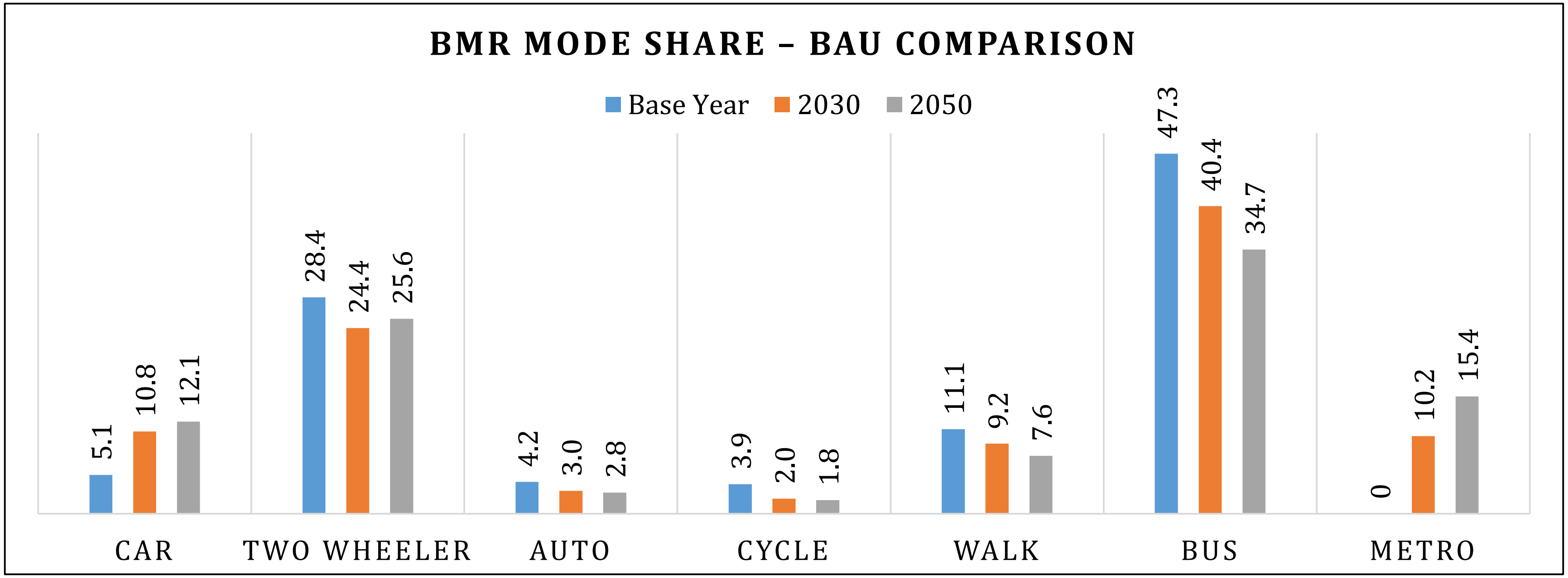
GENERAL FLOW CHART OF MITIGATION & ADAPTATION

Mitigation Methodology Flow Chart



TRAVEL DEMAND FORECAST FOR 2030 AND 2050 (BAU SCENARIO) – MODE SHARE

- Reduction in two-wheeler & auto from base year could be due to increased income levels and shift towards car or metro
- Reduction in Bus and NMT could be due to introduction of metro



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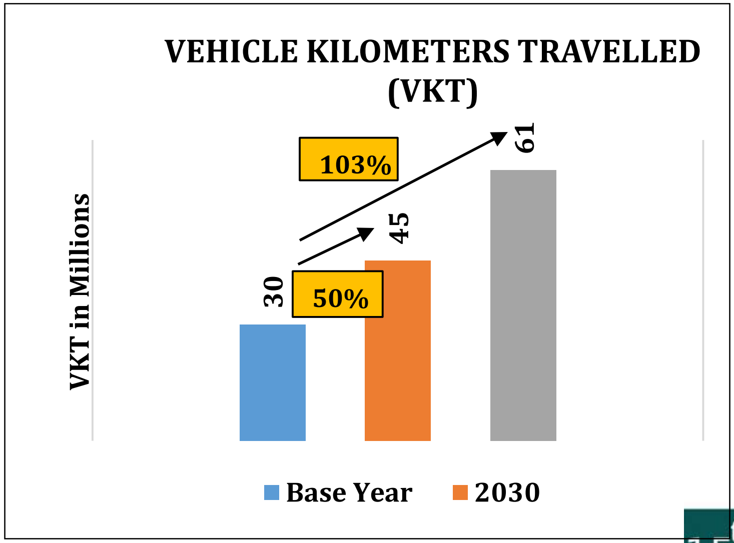
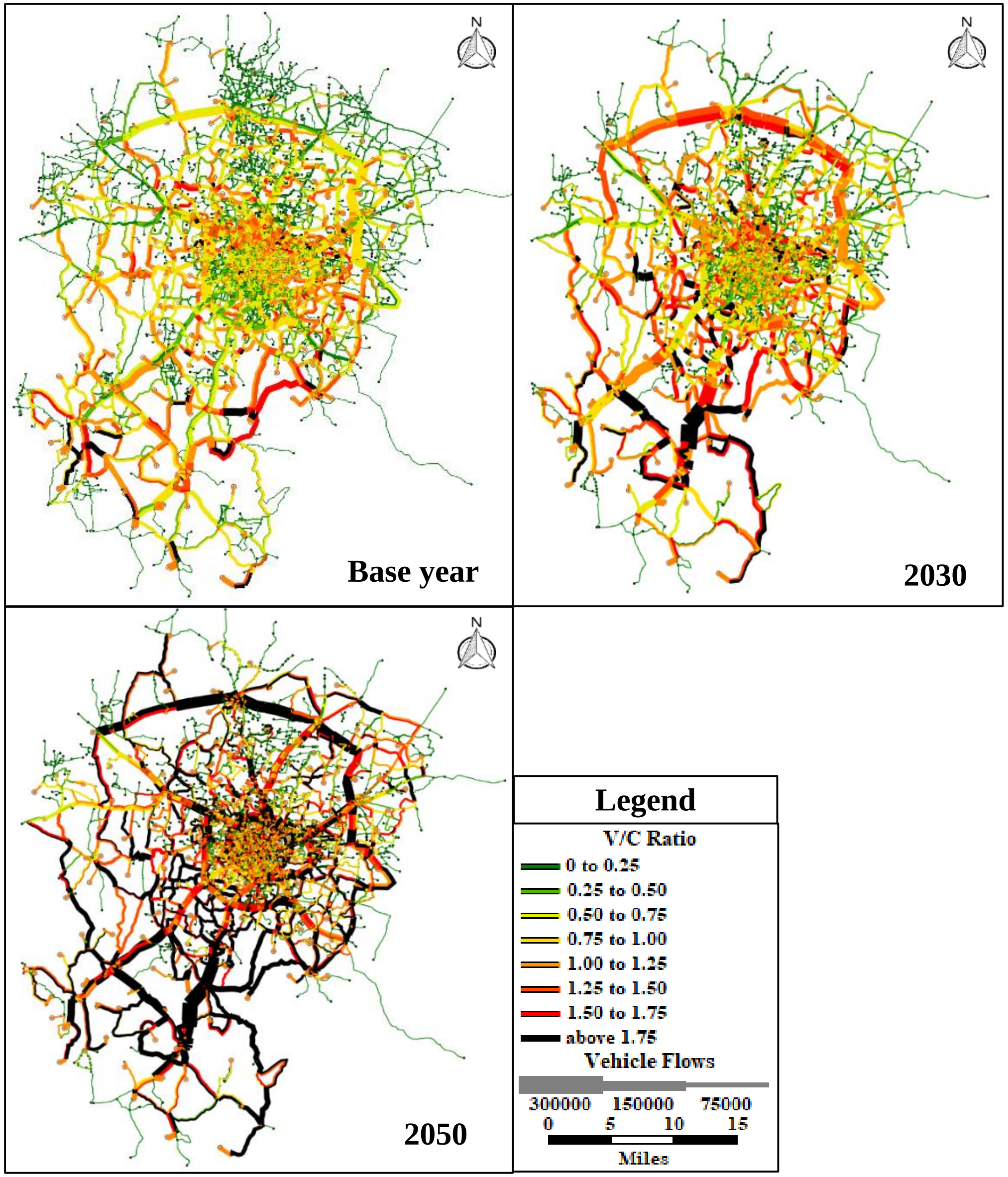
Travel Demand Forecast for 2030 and 2050 (BAU Scenario) - Trip Assignment

User Equilibrium traffic assignment: Every user (in other words, traveller) choses route that minimizes his/her individual travel time or distance and will only increase it if they decide to change their path





Emissions for Base year, 2030 and 2050 (BAU Scenario)

Pollutant	Tonnes/ year (% change w.r.t base year)		
	Base Year	2030	2050
CO	23101	12532 (-46%)	16988 (-26%)
HC	8962	3064.01 (-66%)	2765.35 (-69%)
NOx	7968	2131 (-73%)	7195 (-10%)
CO_2	1023722	1702506 (+66%)	6964265 (+580%)
$PM_{2.5}$	1113	158 (-86%)	560 (-50%)

Emissions (g) = VKT (km) * Emission factor (g/km)

Increased VKT, emission factor value, metro, mode shift towards bus

EVALUATION OF MITIGATION POLICIES FOR BENGALURU CITY

CLIMATRANS

PARTNERS :

