Planning for Low Carbon Mobility for the city of Vadodara

Thesis submitted in
Partial Fulfilment for
the Award of the Degree of

Master of Urban and Regional Planning

by

MAKWANA PARINI MANUBHAI
Second Semester, MURP II – 2020-21

Primary Guide: Dr. Pankaj Prajapati
Secondary Guide: Ms. Chaitali Joshi

Master of Urban and Regional Planning (MURP) Program
Department of Architecture
Faculty of Technology and Engineering
The Maharaja Sayajirao University of Baroda
D. N. Hall, Pratap Gunj, Vadodara, Gujarat, India

JUNE 2021

Planning for Low Carbon Mobility for the city of Vadodara

Thesis submitted in
Partial Fulfilment for
the Award of the Degree of

Master of Urban and Regional Planning

by

MAKWANA PARINI MANUBHAI
Second Semester, MURP II – 2020-21

Primary Guide: Dr. Pankaj Prajapati
Secondary Guide: Ms. Chaitali Joshi

सत्यं शिवं सुन्दरम्

Master of Urban and Regional Planning (MURP) Program
Department of Architecture Faculty of Technology and Engineering
The Maharaja Sayajirao University of Baroda
D. N. Hall, Pratap Gunj, Vadodara, Gujarat, India

JUNE 2021

CERTIFICATE

Planning for Low Carbon Mobility for the city of Vadodara

The contents presented in this Thesis represent my original work and it has not been submitted for the award of any other Degree or Diploma anywhere else.

MAKWANA PARINI MANUBHAI

This Thesis is submitted in partial fulfilment of the requirements for the Degree of Master of Urban and Regional Planning
at the Department of Architecture
Faculty of Technology and Engineering
The Maharaja Sayajirao University, Vadodara, Gujarat, India
The present work has been carried out under our supervision and guidance and it meets the standard for awarding the above stated degree.

Primary Guide:
Dr. Pankaj Prajapati

Secondary Guide:
Ms. Chaitali Joshi

Head of the Department
Dr. Bhawana Vasudeva
Department of Architecture

Dean, Prof. C.N. Murthy
Director of the Master's Programs,
Faculty of Technology & Engineering, The Maharaja Sayajirao University

ABSTRACT

In order for the world to stay within the safety threshold of a 2-degree Celsius increase in average temperature agreed by virtually all governments, the transport sector needs to be decarbonized. Transport accounts for nearly one-quarter of global energy related CO_2 emissions and is the fastest growing contributor to climate change. Increase in the transport demand has made the transportation sector as one of the most energy intensive sector in the country. Transport sector in India accounts for 13.2 % of the total CO_2 emissions from fuel combustion across sectors in the country, of which road transport accounts for the highest share of 87 %. At the current rate of growth, this manifold increase in road transport demand can have huge implications on the overall energy demand of the sector and the associated emissions. Hence, it is imperative that transportation emissions level off and begin to decline within the next decade to reach climate goals. This study will be estimating and projecting the carbon emissions from transport sector of the Vadodara city. Two scenarios will be studied, first the business-as-usual scenario and second, the low carbon scenario. Policies and strategies will be studied to promote low carbon transportation in the city.

THIS THESIS IS DEDICATED TO MY

PARENTS

For their constant belief in me and supporting me at every stage of this master's program.

ACKNOWLEDGEMENT

It is an impeccable fact that every vision needs a spirit of dedication and hard work but more than that it needs proper guidance. Therefore, first and foremost I would like to thank my department for letting me carry out this Study. I am extremely grateful to Head of the Department Dr. Bhawana Vasudeva, for providing me this platform to conduct the study.

I would like to express my deep and sincere gratitude to my thesis guide, Dr. Pankaj Prajapati Sir and Ms. Chaitali Joshi Madam for providing invaluable guidance and untiring help throughout this research. Their dynamism, vision, sincerity and motivation have deeply inspired me. They have taught me the methodology to carry out the research and to present the study as clearly as possible. I am profoundly thankful to Ms. Chaitali Joshi for her constant encouragement and inspiration; it was a great privilege and honour to work and study under her guidance. Also, a great thanks to Dr. Pankaj Prajapati sir for sharing his valuable knowledge.

I am extremely grateful to my Family for their love, prayers and sacrifices for educating and preparing me for my future. I would like to thank all my friends and colleagues to help me whenever I needed them throughout the study. Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

Table of Contents

List of Figures

List of Tables

List of Abbreviation

ASI	Avoid Shift Improve
BAU	Business As Usual
CAGR	Compound Annual Growth Rate
CO2	Carbon Dioxide
EV	Electric Vehicle
GHG	Green House Gas
GT	Gigatons
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public Transport
LCS	Low Carbon Society
LEV	Low Emission Vehicle
MTOE	Million Tonnes of Oil Equivalent
NDC	Nationally Determined Contributions
NMT	Non Motorised Transport
OECD	Organisation for Economic Cooperation and Development
PKT	Passenger Kilometre Travelled
SDG	Sustainable Development Goals
Tg	Teragrams
TOD	Transit Oriented Development
UNFCC	United Nations Framework Convention on Climate Change

CHAPTER 1

1. INTRODUCTION

The greenhouse effect is a major concern in many of the countries in the world. This is caused due to the high degrees of GHGs emissions released into the atmosphere. The growth in the motorization and the travel activities of the population with the rapid urbanization in the country has resulted in the severe growth of greenhouse gas emissions. This increase in the GHG emissions has serious implications on global climate change. Effective mitigation measures and actions are needed to be taken to counter this problem. However, for a developing country like India, there are some data limitations which becomes a major drawback in understanding that how will the changes in demographics, travel behaviour, policy intervention and best practices might affect the future greenhouse gas emissions. Therefore, this study would aim at forecasting carbon emissions from transport sector for current as well as different mitigation scenarios in an urban scale based on the available data on city-level travel patterns particularly for the city of Vadodara.

There will be a very crucial impact on the air pollution levels as the manner in which the cities are developing in India. Therefore, it is necessary that the future changes in the travel pattern as well as the behaviour has to be attained with low carbon emissions. Several planning strategies as well as technological advancements would help to achieve low-carbon developments for these rapidly growing cities. But the question is, whatever the mitigation strategy it is, would it be sufficient enough to cater to the increasing carbon emissions from the transport sector. Understanding how effective a planning strategy and policies or a technical advancement would be is the major question. So, this study would be aimed at assessing how these strategies and policies would change the present trend of swift increase in carbon emissions with the rapid urbanization in Indian cities.

1.1 Transport Sector and CO_2 Emissions

One of the major contributors to GHG emissions is the emissions from the transportation sector. The growing number of cars and trucks has resulted in an incredible rise in GHG emissions. The rapid rise in transportation sector in the past few decades increases the CO_2 emissions in the environment and thus becoming an important worldwide concern.

Transportation sector emits CO_2, the most important greenhouse gas (GHG), and if global warming crosses the safety threshold of 2-degree C then the consequences could be anywhere between bad and catastrophic (Intergovernmental Panel on Climate Change ,IPCC, 2014). In fact, there is evidence already that the safety threshold may actually be 1.5-degree C. To keep global warming below 2 degree C (or 1.5°C) atmospheric concentrations of GHGs must be stabilized and this will eventually require net zero annual emissions (Intergovernmental Panel on Climate Change ,IPCC, 2014).

Worldwide, transport as a whole was responsible for 23% of total CO_2 emissions from fuel combustion and road transport was responsible for 20% (International Energy Agency, 2016). Without persistent and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors and reach around 12 Gt CO_2eq / yr by 2050. Based on current policies and practices, the emissions pathway for the transport sector is projected to increase by 50% by 2030, and to double by 2050, compared to 2010 levels.

Road transport is the largest contributor to global CO_2 emissions from transport, accounting for three quarters of transport emissions. Passenger cars, two-and-three wheelers and mini buses contribute about 75% of passenger transport CO_2 emissions, while public transport (bus and railways) generates about 7% of the passenger transport CO_2 emissions despite covering a fifth of passenger transport globally.

1.1.1 Global Trends in CO_2 Emissions

Transport accounts for almost one-quarter of global energy-related CO_2 emissions. To achieve the crucial deep cuts in greenhouse gas emissions by 2050, transport sector plays a very significant role.

Transport sector carbon dioxide (CO_2) direct emissions increased 29% (from 5.8 Gt to 7.5 gigatons (Gt)) between 2000 and 2016, at which point transport produced about 23% of global energy-related CO_2 emissions, and (as of 2014) 14% of global greenhouse gas (GHG) emissions. Transport CO_2 emissions in non-Organisation for Economic Co-operation and Development (nonOECD) member countries increased from 1.5 Gt in 2000 to 2.9 Gt in 2016, which equals a share of 27% to 41%, respectively. The share of emissions from OECD countries decreased from 58% to 43%, and the total transport CO_2 emissions decreased 50 million tonnes CO_2 from 2.99 Gt in 2000 to 2.94 Gt in 2016. Growth in absolute transport CO_2 emissions between 2000 and 2016 was highest in Asia (92%), Africa (84%) and Latin America (49%), driven by growth in passenger and freight transport activity in these regions. Regional shares of global emissions are rising in Asia, Northern Africa, and Latin America and the Caribbean; falling in Europe and North America and remaining roughly level in Oceania. Passenger and freight transport emissions increased by 36% and 75%, respectively, between 2000 and 2015.

Global transport emissions increased by less than 0.5% in 2019 (compared with 1.9% annually since 2000) due to efficiency improvements, electrification and greater use of biofuels. However, the transport sector is still responsible for 24% of the direct CO_2 emissions from fuel combustion. Road vehicles such as cars, trucks, buses and two and three wheelers' accounts for nearly three quarters of transport CO_2

emissions, and emissions from aviation and shipping continue to rise, highlighting the need for greater international policy focus on subsectors.

1.1.2 Indian Scenario of the Transport Sector

India has a very low per-capita GHG emissions which is even lower than the global average. Despite such low per-capita emissions, globally, India stands fourth in the total share of GHG emissions. In which transport sector is the third largest contributor of CO_2 emissions. Apart from emissions, this sector has also given rise to various negative impacts like congestion on roads, local air pollution, accidents and noise. The intrinsic cost associated with these impacts has been very high. With rapid urbanization and population growth, priorities have shifted from public transport to private vehicles.

As the people in India travel more and transport freight in larger volumes, the transport sector has become the fastest growing energy end use sector in the country. Also, the energy use in India's transport sector has increased fivefold over the past three decades reaching more than 100 MTOE in 2019. Transport is heavily reliant on oil, with 95% of demand being met by the petroleum products and transport also accounts for the half of the India's oil demand.

India's transport sector accounts for 99.6% of the total petrol and 70% of the total diesel consumption in the country (Neilsen, 2013). According to the estimates of the International Energy Agency (IEA), India's transport sector accounts for nearly 3 % of the total transport sector fuel consumption in the world. Between 2005 and 2015, fuel consumption of India's transport sector grew at a CAGR of 8.3 % from 38.8 million tonnes of oil equivalent (MTOE) in 2005 to 86 MTOE in 2015. While over the same period, the world transport fuel consumption grew at a CAGR of 2 % from 2212 MTOE to 2704 MTOE.

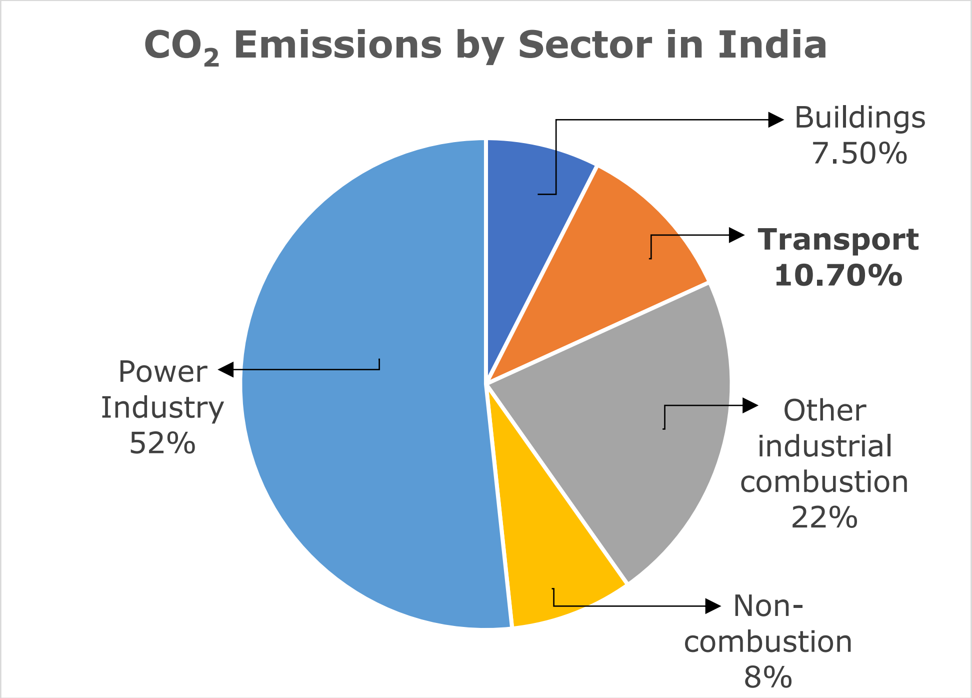


Figure 1.1 Total GHG Emissions by Sector in India

Source: IEA

In India, transport sector accounts for 10% of the total Green House Gas (GHG) emissions (MoEF, GoI, 2015). Since, a major share of the transport sector's energy requirements are met through conventional fossil fuels like petroleum and diesel, the emission intensity of fuel combustion in the sector has increased from 10.5% in 2000 to 11.5% in 2014 (Worldbank, 2018). The Indian transport sector is responsible for 13% of India's energy-related CO_2 emissions, with road transport accounting for 90 per cent of the sector's total final energy consumption followed by rail and domestic aviation (both at 4 per cent) (IEA, 2020).

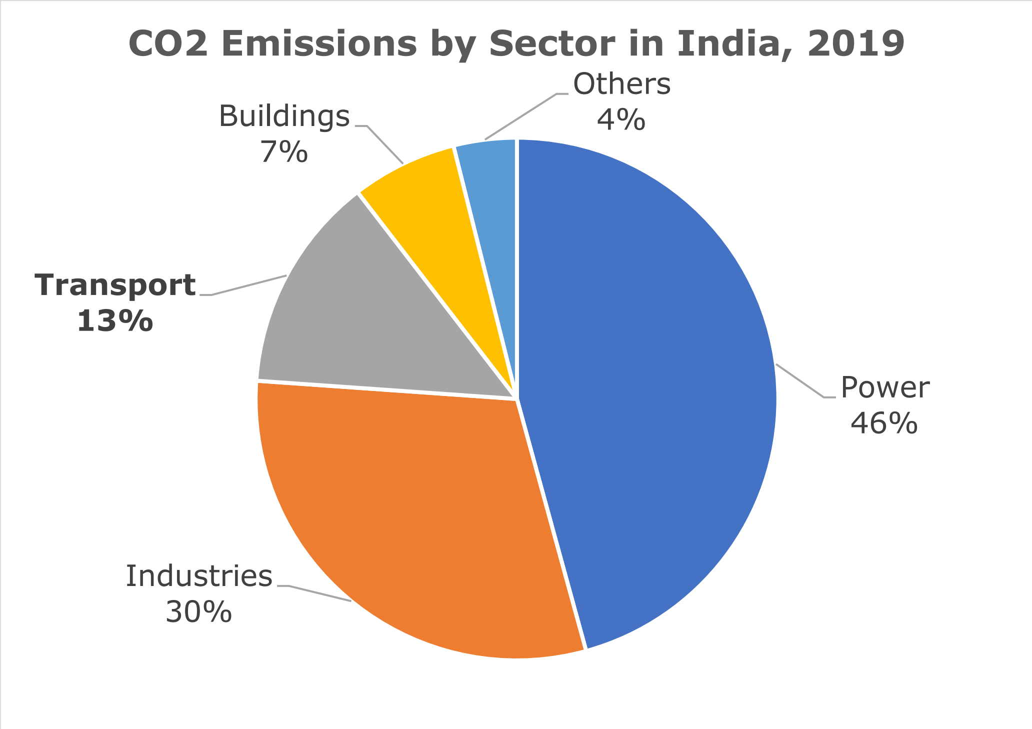


Figure 1.2 CO2 Emissions by sector in India,2019

Source: Indian Energy Outlook 2021, IEA

The figure above shows the carbon emissions from the energy sector of India. Freight transport accounts to nearly half of the CO_2 emissions from road transport.

The National Transport Development Policy Committee (NTDPC) reports that there will be a fivefold growth in the use of road transport for passenger and freight by 2030-31. This growth will have a substantial impact on the overall GHG emissions of the country.

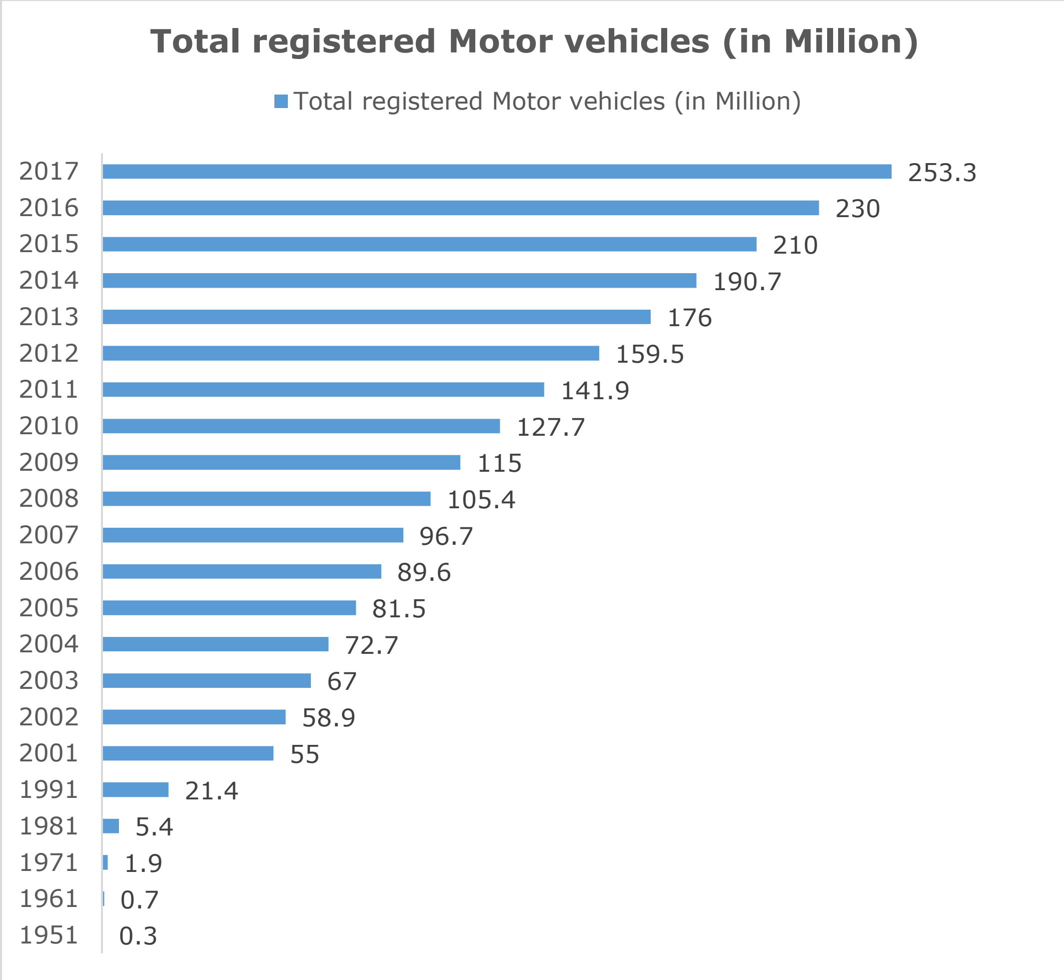


Figure 1.3 Total Number of Registered Motor Vehicles in India

Source: Road Transport Year Book 2016-17

There has been a constant increase in the number of registered motor vehicles in India since 1951. The total number of registered motor vehicles in the country increased from about 0.3 million in March, 1951 to 253 million as on 31st March, 2017. The total registered vehicles in the country grew at a Compound Annual Growth Rate (CAGR) of 10.11% between 2007 and 2017.

1.1.3 Gujarat Scenario of Transport Sector

Analysis of greenhouse gas emissions from the transport sector show that the state's industrially and economically advanced status contributed maximum compared to the other states. Talking of road transport among all the states Gujarat stood just the third with 23.31 Tg after Maharashtra (28.85 Tg) and Tamil Nadu (26.41 Tg) (T V Ramachandran, 2009).

The chart below shows the vehicular population in Gujarat which has been observed to be increased rapidly over the years. The vehicular population in Gujarat has been increased from 5.57 million in 2001 to 25 million 2019.