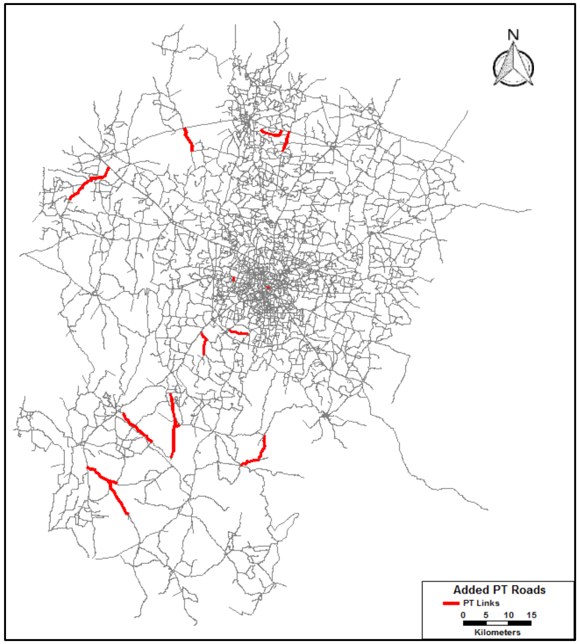
Ref: Vajjarapu, H., Verma, A., & Hemanthini A. R. (2023). Evaluating the Climate Change Mitigation Potential of Sustainable Urban Transport Measures in India, Journal of Urban Planning and Development, Vol. 149, Issue 1, ASCE.

Policy Bundles For Mitigation

Bundle 1	• Increasing network coverage of Public Transit • Cycling and walking infrastructure • Additional tax on purchasing vehicles	**Planning & Regulatory Instruments**
Bundle 2	• Additional tax on purchasing vehicles • Strict Vehicles inspection/ Improvement in standards for vehicle emission • Increase in fuel cost	**Economic & Regulatory Instruments**
Bundle 3	• Increasing network coverage of Public Transit • Defining car restricted roads • Congestion Pricing • Park and Ride • Cycling and Walking infrastructure • Encouraging car-pooling and High Occupancy Lanes • High density mix building use along main transport corridors	**Combination of Planning Regulatory & Economic Instruments**
Bundle 4	• Bundle 3 + All buses and cars running on electricity	**Combination of Planning Regulatory, Economic & Technological Instruments**

INCREASING NETWORK COVERAGE OF PUBLIC TRANSIT

Identifying Congested links	Links that are over congested with traffic are Identified
Add more PT links	More links are added in the zone that has more productions and heavy congestion to reduce load on other links
Re modelling	New travel times are obtained & these are used to re model the flows on roads.



Variables affected:

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

For 2030 and 2050, 60.1 km and 30 km of public Transport road network was increased.

Encouraging carpooling and High Occupancy Vehicle (HOV) Lanes

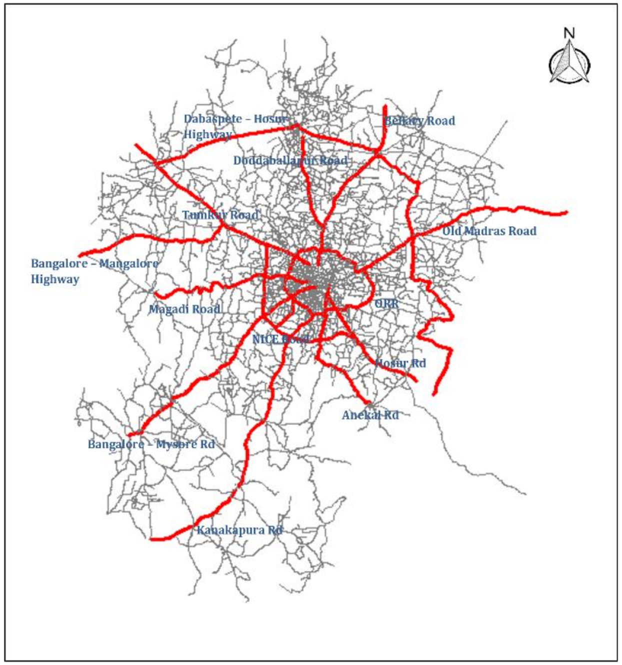
A HOV road network is created

car trips that fall on the HOV network assumed to car pool and a separate OD matrix is created from the original car OD matrix

Assign the car pool trips onto the HOV network and then assign the Public Transportation trips onto the Public transportation network with a preload of car pool OD.

Private Trip assignment with preloads as zero and reduced road capacity.

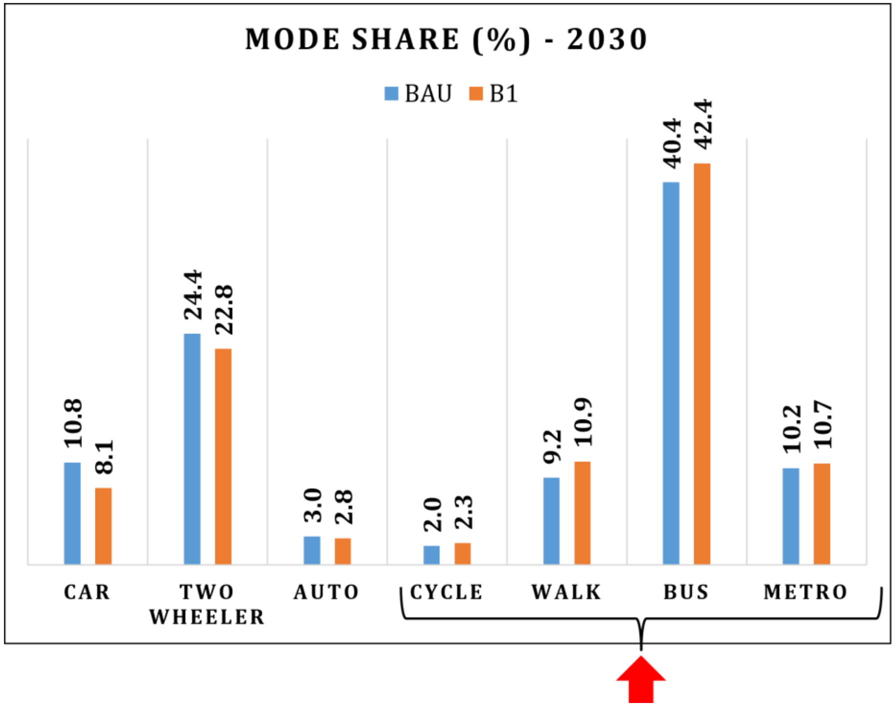
Sub-arterial & arterials roads and main transport corridors of Bangalore where HoV lanes can be provided are good places to implement.

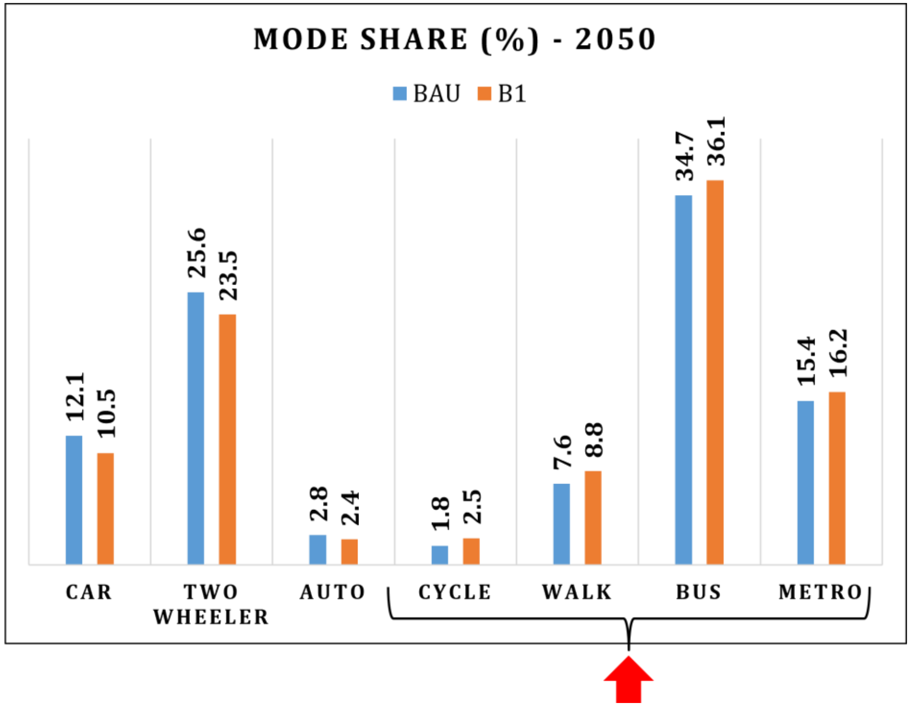


Mode Share Comparisons between Policy Bundles & BAU

- Increasing network coverage of Public Transit
- Cycling and walking infrastructure
- Additional tax on purchasing vehicles

Bundle 1

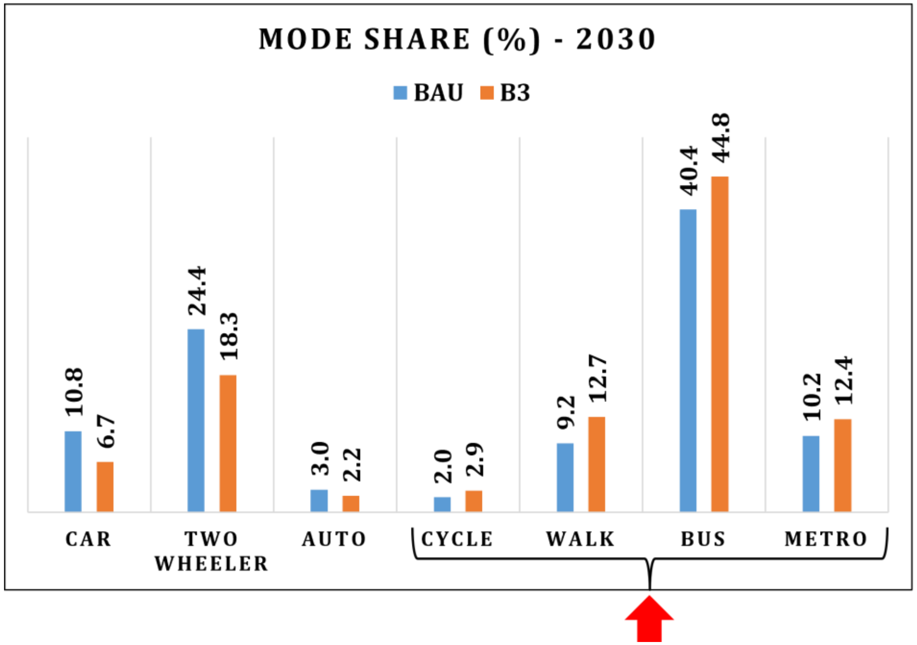


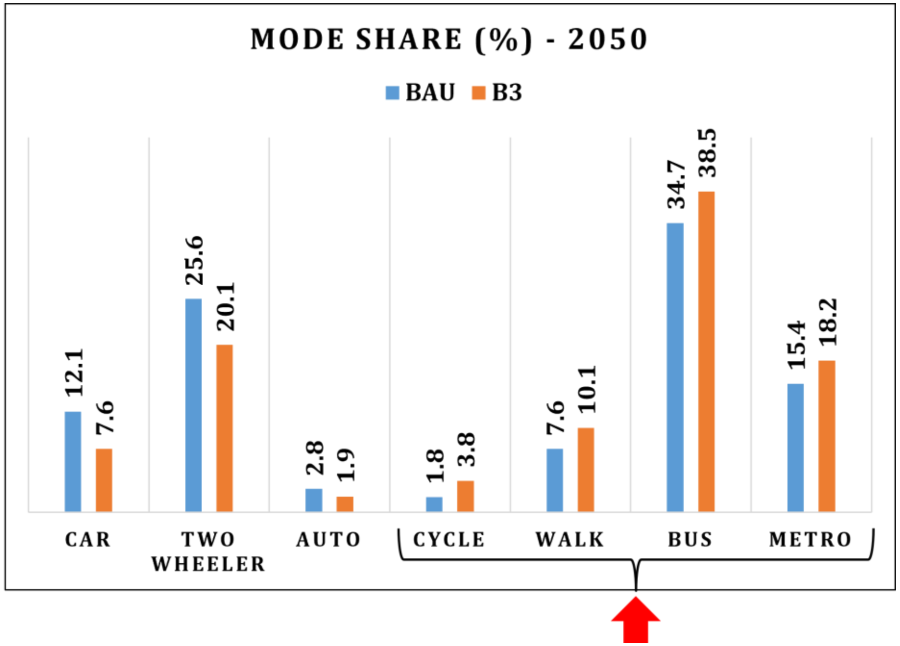


Mode Share Comparisons between Policy Bundles & BAU

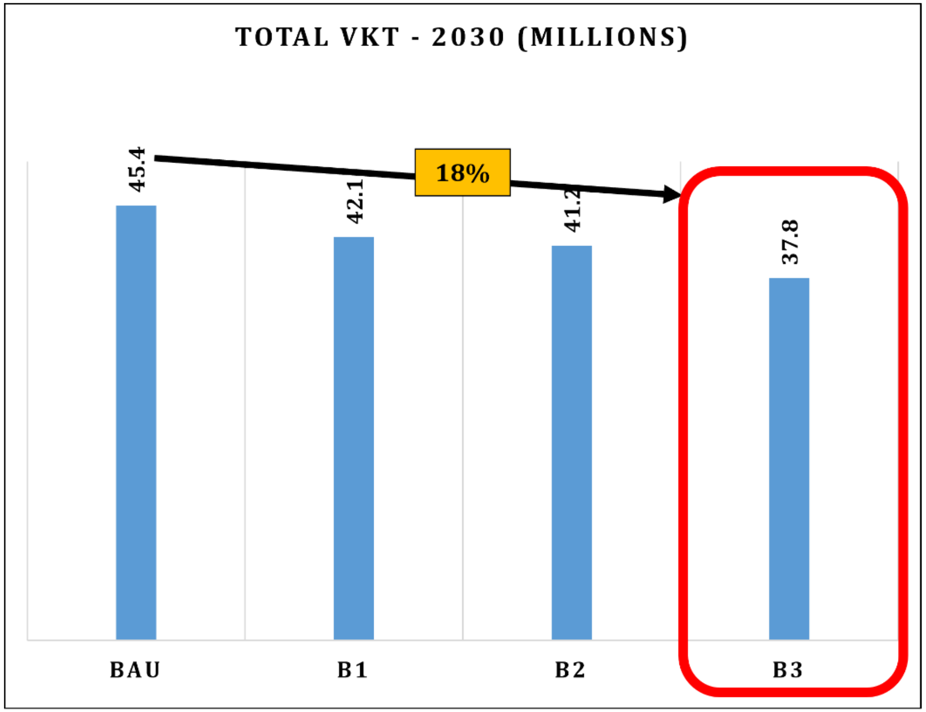
- Increasing network coverage of Public Transit
- Defining car restricted roads
- Congestion Pricing
- Park and Ride
- Cycling and Walking infrastructure
- Encouraging car-pooling and High Occupancy Lanes
- High density mix building use along main transport corridors

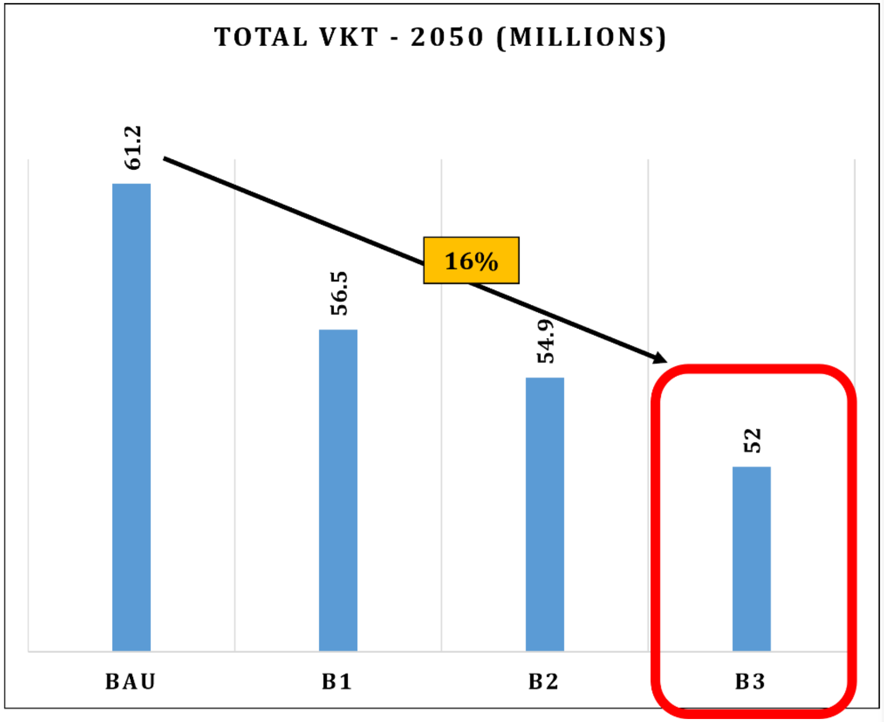
Bundle 3





VKT Comparisons between Policy Bundles & BAU





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Emission Factors

The principal emissions generated from transportation sector:

- Carbon Dioxide (CO_2)
- Nitrogen Oxides (NO_X)
- Carbon Monoxide (CO)
- Hydrocarbons (HC)
- Particulate Matter ($PM_{2.5}$)

Renewable share of electricity in future years is assumed to increase (IEA, 2015).