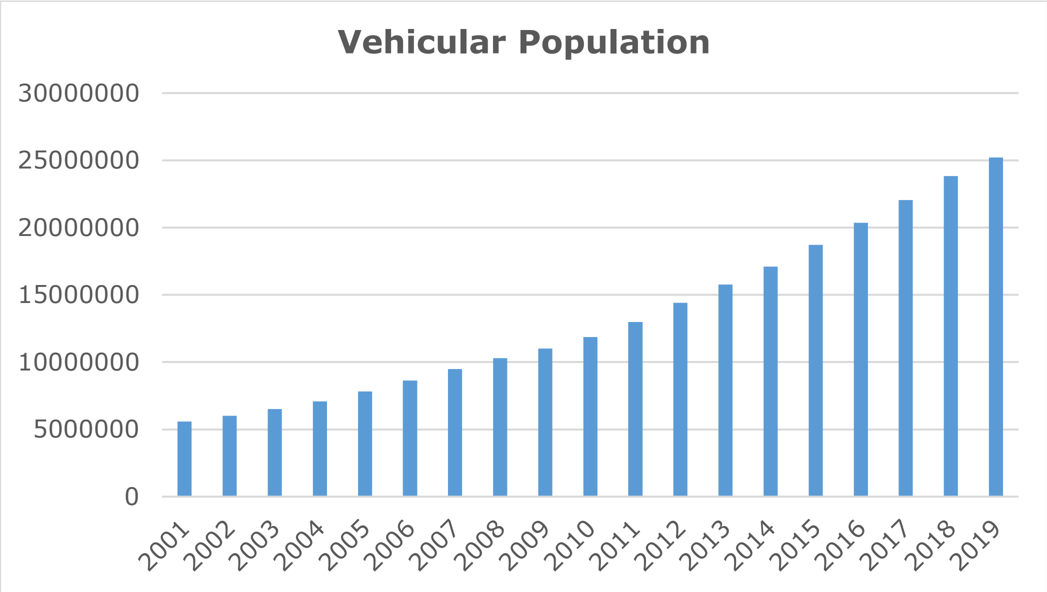


Figure 1.4 Vehicular Population in Gujarat

Source: Commissionerate of Transport, GoG

CAGR of Registered Motor Vehicles during 2007-17 of the Gujarat state has been observed as 8.78%.

1.2 CO_2 Emissions and Global Climate Change

The earth's climate is influenced by numerous factors such as radiation from the sun, reflectivity of the earth, reflection of sunlight by clouds and fine particles, and concentration of greenhouse gases in the atmosphere. The six main greenhouse gases (GHGs) which are identified in the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and per fluorinated compounds (PFCs). In addition, ozone, chlorofluorocarbons and aerosols also contributes to the global warming. These gases come from several sources and differ in their potential to contribute to temperature rise.

CO_2 has been identified as one of the major greenhouse gas in Kyoto Protocol and is mainly generated from the energy supply, transport, residential & commercial, and industrial energy use. CO_2 is generated primarily from the fossil fuels and occupies the largest share of global greenhouse gas emissions.

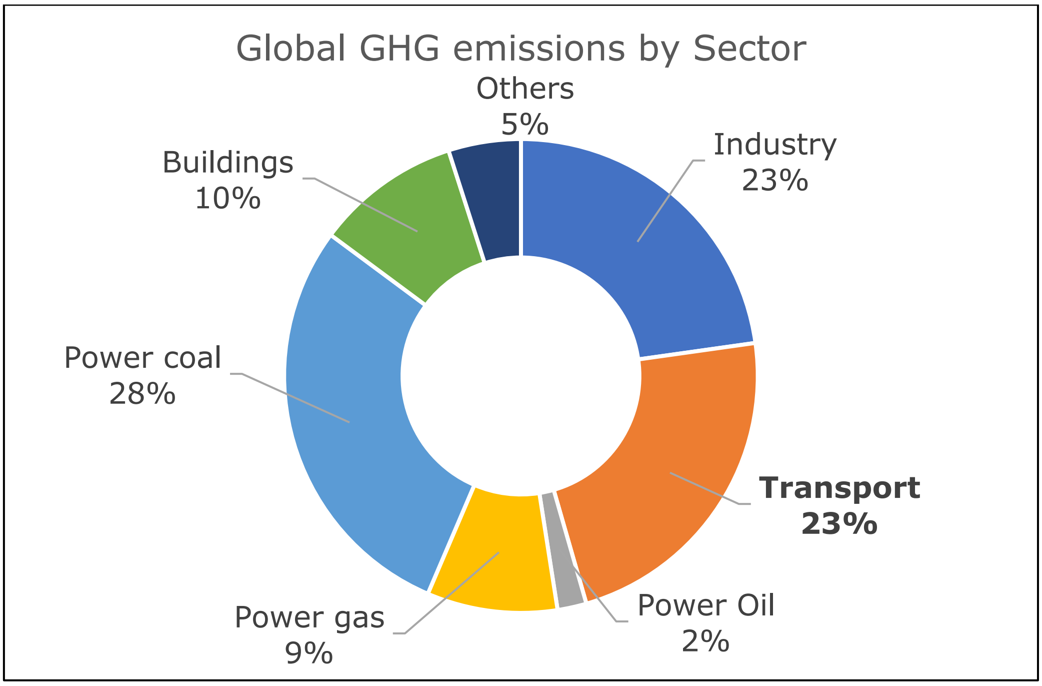


Figure 1.5 Global GHG emissions by sector 2020

Source: IEA

Many Global conferences has been organized (The Earth Summit in Rio de Janeiro in 1992; The Kyoto Protocol in 1997) till date in order to manage the climate change on the global scale. The Paris Agreement, UNFCCC has referred to aiming at 2 °C stabilization targets and also looking for alternatives in order to achieve 1.5°C stabilization targets. The 2°C stabilization targets to stabilize the GHG emission concentration at a level that could maintain the temperature rise below 2°C. This target aims at stabilizing the CO_2 concentration at 450 ppmv (parts per million volume) in the future. Also, the conference of Parties to the UNFCCC held in Doha again agreed to the 2°C target and the continuation of Kyoto Protocol till 2020.

It has also been observed that cities have an intrinsic two-way relationship with climate change. Cities are the major source of emissions and also with the changing climate, the cities themselves would get effected the most, since the cities holds a large majority of population and productive assets. In the total share of GHG emission, the transport sector plays a very major role. Controlling the emissions from the transport sector would substantially help in reducing carbon emissions.

1.3 Literature Review

This review is carried out to find out the present state of knowledge referring to low carbon mobility and to identify the key issues to be addressed in this study.

(Sudeep Grover, 2013) in his study states that transport plays a crucial role in development and constitutes a significant share of world energy consumption. Transportation primarily depends on petroleum, which supplies nearly 95 per cent of the total energy use of world transport and accounts for nearly 60 per cent of oil consumption. Hence, the transport sector has also been largely accountable for the pollution and GHG emissions. In 2005, the total final consumption of petroleum products for the world was 3,420 mtoe, of which 60.4% was consumed by the transport sector. Within the transport sector, road transport consumes the largest share of 76%. Transport emissions are one of the reasons for CO_2 existence in the urban environment. The growth in the emissions is in many ways directly related to the development of emerging economies such as India. Timilsina and Shrestha (2009) have studied the reasons behind the increase in CO_2 emissions in transport sector in Asia. They also suggested that in order to report the CO_2 emissions reduction, a quick switching to clean fuels and shifting to public transportation modes, such as bus, rail and water transportation, could help achieving this objective. Their study finds that of the six factors considered, three economic development, population growth, and transportation energy intensity—are responsible for driving up transport sector CO_2 emissions in Bangladesh, the Philippines, and Vietnam. In contrast, only economic development and population growth are responsible in the case of China, India, Indonesia, Malaysia, Pakistan, Sri Lanka, and Thailand.

(Banister, 2011) in his study argued that the current situation is unsustainable, and that transport must contribute fully to achieving carbon reduction targets. An alternative is presented, based on the sustainable mobility paradigm that looks at ways to reduce the need to travel in cities. The belief that high mobility and technology provides the solution is misdirected, as technological innovation can only get us part of the way to sustainable transport, and this may enable more travel. There are more probabilities for cities to switch to low carbon transport futures, where vision and action are based on a combination of economic, planning and technological innovations working in equally supporting ways. His study also included some measures for reducing carbon emissions, the first is by substitution which means that reducing the need to travel, other is transport policy measures which can decrease levels of car use through the promotion of walking and cycling and the development of the new transport hierarchy. This can be achieved through slowing down the urban traffic and transferring space to public transport, through parking controls and road pricing, and through making it easier to use public transport. Third is the land Use planning measures the one which addresses the physical segregation of activities and the means by which distance can be reduced. The purpose was to build sustainable mobility into the patterns of urban form and layouts, which in turn may lead to a switch to green modes and public transport. And the last is by increasing the efficiency through technological innovation.

(Dhar & Shukla, 2015) in their study finds that the transport sector actions that moderate demand for passenger and freight transport, shift demand to more sustainable modes, advance and improve the efficiency of vehicle technologies and shift to cleaner fuels will address concerns of policy makers for energy security and local environmental issues and, also deliver the climate co-benefits due to reduced carbon intensity of transport sector. However, these climate co-benefits are relatively small when compared to the level of mitigation needed for the 2 degree C stabilization target. Significant co-benefits can be gained by aligning the policies and actions defined for national sustainable transport which aims to garner national benefits and low carbon transport which aims to contribute to the global climate stabilization target. This would require recognizing that across national and global domains there is: i) asymmetry in the amounts of co-benefits, ii) complementarity of co-benefits, iii) contrasting co-benefits and co-costs, and iv) difference in the timing of the benefits.

(Dhar, Pathak, & Shukla, 2013) in their study talks about the two scenarios, that is one the business-as-usual scenario (BAU) and two the Low carbon society scenario (LCS). The future representing the continuation of past trends, usually referred to as a business-as-usual (BAU) scenario, is often used as a benchmark for assessing the policy interventions for achieving any other scenario. A BAU scenario assumes that the future economic development will be along the conventional path. And the Low carbon society scenarios visualise social, economic and technological transitions through which societies will respond to climate change. The objective of the city level low carbon planning would be to develop a 'low carbon city roadmap' which: i) is consistent with the national mitigation roadmap and programs like 'mission on sustainable habitats'), ii) aligns the city's sustainable development objectives with the cost-effective mitigation responses in the city, and iii) delivers co-benefits, such as improved local air quality, and reduces risks.

Investments in public transport will slow down the growth of private transport, but will not be able to reverse it. Therefore, planning for mitigating the impacts of private transport should also be thought by city planners. They stated, that the transport sector, at present, is heavily dependent on oil (petrol and diesel), however, in the future there will be diversification towards electricity, biofuels and natural gas. The level of diversification was even greater in an LCS scenario. City planners should run various land-use scenarios to explore density and diversity for the future. Land-use planning also needs to better integrate the NMT (Non-Motorized Transport) modes with public transport. Decisions regarding urban forms and structures can deliver various co-benefits, reduce climate related risks, and, in general, enhance quality of life in the immediate future as well as in the long-term.

As localities strive to minimize greenhouse gas emissions, compact, mixed-use, and transit-oriented development which promotes walking, bicycling, and mass transit use will naturally become more viable. Reduced trip distances will allow these alternative modes to compete with the automobile, helping to improve the mobility and accessibility for all residents. The tools available to local governments to reduce greenhouse gas emissions in the form of zoning regulations, building codes, pricing policies, public education, and investment decisions are many and can be utilized to great effect (Deborah Salon, 2008).