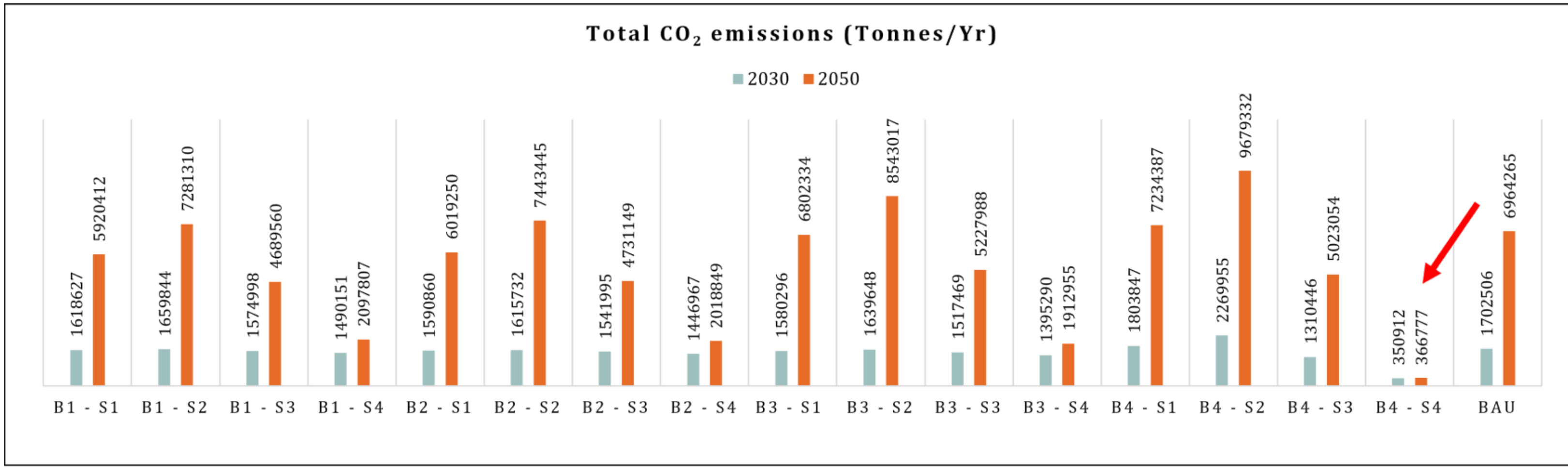
4 Scenarios with different energy mixes

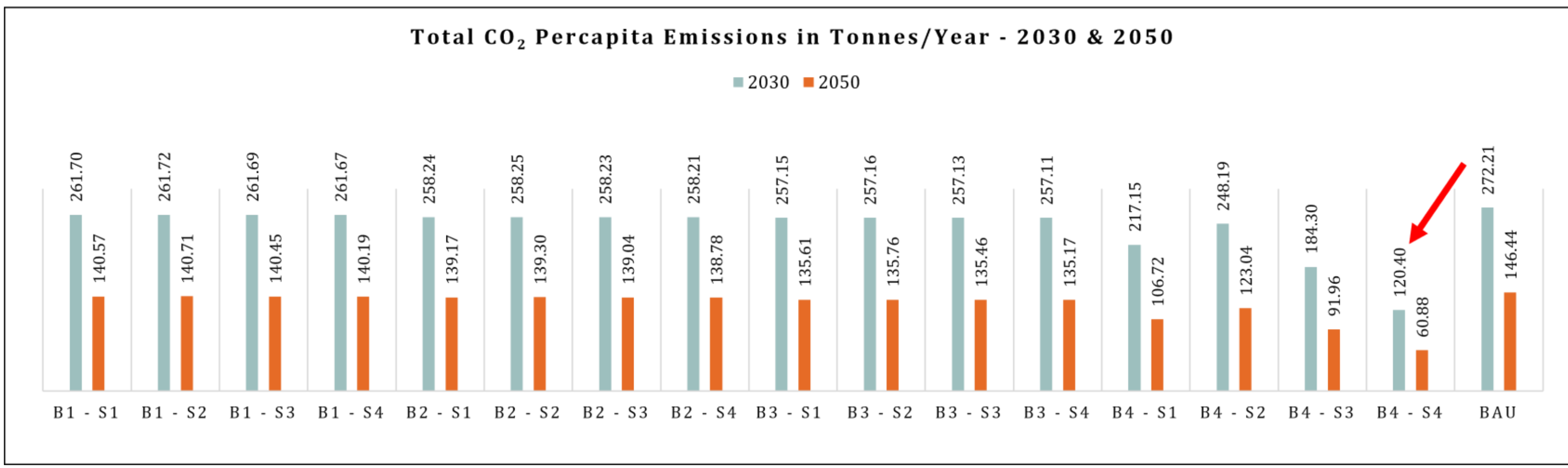
- **Scenario 1:** New Policies Scenario (IEA, 2015) – Non-renewable sources & renewable (74% - 26%)
- **Scenario 2:** Electricity from non-renewable Sources (100 %)
- **Scenario 3:** Half electricity from renewable and another half from non-renewable sources (50 % - 50 %)
- **Scenario 4:** Electricity from Renewable Sources (100 %)

Source: Sharma and Chandel (2020)

Total Emissions (g) = VKT (Km) * Emission Factor (g/km)

Total Vehicular & Total Percapita Emissions – CO_2





Bundle 4 – Percentage Emission Reduction

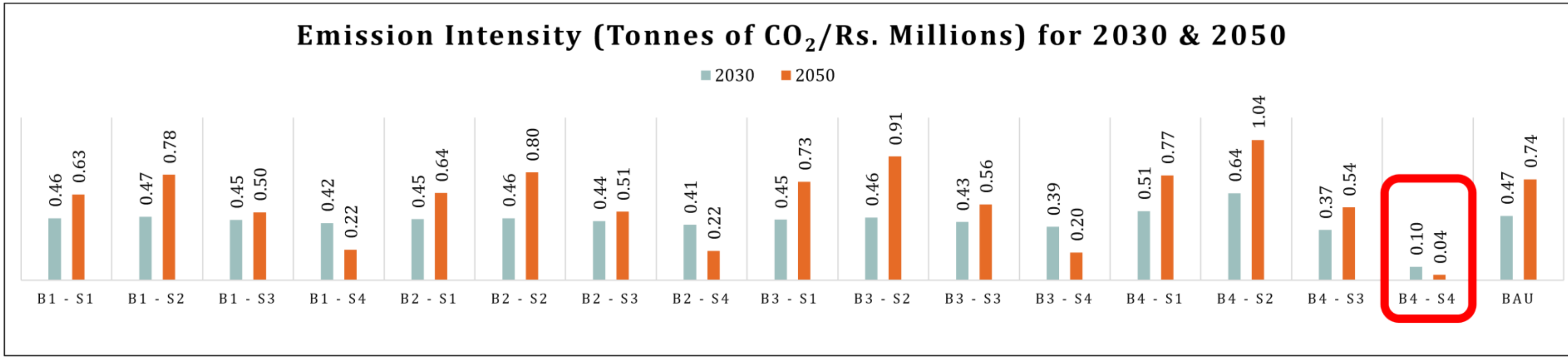
Percentage Reduction in Emissions with B4-S4 from BAU					
Year/Pollutant	**CO**	**HC**	**NOx**	**CO_2**	**$PM_{2.5}$**
2030	46	48	57	80	60
2050	53	70	66	94	72

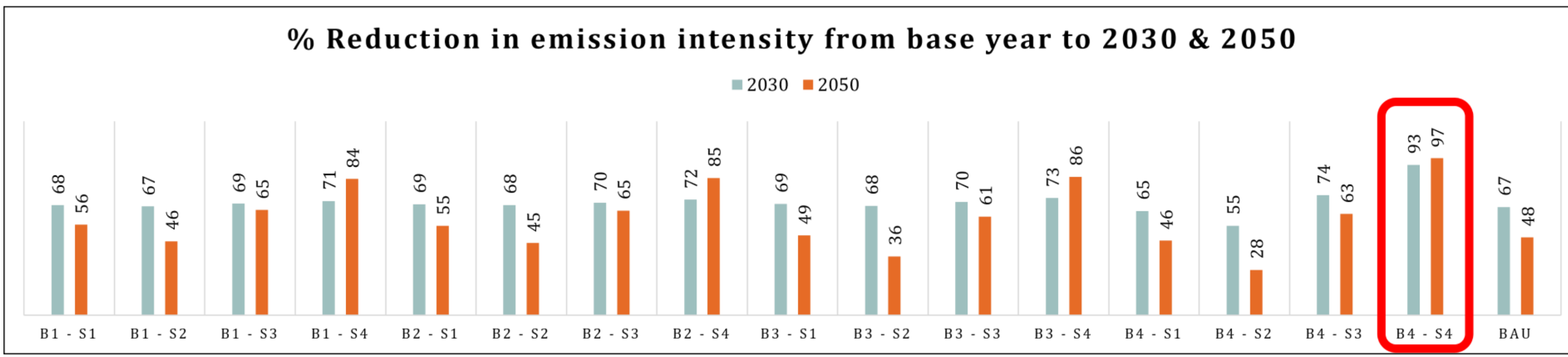
Percentage reduction in emissions when electricity generation is purely from hydropower, solar and wind without bioenergy

Percentage reduction in emissions w.r.t BAU for No Bio scenario and B4-S4			
	Year	BAU - No Bio	B4-S4
CO	2030	36	73
	2050	28	77
HC	2030	No change	58
	2050	No change	80
NOx	2030	91	99
	2050	83	98
CO_2	2030	89	98
	2050	82	98
$PM_{2.5}$	2030	90	97
	2050	92	98

Bio energy produces CO, NOx and $PM_{2.5}$ emissions

Total Emission Intensity Comparison - 2030





Further, assuming electricity will be purely generated from hydropower, solar and wind without using bio energy in BAU scenario, additional **19%** and **30%** reduction in total CO_2 emission intensity can be achieved in BAU 2030 & 2050 respectively from base year.