(Kazuki Nakamura, 2013) finds that the effects of low-carbon transport measures for each strategy may vary according to development stages and types of urban land-use transport systems. For AVOID and SHIFT strategy, the early-stage measures, such as land-use control and mass-transit development, are potentially more effective for developing cities than for developed cities, as they have the larger amount of prospective development. On the other hand, developed cities find it more effective to introduce the later-stage measures, such as traffic control and advanced transport systems. For IMPROVE, while the effects depend more on the technological levels, higher-density cities may be advantageous to LEV promotion as they can provide a more efficient supply of electricity. While various levels of CO_2 mitigation can be generated by types of measures, there is no single solution to achieve the challenging target of mitigation for each country and city. This requires the design of a policy package among them, as in a back casting approach. Low density and car dependent cities may have a disadvantage in implementing measures for AVOID and SHIFT because they are less feasible for the mand, consequently, they are less effective. As a result, the contribution of LEV promotion for IMPROVE to the mitigation is required more in these cities. However, the enhancement of fuel economy could generate more travel demand, which may undesirably affect the mitigation effect. Therefore, it is essential even for them to broadly design the package from many different strategies to reduce the possibilities of rebound effects. Also, the primary execution of measures for AVOID and SHIFT is important for Asian developing cities. Motorisation and urban sprawl takes place in the short term under rapid economic growth, and this makes cities irreversibly low density and car-dependent. The early-stage measures can make a significant difference by developing a necessary urban land-use transport system to accommodate the following stage measures. Due to the short-term economic growth, the implementation of measures should be made in the short term to avoid rapid increase in CO_2 emission and even mitigate the emission.

(FICCI, 2020) in their report on India Roadmap on Low Carbon and Sustainable Mobility states that the Indian roadmap will lay out a long-term direction for policy interventions for a low carbon and sustainable mobility ecosystem for India and will provide the vision for an integrated approach to decarbonisation of the transport sector in the short term (2022), medium term (2030) and long term (2050). While the global roadmap provides the way towards decarbonisation of the transport sector by 2050, the India roadmap sets itself apart through a phased approach to decarbonisation. The process of building the India roadmap involves a mapping of the landscape of sustainable mobility policy framework in the country, bottom-up industry-led consultation and inputs, and interface with the government and other stakeholders in the mobility interplanetary in India. The India roadmap has 8 components –

- Urban transformation for healthy, inclusive lifestyles and efficient, resilient, prosperous cities
- Low-carbon energy supply strategy
- Improve intermodal and mode-wise system efficiencies
- Optimize supply chains to manage freight transport emissions
- Avoid vehicle kilometers travelled for commuting, shopping and accessing services
- Provide low-carbon solutions for the rural (nonurban) populations
- Fast-track action on adaptation in the transport sector
- Large scale positioning of economic instruments and leveraging finance

(Robin Hickman, 2011) gave different packages of measures and developed scenarios for each context which are consistent with contraction and convergence objectives. CO_2 reduction potentials were modelled and quantified by package and scenario. Their paper argued for a ‘strategic conversation’ at the city level, using scenario analysis, to discuss the priorities for intervention in delivering low carbon transport futures. A greater focus was required in developing participatory approaches to decision making, alongside network investments, urban planning, low emission vehicles and wider initiatives. Ambitions towards equitable target emissions may assist in setting sufficiently demanding targets. Only then a wider awareness and ownership of potential carbon efficient transport futures likely to take place. For Delhi he gave eight policy packages of measures as follows:

- PP1: Low Emission Vehicles
- PP2: Alternative Fuels

- PP3: Vehicle Class Market Share (car/SUV/2-wheeler/3-wheeler)
- PP4: Public Transport
- PP5: Walking and Cycling
- PP6: Urban Planning
- PP7: Wider 'Behavioral' Intrusions (combined pricing regimes, traffic demand management (TDM), ecological driving and slower speeds, information and communication technologies (ICT), long distance travel substitution)
- PP8: Freight Transport

Four scenarios for 2030 were analysed by him, the first was the business-as-usual scenario, then scenario-1 as Lower Carbon Driving, scenario-2 as More Active Travel and Scenario-3 as Sustainable Transport. In BAU scenario the future is an extension of existing trends over the next 20 years and some investment in public transport, limited change in the efficiency of the car and in the use of alternative fuels. Large projected growth in traffic, with an approximate 700% increase in CO_2 emissions on 1990 levels. In scenario 1 as Lower Carbon Driving a strong and successful push on technological innovation, including low emission vehicles, alternative fuels and smaller vehicle types, with an approximate 500% increase in CO_2 emissions on 1990 levels was considered. The scenario 2 as More Active Travel included less optimistic about the potential implementation of low carbon vehicles and relies more on public transport, walking and cycling investment and behavioural measures, with an approximate 300% increase in CO_2 emissions on 1990 levels. The scenario 3 as Sustainable Transport combined the best technological and behavioural application of scenarios 1 and 2 to deliver an approximate 200% increase in transport CO_2 emissions, on 1990 levels.

Scenario -3 as Sustainable Transport was concluded as the most effective scenario in which high levels of low emission vehicle take up, a small size car fleet, and high investment in public transport, walking and cycling, and a supportive urban structure, were all envisaged. The scenario, when modelled, achieved a 68% reduction in transport CO_2 emissions on BAU levels and a 167% increase on 1990 levels. In Scenario 3 (and 2) overall travel distance increases markedly on current levels, but car distance remains similar to 2010 projections, with the difference taken up by a very large increase in bus (potentially a wider bus rapid transit network, but also more extensive use of a clean bus fleet), rail (an extended metro system) and cycling. Two and three-wheeler also have much potential, if cleanly fuelled (three wheelers are currently fuelled with compressed natural gas).

1.4 Justification of the Study

Increase in the demand for transport has made the transport sector as one of the most energy intensive sector in the country. Presently, the transport sector accounts for 24 % of the total energy consumption in the country (TERI, 2018) and 98.5 % of which is met by petroleum products (TERI, 2016). India's transport sector accounts for 99.6 % of the total petrol and 70 % of the total diesel consumption in the country (Neilsen, 2013). In India, transport sector accounts for 10 % of the total Green House Gas (GHG) emissions (MoEF, GoI, 2015). Transport sector in India accounts for 13.2 % of the total CO_2 emissions from fuel combustion across sectors in the country, of which road transport accounts for the highest share of 87 % (UIC/IEA, 2016).

At the current rate of growth, this manifold increase in road transport demand can have huge implications on the overall energy demand of the sector and the associated emissions. India's CO_2 emissions are projected to triple by 2040 from 2013 levels if sectoral policies to manage energy demand are not put in place. Considering the high reliance of the sector on fuel consumption coupled with India's high import dependence of crude oil (83 % of total oil consumption) it is imperious to plan for sectoral policies that can manage fuel and energy demand from the sector in the coming decades and can impact the future carbon emissions. In this context, mitigation and adaptation strategies in the transport sector will play a significant role in achieving the Nationally Determined Contributions (NDCs) targets, which represent a exclusive opportunity for India to reduce its emissions and energy consumption.

With an objective of promoting energy efficient low carbon growth of the road transport sector, it is necessary to develop and implement effective mitigation actions in order to control the future carbon emissions from transport sector. It would be necessary to focus on several mitigation initiatives to develop energy efficient and low carbon transport systems to reduce emissions from the transport sector.

Hence, there arises a need for proper framework to deal with CO_2 emissions from transport sector has to be developed. The first step for the framework would be to measure the CO_2 emissions. This would include measuring present CO_2 emissions from the transportation sector and forecasting the future emissions if continued in the same path. According to the study by Asian Development Bank on Transport and CO_2 emissions, the framework would precisely comprise of the following three steps. (ADB, 2009)

- Analyze the present status, which would include monitoring the transport activities, fuel use, CO_2 emissions and Energy use.
- Project the future transport demand based on projected incomes, land uses, and other variables in order to assess the future emissions and energy use.
- Based on the above results, evaluate the impacts of different policy interventions that would result in change in CO_2 emissions from the business-as usual scenario.

There had been several studies which had attempted to quantify the impact of transport sector on carbon emissions worldwide, but most of them has focused on a country level assessment and mostly carried out by a top-down approach. However, bottom-up approach is necessary for better understanding of the transport system, through various transport activity and characteristics data.

Most of the researches done till date by top-down approach or bottom-up approach, it is done at a national scale. But there are few drawbacks in the researches of national level as the result of these analysis points to the emissions magnitude problem and also all such researches rely on scarce data source and credible assumptions. Also, these assumptions are based on either, fuel use pattern, or vehicle counts, or demographics; rather than city level analysed travel trends. These studies have mostly considered only nationwide data and analysed accordingly. In order to understand the implication and future trends of various carbon reduction measures on ground level it is appropriated to consider the travel behaviour of individuals, thus the study has to be done at a much smaller scale. Carrying out such an analysis for a city would help understand all these aspects of carbon emission forecasts in much detail, incorporating both travel behaviour as well as demography. Even with the availability of such scarce data, an analysis focused on city level travel pattern and behaviour can contribute to the knowledge of emissions and energy use at urban scale. So, this study would be done on an urban scale, for the city of Vadodara, Gujarat, India.

1.5 Why Vadodara?

This research studies the CO_2 emissions from transport sector of the city of Vadodara, Gujarat. Vadodara is the third largest city in the Gujarat state and is one of the focal points of industrial growth in Western India. Along with eleven other major cities across the country, the city became a metropolis in 1991, by crossing the one million-population mark. According to census 2011, there are 90.70% urban population residing in the city.

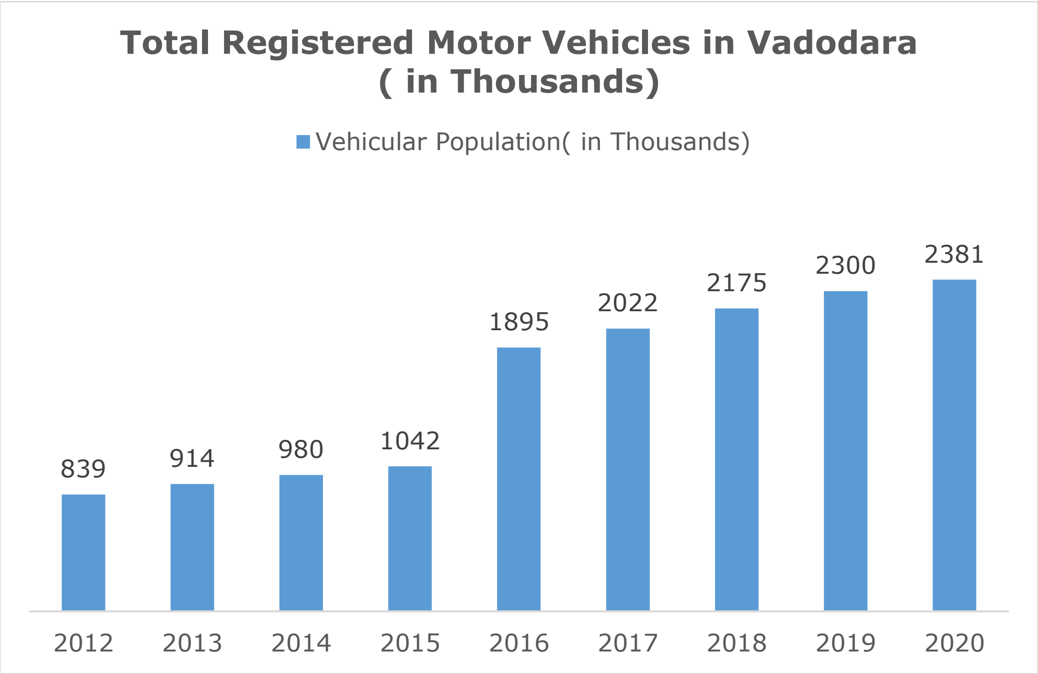


Figure 1.6 Total Registered Motor Vehicles in Vadodara

Source: RTO OFFICE Vadodara, Statistical Yearbook India 2018

The vehicular population of Vadodara city has observed drastic increase in the year 2016 and then kept on increasing. The total registered motor vehicles in the Vadodara city are 23.8 lakhs. Vadodara district shares only 3% of the state population but accommodates 9.5% of the registered vehicles in the state. The CAGR of Registered Motor Vehicles during 2007-17 of the Vadodara city has been observed as 8.91%.

Public transport in Vadodara constitutes city buses and intermediate public transport (IPT) systems -- auto rickshaws, taxis and tempos. The Gujarat State Road Transport Corporation (GSRTC) operates the city bus service. Additionally, a few industrial establishments on the outskirts of the city such as in the GIDC area, IPCL, GSFC etc. operate their own buses. These buses, along with private operators, supplement the GSRTC services. City bus transport has not grown in proportion with the growth in population. Also, city buses have not seen any considerable growth since 1986; this has however popularised the IPT system, which plays a vital role in city passenger transport. There has been a gradual increase in the number of IPT vehicles every year and among the IPT vehicles auto-rickshaws are growing at a rate of 4.76% p.a. as against taxis, which are growing at a high rate of 25.28% p.a.

Vadodara does not have Public transportation such as BRTS in Ahmedabad but it do have city buses VITCOS which run all over the city. It would be feasible to develop policies and strategies to make people shift to public transportation from private transportation which in turn would reduce the carbon emissions in the city and provide a low carbon transport system for the city.

1.6 Aim of the Study

The Aim of this study is to estimate the carbon emissions (CO_2) of the city and promote low carbon mobility in the city.

1.7 Objectives of the Research

This research would mainly focus on fact that how the transport impacts the global GHG emissions particularly in cities of developing country like India. It would enable to predict that if the same trend is followed and no measures are taken then how the emissions would increase. At the same time comparing it with a scenario where some mitigation measures are applied by policy proposals. The objectives of the study will be as following:

- To evaluate the CO_2 emissions from transport sector of the city
- To propose the required mitigation measures and policies to reduce the carbon emissions of the city and providing the city low carbon transport.
- To compare the business-as-usual scenario and the alternate low carbon scenario.

1.8 Research Questions

In order to achieve the above objectives, the research questions to be answered are:

- What is the present carbon emission per year from transport sector for the city?
- If no measures are taken and no changes being made then how would the future emissions increase?
- What all alternatives or measures or policies could be applied in order to better the situation?
- After incorporating the alternatives or mitigation measure, how the trend will be changed?
- What would be the shift if the business-as-usual scenario is compared with the alternate scenario of low carbon?

1.9 METHODOLOGY

CONCEPTUALISATION

- Understanding the need for the study
- Formulating aim, objectives and scope of the study
- Site selection & justification of the selection
- Formulating research framework to conduct the study

LITERATURE REVIEW

- Understanding the climate change
- Understanding the role of transportation in climate change
- Varous trends studied in past
- Methods to evaluate the carbon emission from transport sector
- Understanding measures taken till date to promote low carbon transportation.
- Scenarios studied in this sector.

DATA COLLECTION

- Secondary data collection such as vehicular population of the Vadodara city over the years
- mode share of vehicles for different years,
- trip length and
- trip rate.

DATA EVALUATION AND ANALYSIS

- Base year emission inventory will be generated considering 2019 as base year.
- First bussiness as usual scenario will be considered and carbon inventory will be generated for it for year 2030 and 2040.
- Then a low carbon scenario will be generated which would help a city in reducing the carbon emissions from transport sector.
- Feasibility of low carbon scenario will be checked through questionairre.
- Strategies and Policies will be studied for promoting low carbon transport.

CONCLUSION

- Comparing both the scenarios i.e Bussiness as usual and low carbon transport scenario and drawing the conclusion.

1.10 Complete Methodology for Emission Calculation

The process can be divided into four steps. The steps are mentioned below.

Step.1 Calculating Total Transport Demand

The Transport Demand can be calculated by the following equation:

$$\mathbf{TD_i = \Sigma Tr_i \times Tl_i \times Pop_i \times 365}$$

(Dhar & Shukla, Low carbon Transport Scenarios in India: Cobenefit analysis , 2015)

TD_i= Travel demand for the year i (PKT)

Tr_i = Average trip rate for the year i

Tl_i = Average trip length for year i (km)

Pop_i = projected population for year i

Once the total Passenger Kilometres travelled has been calculated for respective years, mode wise PKT has to be calculated. In the next step, the mode wise PKT would be calculated.

Step.2 Mode Wise PKT Calculation

To Calculate the mode wise PKT, the mode share percentage has to be multiplied with the total passenger kilometres. By multiplying both, mode wise PKT would be achieved.

Mode Wise PKT = % of modal share (each mode) x TD_i

Step.3 Emission Factors

Emission Factors has been taken as an average for each mode with different fuel type. Emission Factors has been taken from India Specific Road Transport Emission Factors, India GHG Programme.

Mode of Vehicle	Emission Factor (kg/km)
Two-Wheeler	0.044
Four-Wheeler	0.169
Bus	0.0151
IPT	0.10768
Cycle	-
Walk	-

Table 1.1 Mode Wise Emission factor

Step.4 CO2 Emission Calculation

For calculating the CO_2 Emissions, the mode wise PKT will be multiplied with the emission factor of each mode.

CO2 Emissions(kg/year) = Mode wise PKT (km/year) x Emission Factor(kg/km)

CHAPTER 2

2. BASE YEAR INVENTORY

In this study the base year is considered to be 2019 and on the basis of 2019 inventory forecasts are made for 2030 and 2040. Data regarding population, trip length, and trip rates and mode shares has been collected from different studies done on Vadodara assuming they are nearly accurate.

2.1 Total Travel Demand

For the calculation of total passenger kilometres travelled, data such as population, average trip rate and average trip length is required. The projected population for Vadodara city for year 2019 has been taken. And Average trip rate and trip length has been taken from literature.

DATA FOR 2019	
POPULATION	2327345
AVERAGE TRIP RATE	1.6 per day
AVERAGE TRIP LENGTH	5.4 km

Table 2.1 Data for Travel Demand Calculation

From the above data, the total traffic demand (PKT) for the year 2019 has been calculated and it comes to be *7,339,515,192* kilometres for the whole year.

2.2 Mode Share and Mode Wise Passenger Km Travelled

Based on the percentages of mode share, the mode wise passenger km travelled has to be calculated.

MODE SHARE	YEAR 2019
2W	60.97
E_2W	0.03
4W	12.86
E_4W	0.14
BUS	5.2
E_BUS	0.8
IPT	5.997
E_IPT	0.003
CYCLE	4
WALK	10

Table 2.2 Mode share percentages

The dominant mode share in the city is of Two-Wheeler. The public transport accounts for 12% of the total share. Electric mode accounts for a very negligible mode share.

Based on the mode share percentages, the mode wise passenger km travelled has to be calculated.

The table below shows the mode wise passenger km travelled.

MODE SHARE	Mode Wise PKT(km)
2W	4474902413
E_2W	2201854.55
4W	943861653.7
E_4W	10275321.27
BUS	381654790
E_BUS	58716121.54
IPT	440150726.1
E_IPT	220185.455
CYCLE	293580607.7
WALK	733951519.2

Table 2.3 Mode Wise Passenger Km

2.3 CO_2 Emissions

The emission factors from table.1 has been taken in order to calculate the total CO_2 emissions. The mode wise CO_2 emission values are listed in the following table.

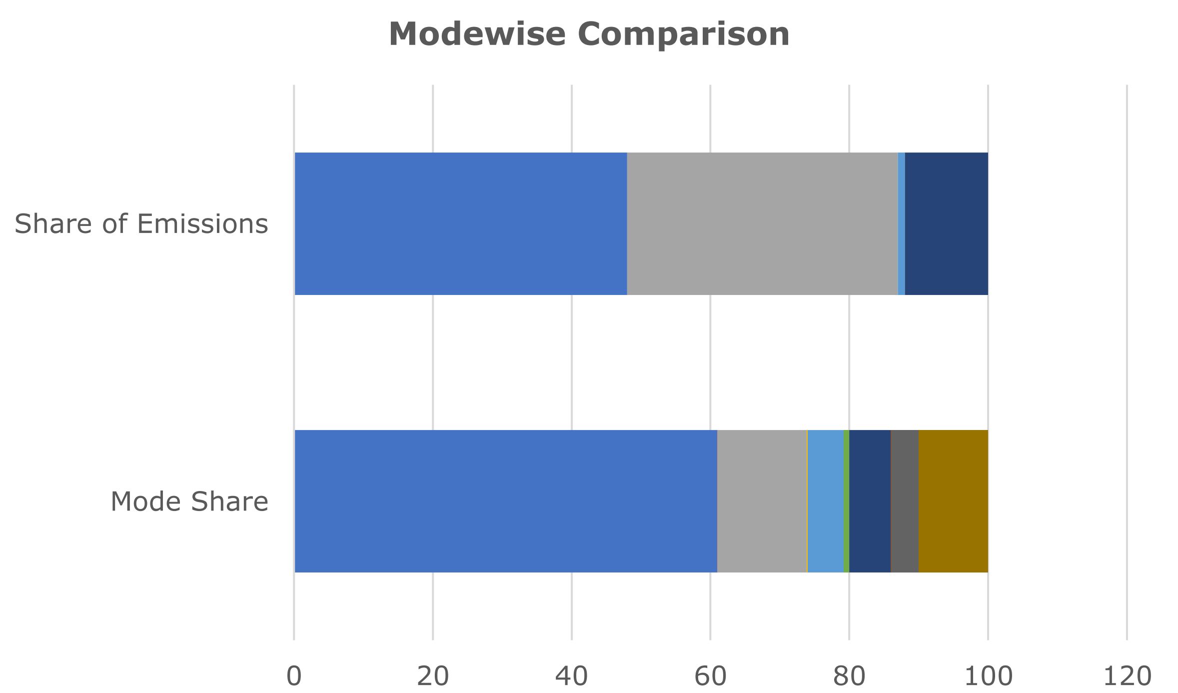
MODE SHARE	CO_2 EMISSIONS (kg)
2W	196895706.2
E_2W	0

4W	159512619.5
E_4W	0
BUS	5762987.329
E_BUS	0
IPT	47395430.18
E_IPT	0
CYCLE	0
WALK	0
TOTAL EMISSIONS	**409566743.1**

Table 2.4 Mode Wise CO_2 Emissions

The total emissions come out to be 0.40 million tonnes for the base year 2019 for Vadodara City.