EQUITY ASPECTS TO MITIGATION ACTIONS

- Women travelers across income groups contribute lesser to GHG emissions
- The social and economic cost burden of economic and regulatory policies could be differentially higher on low income women travellers

Ref: Vajjarapu, H., Verma, A. (2022). Understanding the mitigation potential of sustainable urban transport measures across income and gender groups, Journal of Transport Geography, Volume 102, 103383

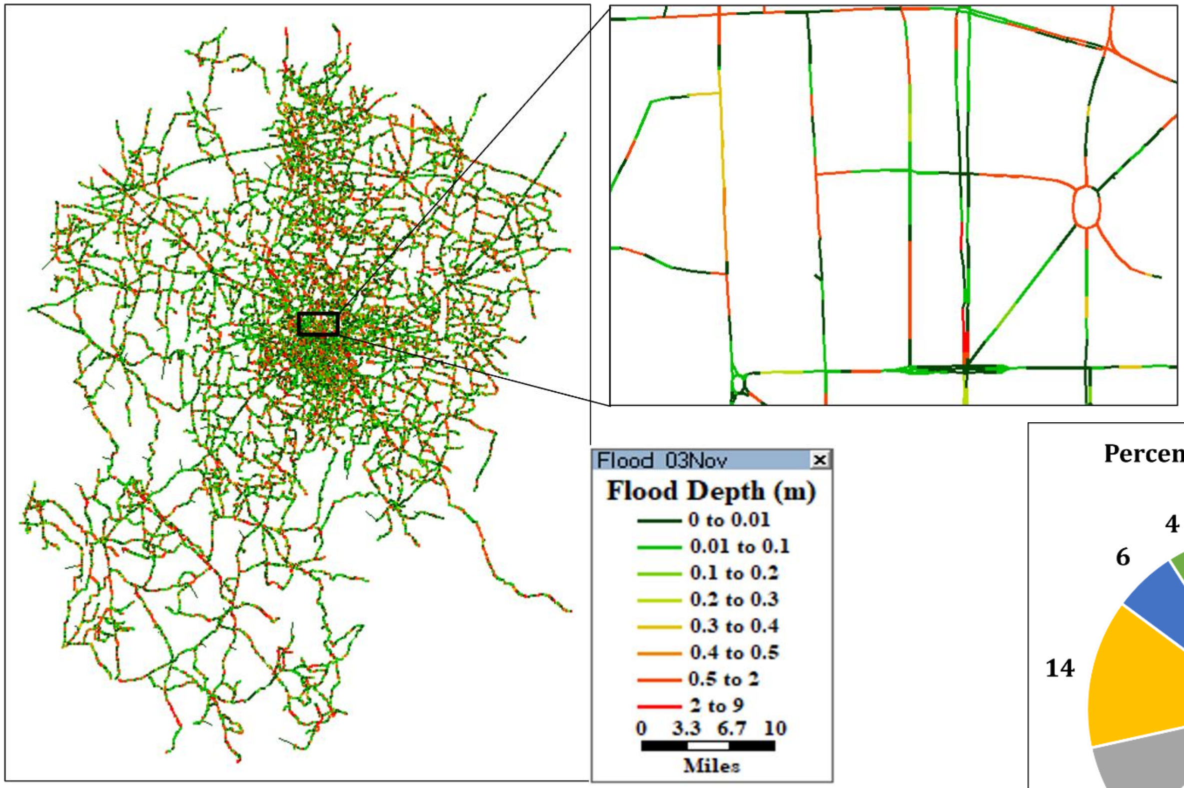
EVALUATION OF ADAPTATION POLICIES WITH RESPECT TO URBAN FLOODING FOR BENGALURU CITY

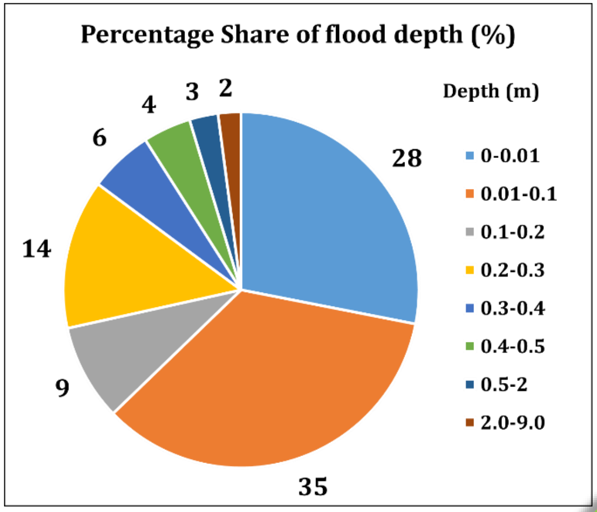
CLIMATRANS

PARTNERS :