The share of emissions mode wise can be understood from the below figure:



	Mode Share	Share of Emissions
2w	60.97	48
2w EV	0.03	0
4w	12.86	39
4w EV	0.14	0
bus	5.2	1
bus EV	0.8	0
IPT	5.997	12
IPT EV	0.003	0
cycle	4	0
walk	10	0

Figure 2.1 Mode Wise Emission Comparison

It is observed that the share of CO_2 emissions varies greatly with the modal share percentages. The maximum contributor of CO_2 emissions are the two-wheelers i.e., 48% followed by four wheelers that is 39%. Also, it is observed that there is a drastic increase in the percentage share of four wheelers from 13% in mode share to 39% in CO_2 emission shares. This is mainly due to the lower fuel efficiency of four wheelers and relatively low average occupancy.

CHAPTER 3

3. SCENARIOS

For this study, two scenarios have been developed namely, business as usual scenario and Low carbon scenario. In this chapter these scenarios would be discussed in detail and how these scenarios are different from one another. Just for an idea, in the Business-as-usual scenario the present trends are taken and forecasts has been done based on that. And in the low carbon scenario, policies for low carbon transportation are taken into account and forecasts has been done.

3.1 Business-as-Usual Scenario

This scenario is for future patterns of activity, which is based on the assumption that, there would be no significant change in technology, economics, policies, as well as peoples' attitude and priorities, thus it is expected that the normal circumstances continue unchanged. This scenario is focused in projecting the future based on the present trends. Though the inclusion of electric vehicles as per state policies is considered. The main feature of this scenario is that it would only consider the activities which are already proposed making them exceptions to the basic idea of forecasting trends.

In this scenario, the assumptions are made for the mode share of vehicles as per their growth rate. The mode share of electric vehicles has been assumed as per the State EVs Policy. With the increase in income levels there is a major shift towards motorized transport than walking and cycling. Hence the mode share for walking and cycling has been reduced.

There is a tremendous growth of population in the last few decades. This has resulted in the increase in travel demand to a very great extent. With the increase in GDP and income levels, the affordability of people has increased. Thus, if looked upon transport sector, there is a growing trend of private vehicles over public transport and non-motorized transport. And with the increased share of private vehicles the CO_2 emissions has also grown tremendously. Not only CO_2, even other pollutants have already exceeded their limits in many places in India. Energy crisis is also a major domain of concern for the future. Particularly for a developing country like India where already half of the country doesn't have access to proper healthy energy, it becomes a major concern to look upon.

In business-as-usual scenario, it would be estimated that what damage would be caused if we let happen things in the way it's happening now. So, the main objective of this scenario is to see the effectiveness of the present planning strategies and technological advancements. Also, this scenario would act as a base for comparing the other scenarios and to find out the deviation from the BAU scenario. This would also help in analysing the emissions generated from different modes in different scenarios.

3.2 Low Carbon Scenario

This scenario will be considering the strategies to reduce to carbon emissions from transport. The main purpose of this scenario is to understand how collectively different measures bring about a deviation from the BAU scenario in terms of CO_2 emissions and energy use. This scenario incorporates both the aspects, better planning as well as incorporation of sustainable technologies in order to reduce CO_2 emissions in future years. The Assumptions taken in this scenario: Higher penetration of EVs will be considered resulting in low carbon transportation. Planning Strategies to reduce travel, increase in walking and cycling share compared to BAU scenario.

This scenario would be looking into the following aspects for CO_2 emissions reduction.

- Increase in mass transit use by developing transit-oriented zones, restructuring land value tax to increase value of land served by public transportation, improving the quality of public transportation, providing linkages with multiple modes of travel, and by expanding the service area of mass transit.

- Discouraging private vehicle use by putting congestion charges, and through driving and parking restrictions in certain zones.
- Supporting non-motorized means of travel by providing scientifically designed walkways and bicycling tracks.
- Increase in vehicular efficiency and use of alternate fuels by enforcing various fuel efficiency standardization norms and incentivizing and providing special privileges for the use of hybrid or alternate fuel vehicles for city fleet.
- Increase in the share of renewables and captured energy generation in order to decarbonize the electricity generation.

CHAPTER 4

4. FORECASTS

This chapter includes the emission forecasts for the scenarios explained in previous chapter. The end values of CO_2 emissions have been forecasted for both 2031 and 2041 year considering both the two scenarios. The travel demand, and mode shares has been predicted. On the basis of which the total and per capita CO_2 emissions has been calculated.

4.1 Travel Demand Forecast

For forecasting the travel demand the first thing is to forecast the population for both the years. Population is projected using the three methods, Arithmetic Increase Method, Incremental Increase Method and Geometric Increase Method. The average value of all three methods has been used.

	Arithmetic Increase Method	Incremental Increase Method	Geometrical Increase Method	AVERAGE
2031	2442603	2572359	3752402	2922455
2041	2746693	3006205	5366787	3706562

Forecasted Population of Vadodara	
2031	2922454
2041	3706561

Table 4.1 Population Forecast

The average trip rates and average trip lengths for the year 2030 and 2040 has been assumed based on the Study of Transportation strategies and policies in urban areas in India.

YEAR	AVG. TRIP RATE	AVG. TRIP LENGTH
2031	1.6	9.1km
2040	1.7	10km

Table 4.2 Trip rate and Trip length

Based on the above table and using the equation used for travel demand calculations the total PKT values has been calculated.

Estimated Total PKT	
2031	15531089538
2041	22999211005

Table 4.3 Total Travel Demand

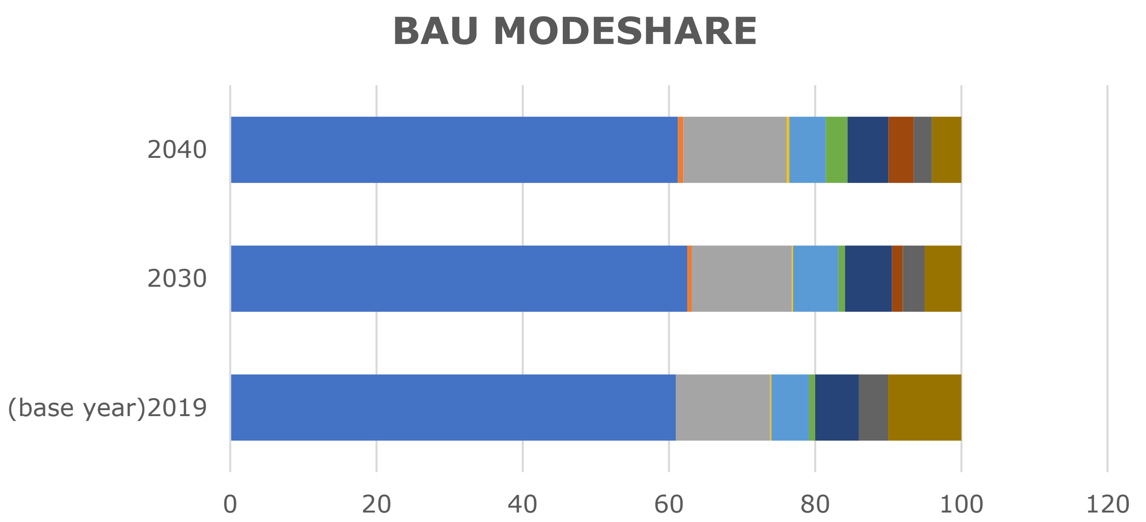
The total travel demand for the years 2031 and 2041 comes to be 15.53 billion and 22.99 billion for both the scenarios respectively.

4.2 Mode Shares

The most important aspect is the mode share which brings a difference in the results of different scenarios. The mode shares have been worked out based on various assumptions of respective scenario.

4.2.1 Business-as-Usual Scenario

The mode shares for the years 2031 and 2041 have been predicted using the CAGR values for all modes.



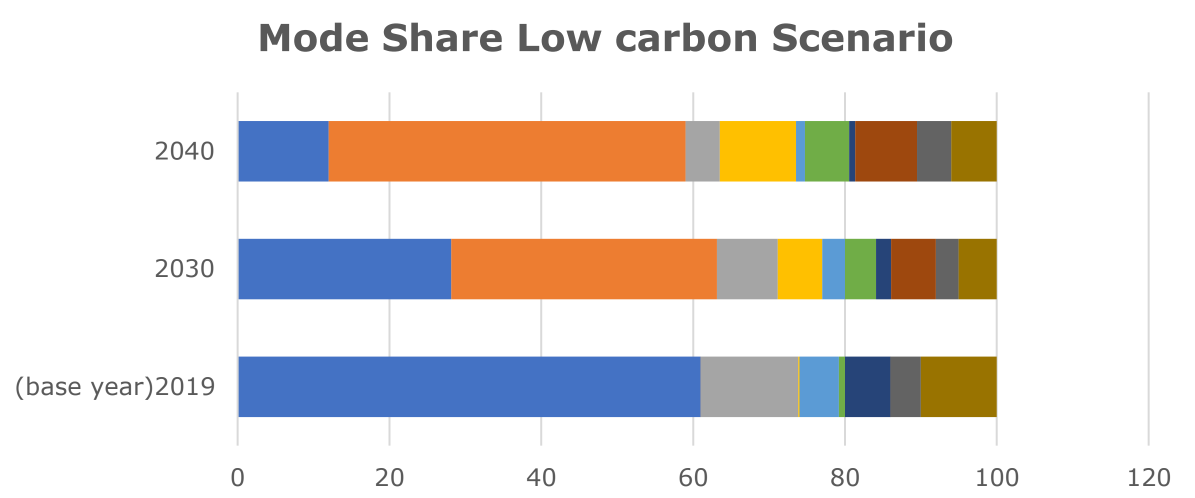
	(base year)2019	2030	2040
2w	60.97	62.5	61.25
2w EV	0.03	0.63	0.75
4w	12.86	13.7	14.1
4w EV	0.14	0.16	0.35
bus	5.2	6.2	5
bus EV	0.8	0.91	3
IPT	5.997	6.4	5.6
IPT EV	0.003	1.5	3.45
cycle	4	3	2.5
walk	10	5	4

Figure 4.1 Modal Share BAU scenario

It is observed that the share of conventional two wheelers initially increase in the year 2031 and then declines a little due to increase in share of electric two wheelers, though the share of four wheelers still increases. Electric vehicles share a very negligible amount for both 2031 and 2041. The share of bus and IPT modes increases in 2031 but decreases in 2041 due to increase in penetration of electric bus and IPT mode. The share of walking and cycling reduces drastically due to more increase in motorization with increase in income and demand. These mode shares are further used to calculate the mode wise PKT and further evaluated to get the CO_2 emission.

4.2.2 Low Carbon Scenario

The mode share for low carbon scenario has been predicted based on the assumptions for this scenario.



	(base year)2019	2030	2040
2w	60.97	28.13	12
2w EV	0.03	35	47
4w	12.86	8	4.5
4w EV	0.14	5.86	10.05
bus	5.2	3	1.2
bus EV	0.8	4.1	5.8
IPT	5.997	2	0.8
IPT EV	0.003	5.9	8.15
cycle	4	3	4.5
walk	10	5	6

Figure 4.2 Modal Share Low carbon Scenario

There is drastic change in the conventional two-wheelers and four-wheelers. The reduction in conventional two-wheelers from 60.97% in 2019 to 28.13% in 2031 and to 6% in 2040. Conventional four wheelers will also be reduced and there will be high penetration of electric vehicles.

The share of walking and cycling would be increased compared to BAU scenario resulting from planning policies.