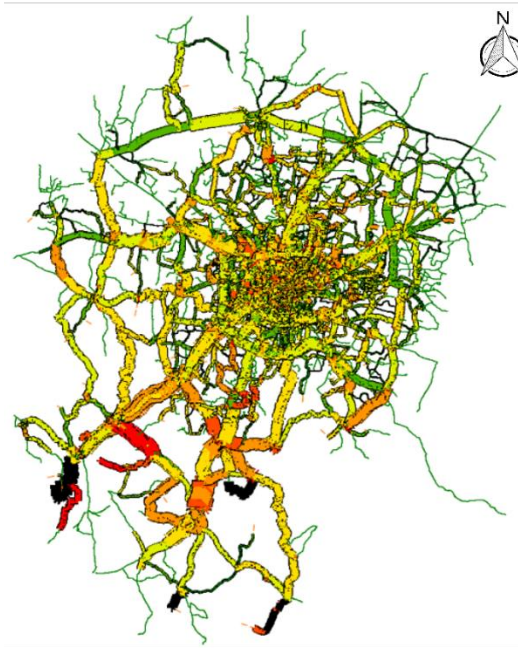
BMR Maps

Road network with flood level Map - BMR



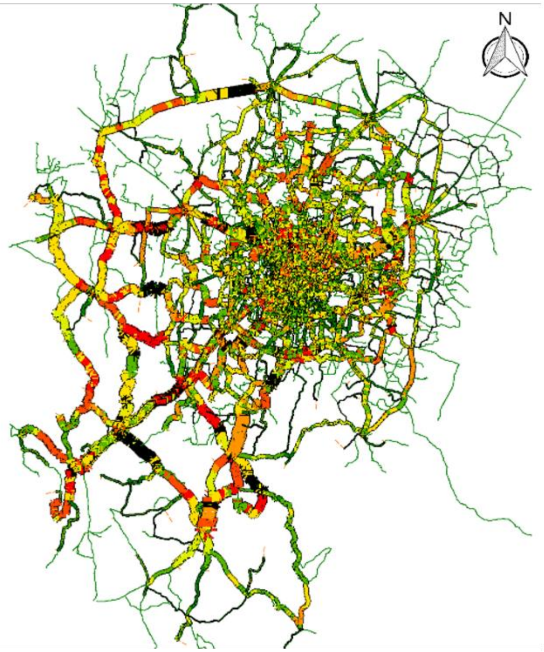


Trip Assignment – BAU Flooding



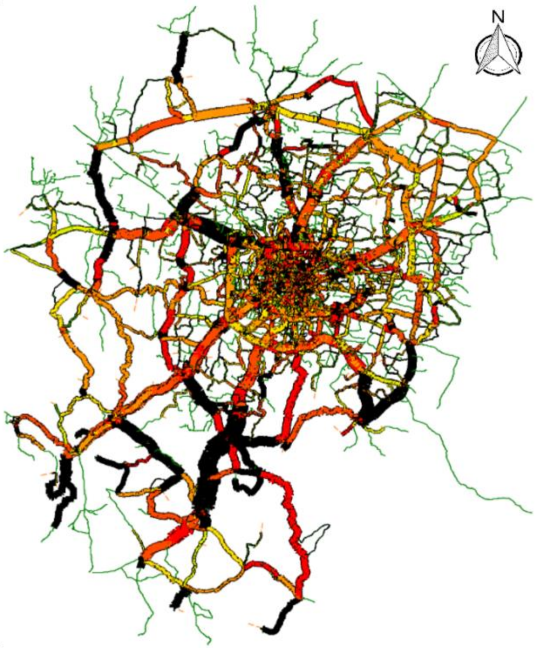
Base Year

BAU Flooding



2030

BAU Flooding

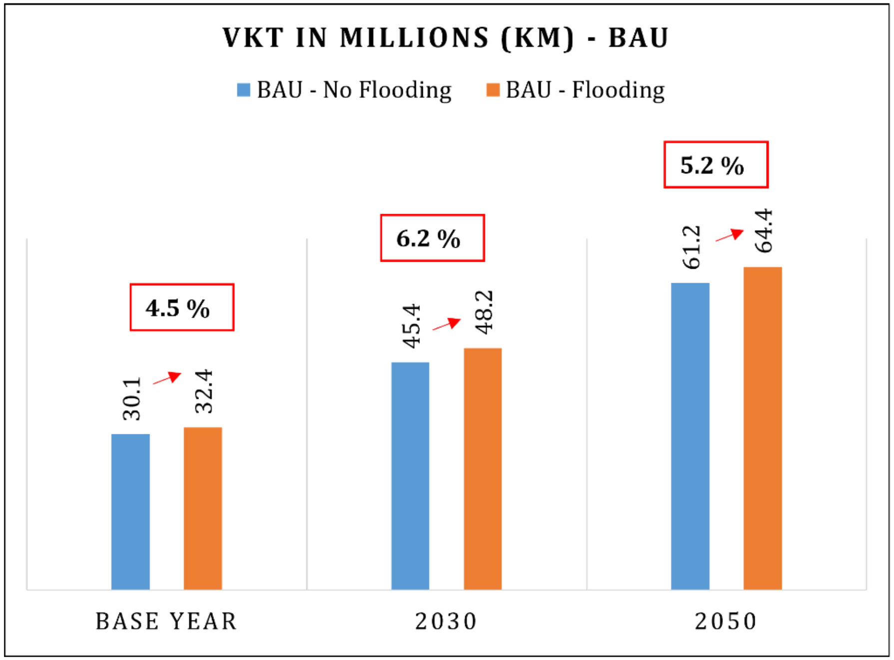


2050

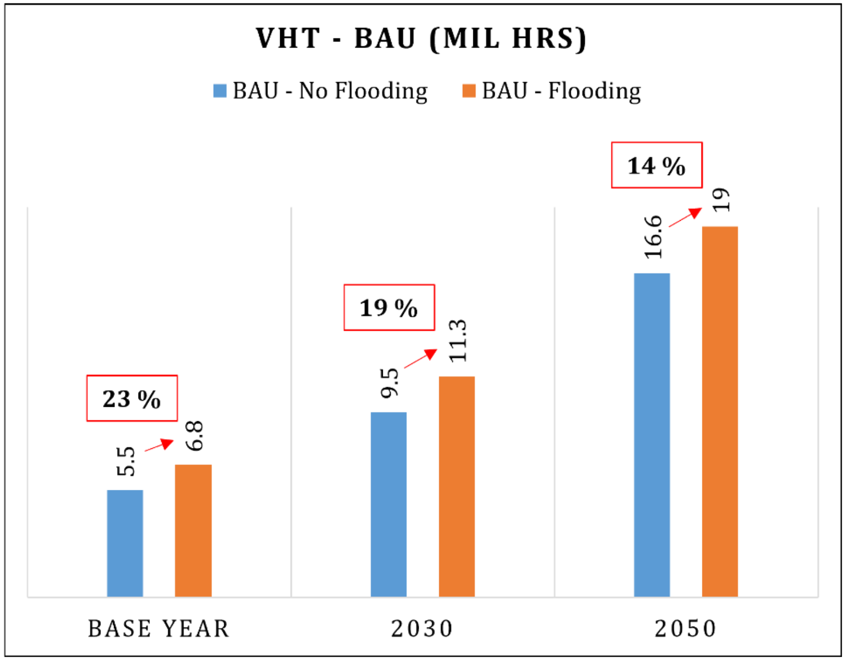
BAU Flooding

BAU - Travel Demand Model Results

Vehicle Kilometers Travelled

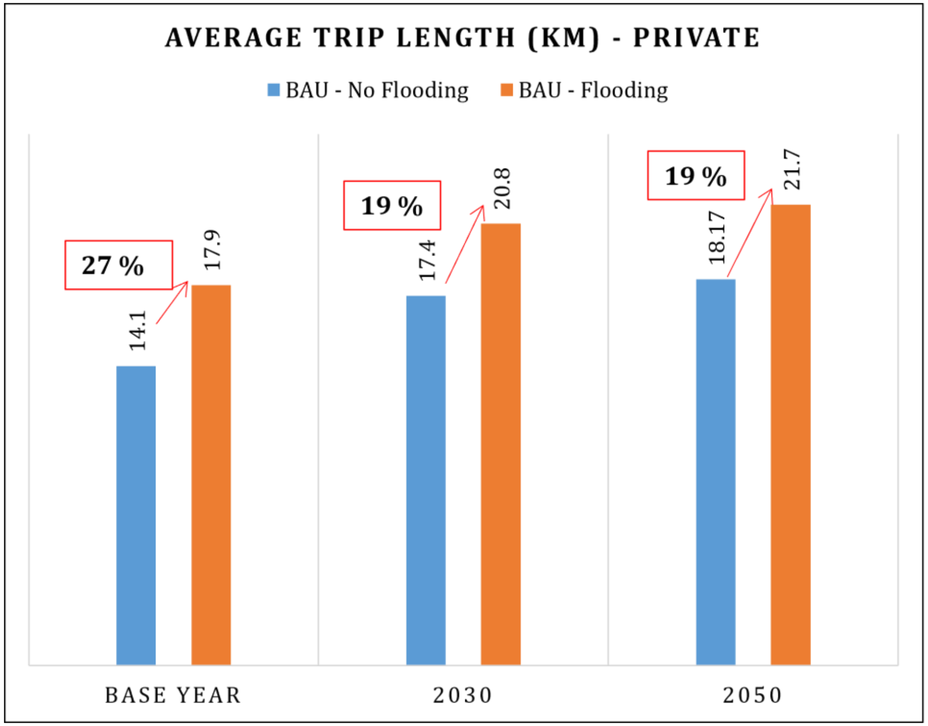


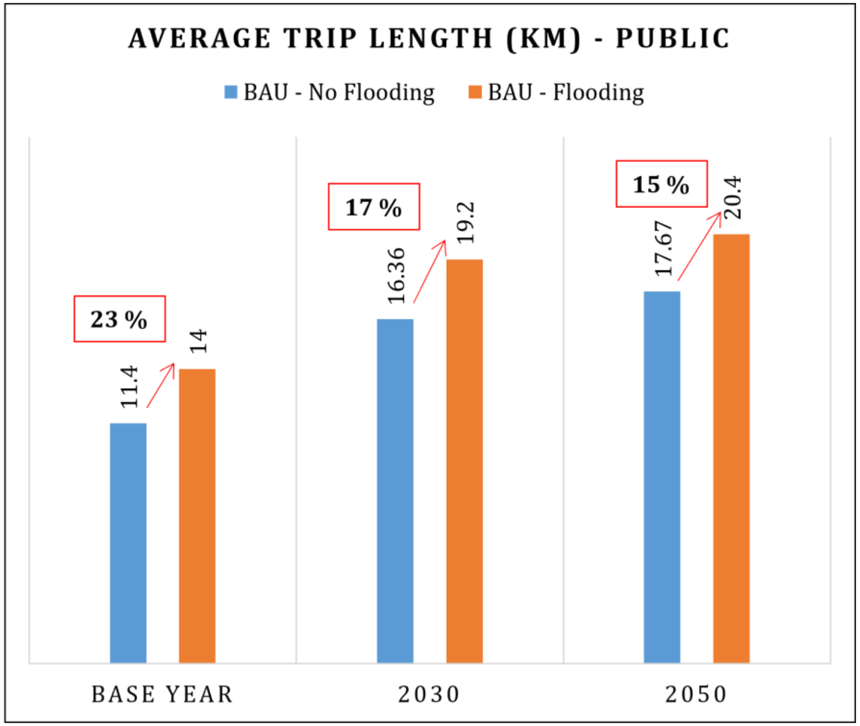
Vehicle Hours Travelled



BAU - Travel Demand Model Results

Average Trip Length (kms) - BAU





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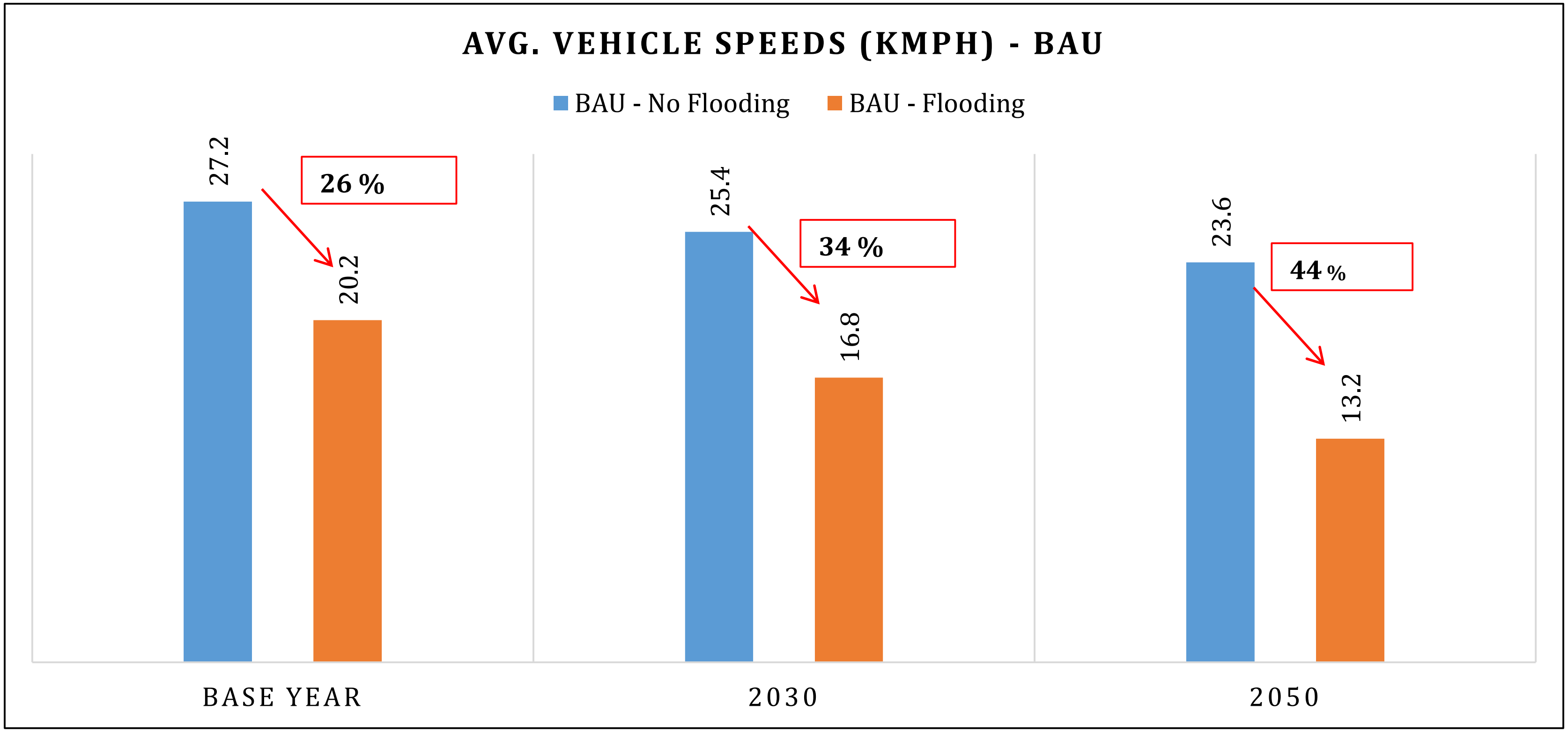
BAU - Travel Demand Model Results

Avg. Daily Vehicle Speed - BAU



Policy bundles for Adaptation

Bundle 1

- Replacement of impermeable road surface with permeable material in vulnerable areas
- Slum relocation and rehabilitation
- Providing proper drainage facilities at vulnerable areas
- Construction of redundant infrastructure

Land use + Infrastructure

Bundle 2

- Rerouting people during flooding
- Restricting development in low lying or vulnerable areas
- Slum relocation and rehabilitation

Land use + Information (Traffic Management)

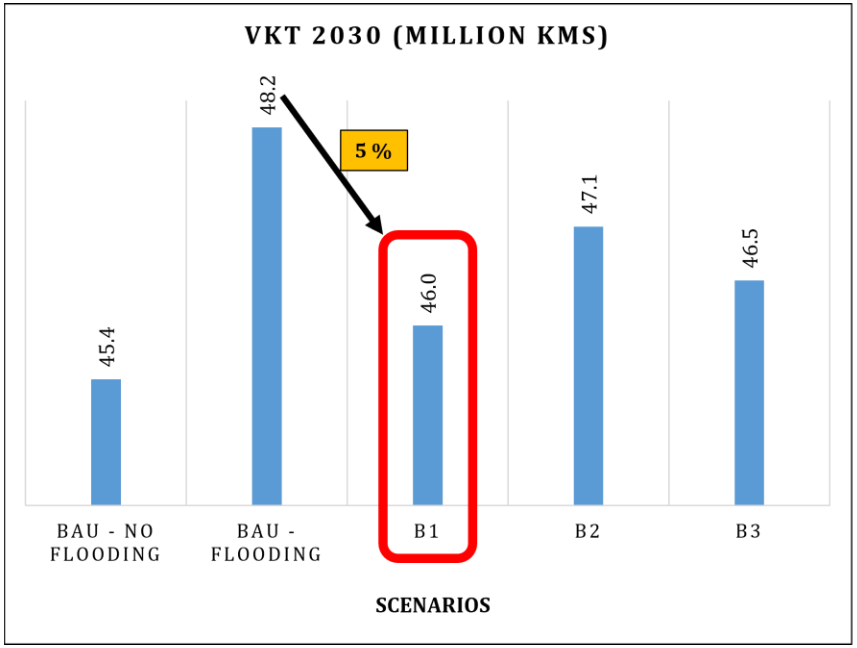
Bundle 3

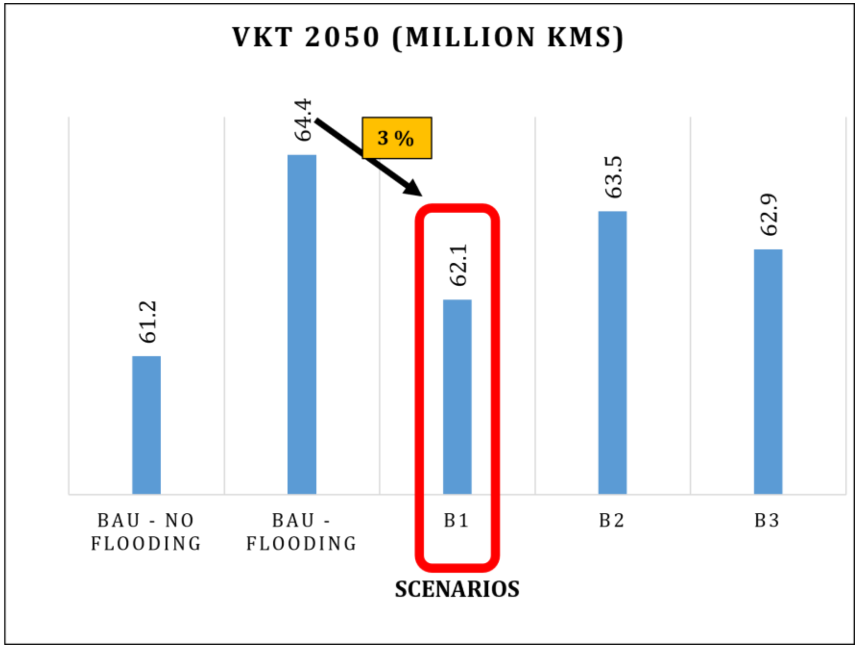
- Replacement of impermeable surfaces with permeable material in vulnerable areas
- Providing proper drainage facilities at vulnerable areas
- Rerouting people during flooding

Infrastructure + Information (Traffic Management)

Results

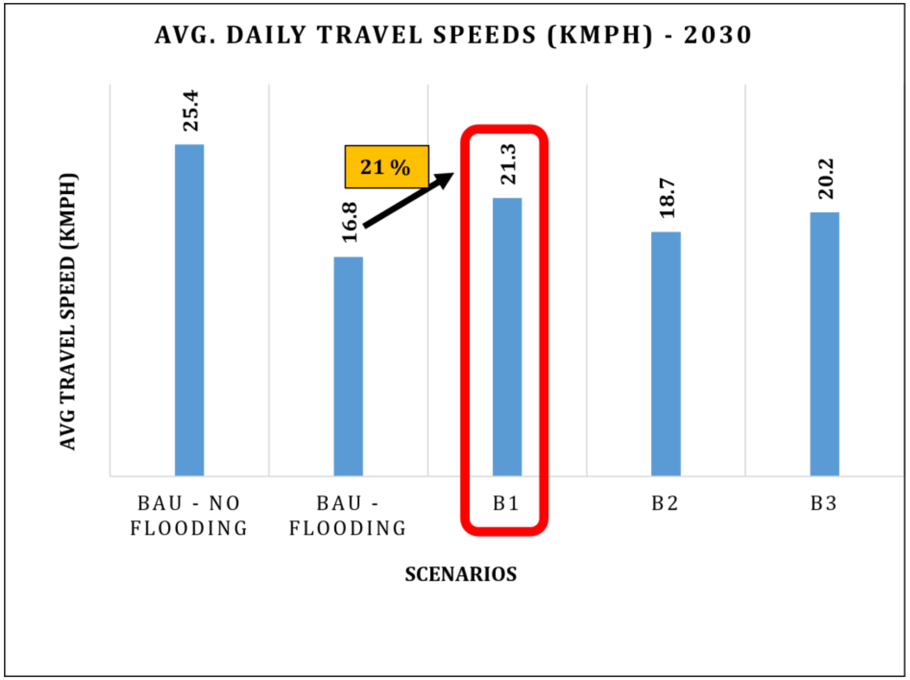
Comparisons of Vehicle Kilometers Travelled (VKT)