4.3 CO_2 Emissions

Finally, the mode wise CO_2 emissions are calculated based on the modal share and the energy and CO_2 emission factors. Then the total and per capita emissions is calculated for the respective years.

4.3.1 Business-as-Usual Scenario

The BAU mode shares has been used to calculate the PKT for each mode which has then been multiplied by the emission factors to get the values.

MODE SHARE	**CO_2 EMISSIONS (kg/year)**	
	2031	**2041**
2W	427104962.3	619828736.6
E_2W	0	0
4W	359591316.1	548048199
E_4W	0	0
BUS	14540206.03	17364404.31
E_BUS	0	0
IPT	107032814.2	138687082.3
E_IPT	0	0
CYCLE	0	0
WALK	0	0
TOTAL EMISSIONS	**908269298.5**	**1323928422**

Table 4.4 CO_2 Emissions BAU Scenario

The total CO_2 emissions has increased from 0.40 million tonnes in the year 2019 to 0.90 million tonnes in 2031 and 1.32 million tonnes tons in 2041. The emissions will be increased by 2.2 times in 2030 from 2019 levels and by 3.23 times in 2040 by 2019 levels.

4.3.2 Low Carbon Scenario

The low carbon scenario mode shares have been used to calculate the PKT for each mode which has then been multiplied by the emission factors to get the emission values.

MODE SHARE	**CO_2 EMISSIONS (kg/year)**	
	2031	**2041**
2W	192231401.4	121435834.1
E_2W	0	0
4W	209980330.5	174908999.7
E_4W	0	0
BUS	7035583.561	4167457.034
E_BUS	0	0
IPT	33447754.43	19812440.33
E_IPT	0	0
CYCLE	0	0
WALK	0	0
TOTAL EMISSIONS	**442695070**	**320324731.2**

Table 4.5 CO_2 Emissions Low Carbon Scenario

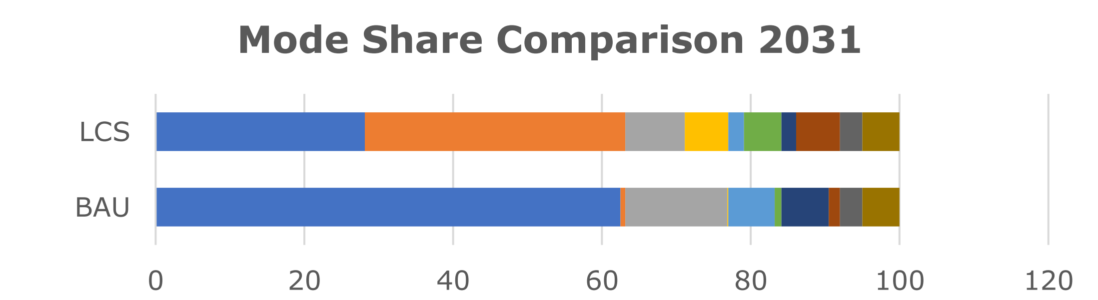
The total increase in CO_2 emissions is very minor. It has increased from 0.40 million tonnes in the year 2019 to 0.44 tonnes in 2031 and then decreased to 0.32 tonnes in 2041. The emissions will be increased by 1.08 times in 2030 from 2019 levels and will be reduced by 0.78 times in 2040 by 2019 levels.

4.4 Comparison of Scenarios

A comparative analysis needs to be done based on the two scenarios in order to understand how these scenarios are different from one another. Also, to understand that if no changes are made how would be the trend followed and if proper policy framework used than how much emissions can be reduced.

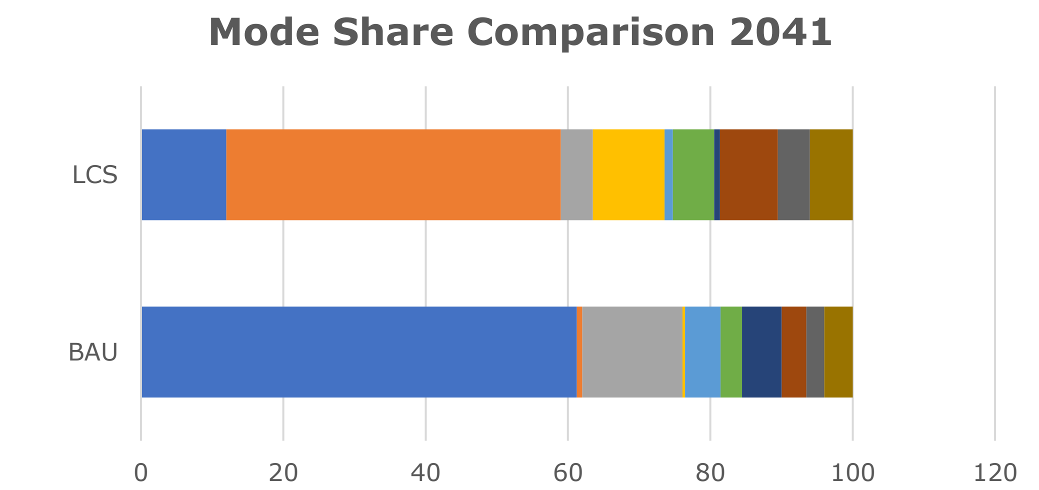
4.4.1 Mode Share Comparison

The difference in the mode share is one of the major reason that determines the reduction of CO_2 emissions for different scenarios. And the mode share would vary in both the scenarios.



	BAU	LCS
2w	62.5	28.13
2w EV	0.63	35
4w	13.7	8
4w EV	0.16	5.86
bus	6.2	2.11
bus EV	0.91	5
IPT	6.4	2
IPT EV	1.5	5.9
cycle	3	3
walk	5	5

Figure 4.3 Mode Share Comparison 2031



	BAU	LCS
2w	61.25	12
2w EV	0.75	47
4w	14.1	4.5
4w EV	0.35	10.05
bus	5	1.2
bus EV	3	5.8
IPT	5.6	0.8
IPT EV	3.45	8.15
cycle	2.5	4.5
walk	4	6

Figure 4.4 Mode Share Comparison 2041

It is observed that for both the years, the percentage share of conventional two wheelers and four wheelers is decreasing from BAU Scenario to Low carbon scenario. Also, there is a drastic change in the percentage share of EVs in 2031 and 2041. It is assumed that there would be a very high penetration of electric vehicles by the year 2041.

4.4.2 CO2 Emissions Comparison

The CO2 emissions also vary for different scenarios. It has been observed that there is a substantial reduction of total emissions in the low carbon scenario due to high penetration of EVs in that scenario.

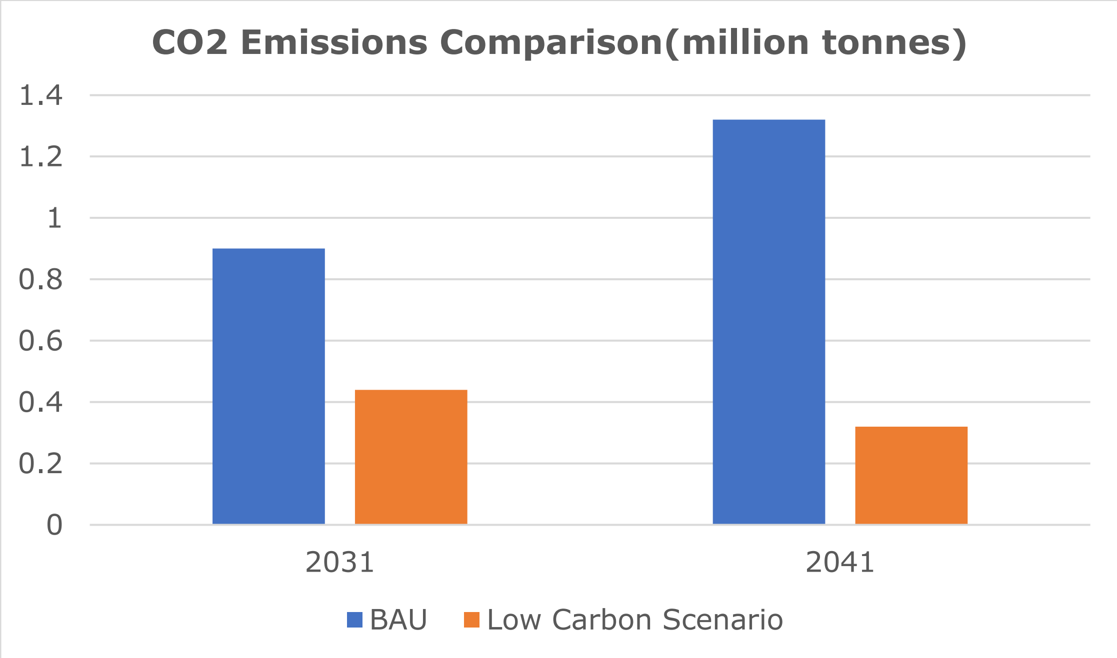
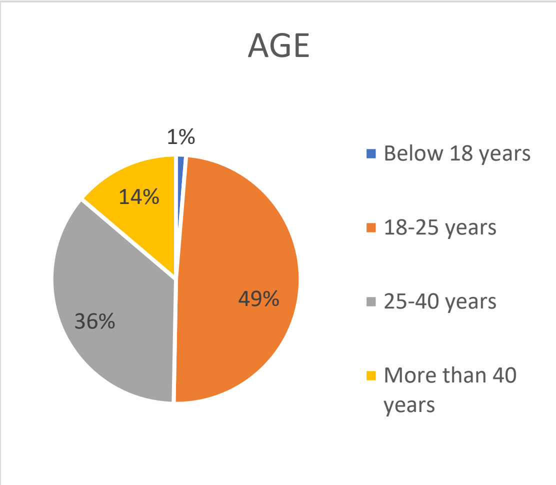


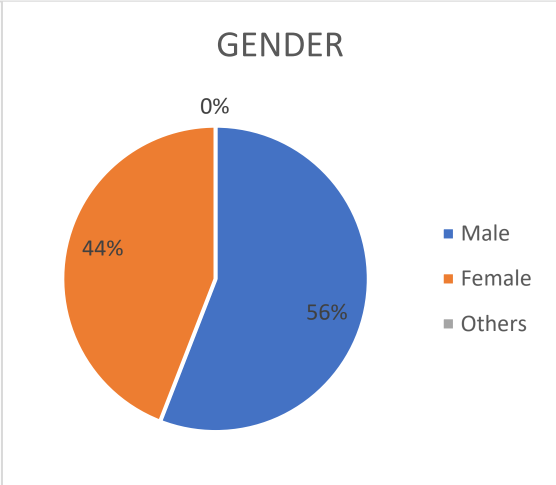
Figure 4.5 CO_2 Emissions Comparison

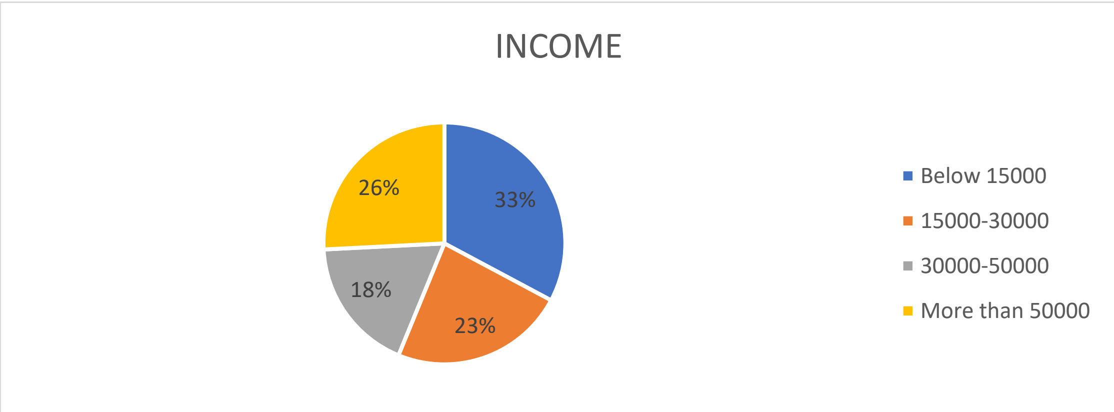
It is observed that the low carbon scenario helps in achieving low carbon transport substantially. Higher share of electric vehicles along with decarbonization of electricity, and higher fuel efficiency of vehicles has a very high impact on the reduction of CO_2 emissions. Hence, higher penetration of EVs in Low Carbon Scenario helps to a great extent to achieve low carbon transportation.