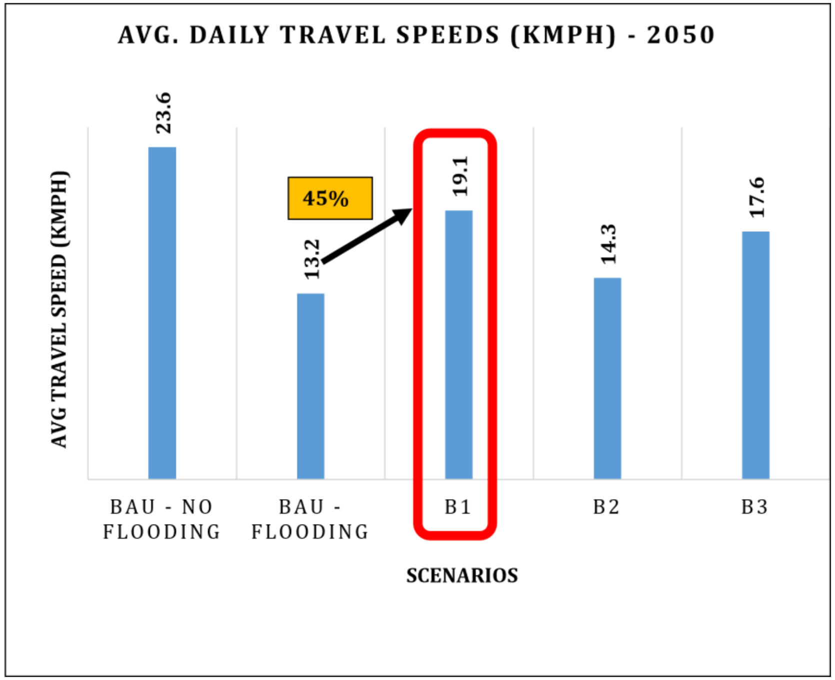




Results

Comparison of Daily Vehicle travel speeds





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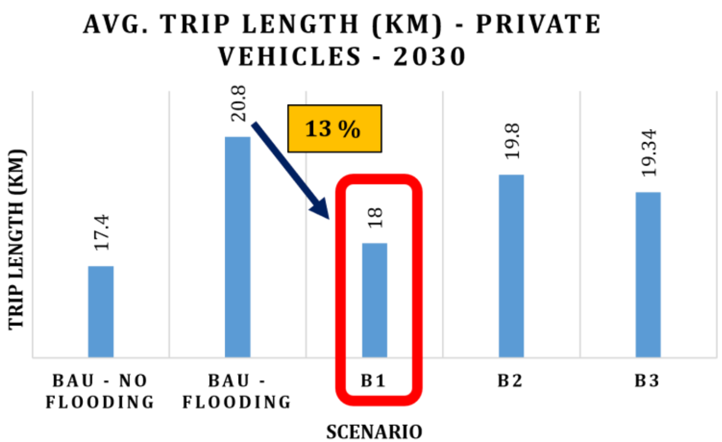
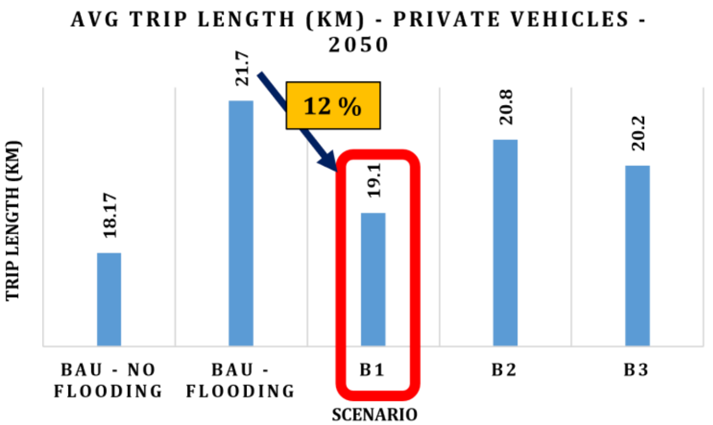
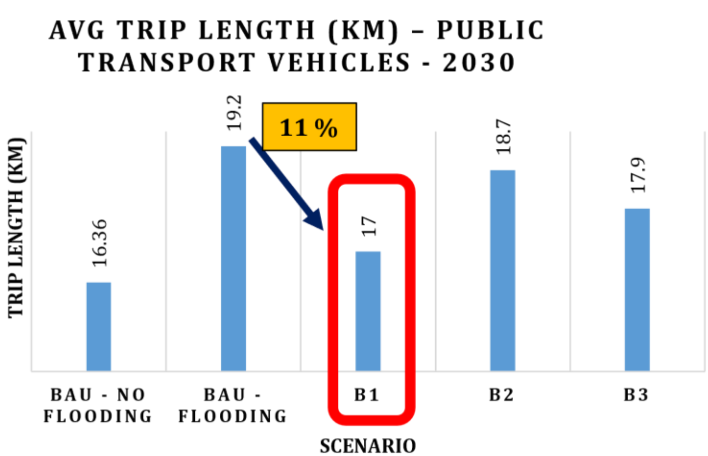
Results

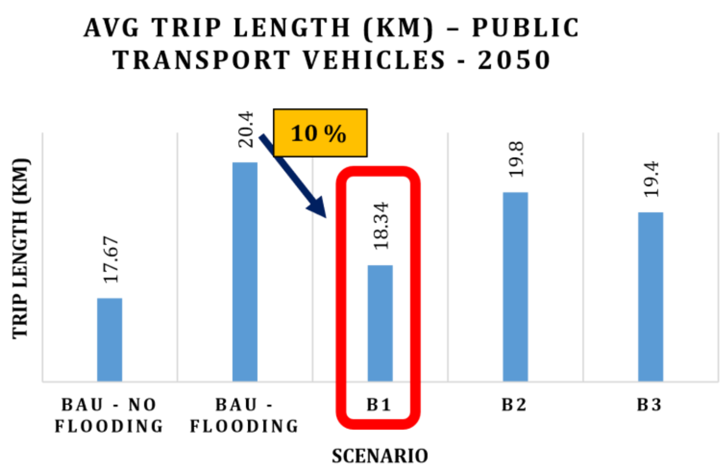
Comparison of Avg. trip lengths





Private

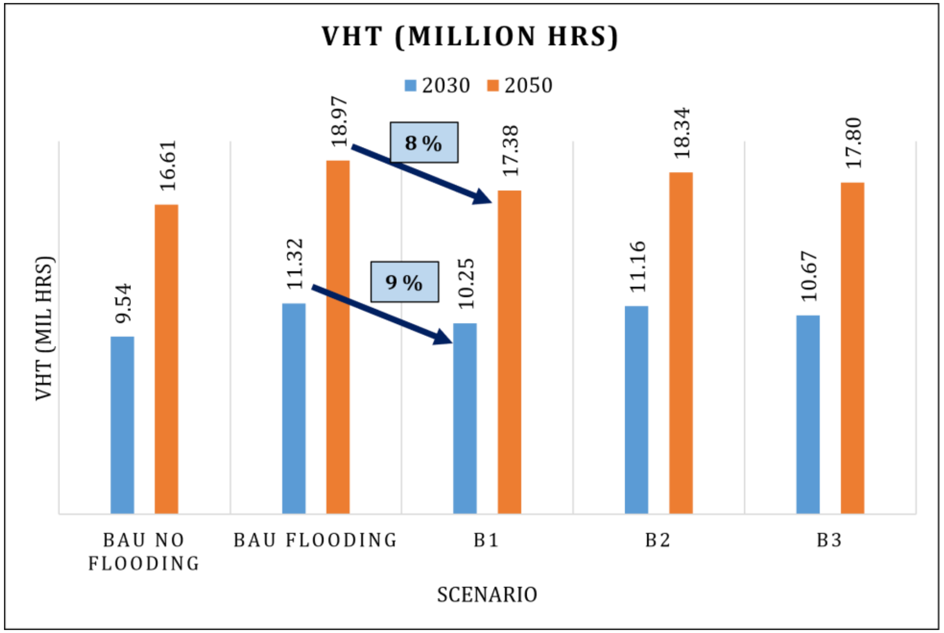




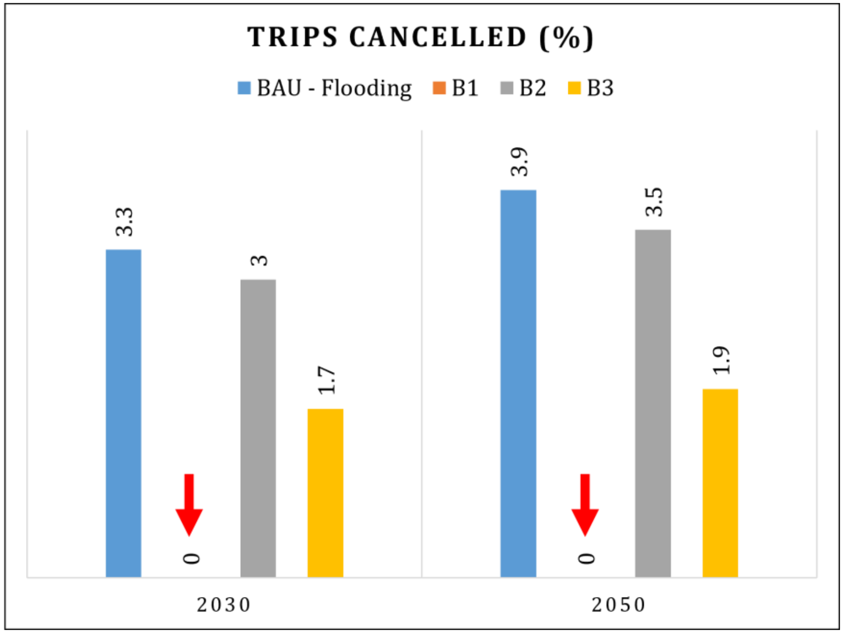
Public

Results

Comparison of Vehicle Hours Travelled (VHT)



Comparison of Cancelled Trips



RELATED PUBLICATIONS

1.Vajjarapu, H., Verma, A., & Hemanthini A. R. (2023). Evaluating the Climate Change Mitigation Potential of Sustainable Urban Transport Measures in India, Journal of Urban Planning and Development, Vol. 149, Issue 1, https://doi.org/10.1061/(ASCE)UP.1943-5444.0000890

2.Vajjarapu, H., Verma, A. (2022). Understanding the mitigation potential of sustainable urban transport measures across income and gender groups, Journal of Transport Geography, Volume 102, 103383, ISSN 0966-6923, https://doi.org/10.1016/j.jtrangeo.2022.103383

3.Vajjarapu, H., & Verma, A. (2021). Composite adaptability index to evaluate climate change adaptation policies for urban transport. International Journal of Disaster Risk Reduction, Elsevier, 58, 102205., https://doi.org/10.1016/j.ijdrr.2021.102205

4.Vajjarapu, H., Verma, A., & Hemanthini A. R. (2020). Evaluating climate change adaptation policies for urban transportation in India, International Journal of Disaster Risk Reduction, Elsevier 47, 101528. https://doi.org/10.1016/j.ijdrr.2020.101528

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THANK YOU