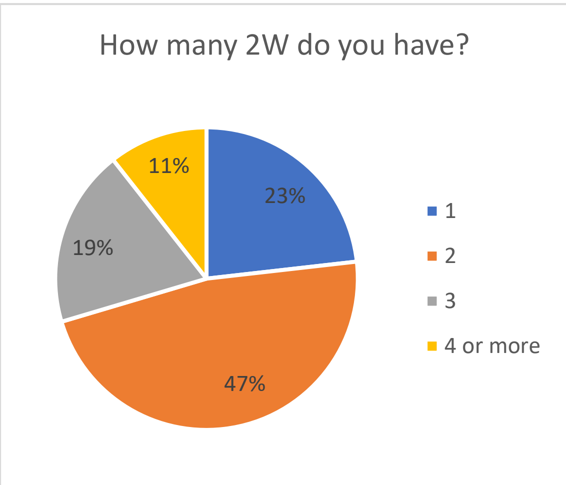
4.5 Feasibility Check for EV

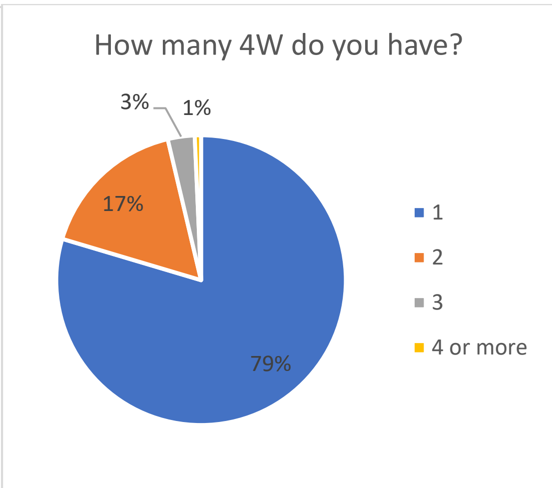
As it is observed that shift to more cleaner vehicles which are energy efficient and electric vehicles plays an important role in promoting low carbon transportations. A shift to EV mode will be helpful in reducing the CO_2 emissions to a great extent. But it is necessary to check whether the people of the city are willing to shift to EVs or not. To know if the low carbon scenario is feasible or not, a primary survey has been carried out through google forms and 150 respondents were recorded. The questionnaire was a close-ended questionnaire and sampling method used was snowball sampling. The results of the survey are as following:

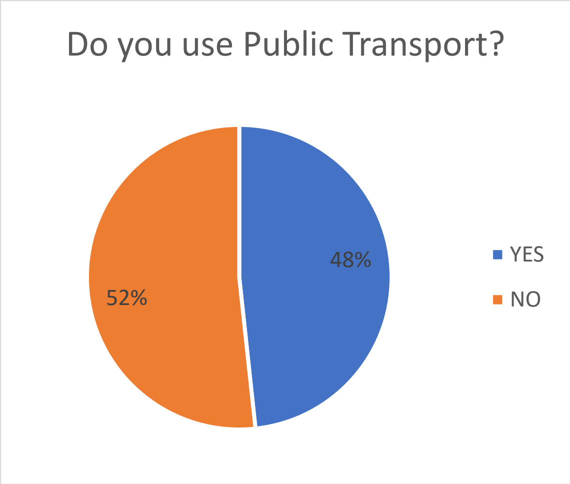


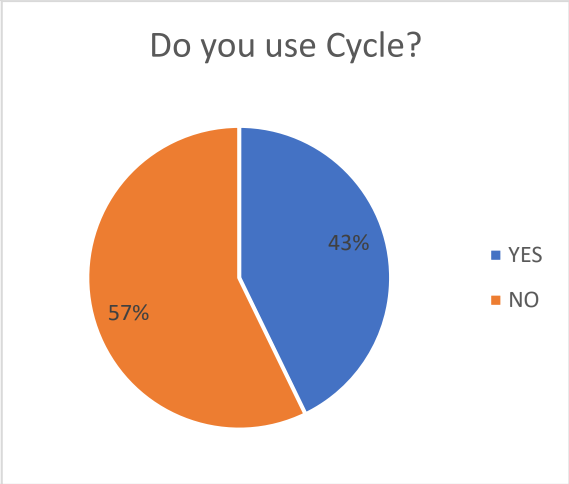


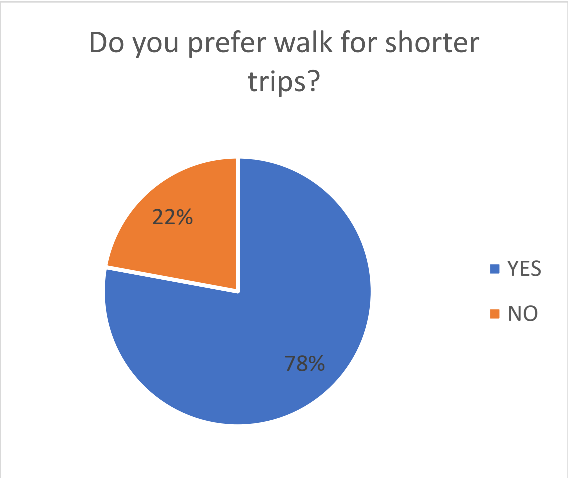


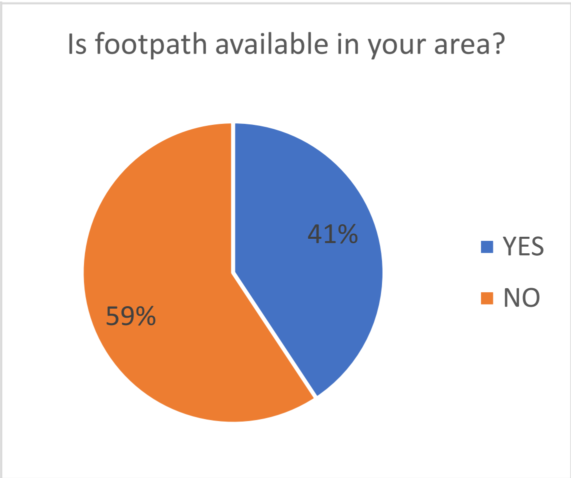


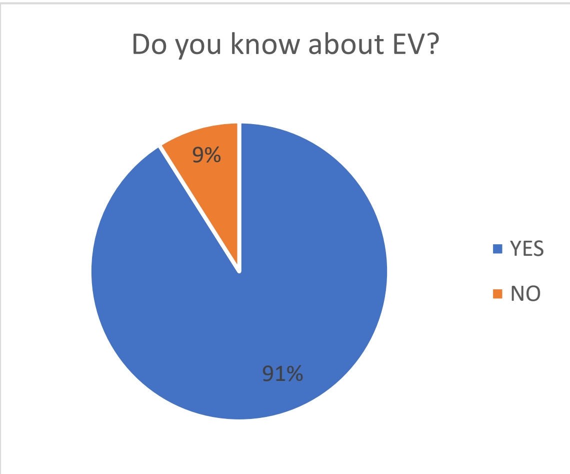


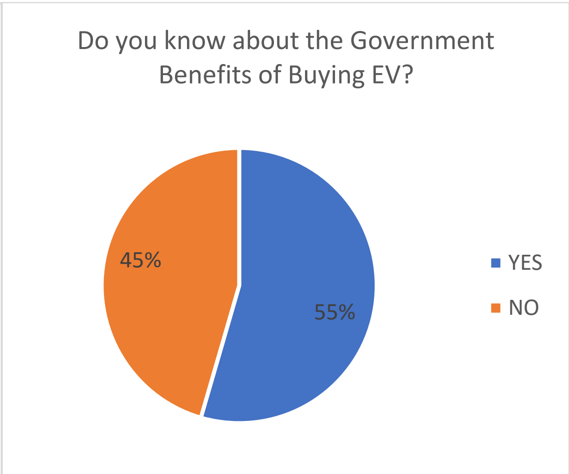

Do you use Public Transport?
48%
52%
YES
NO

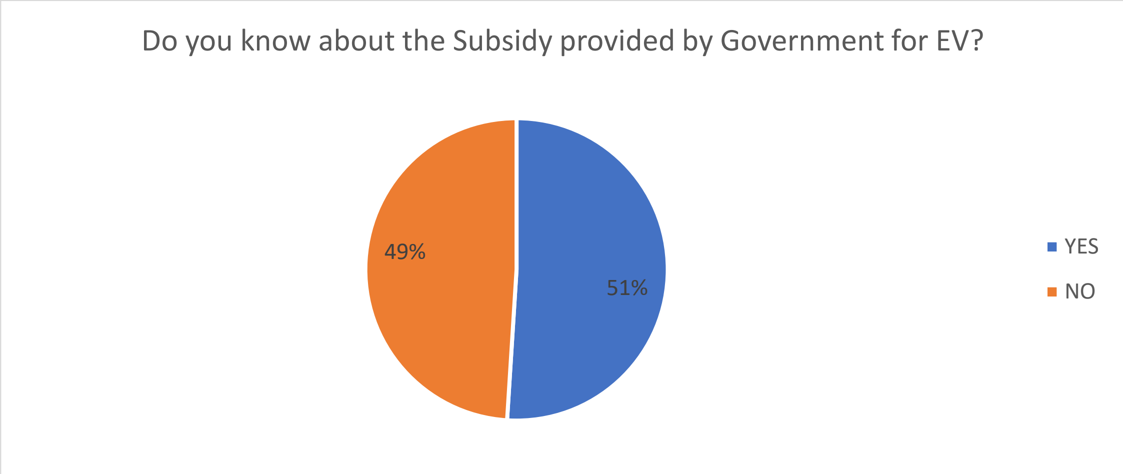

Do you use Cycle?
43%
57%
YES
NO


Do you prefer walk for shorter trips?
22%
78%
YES
NO

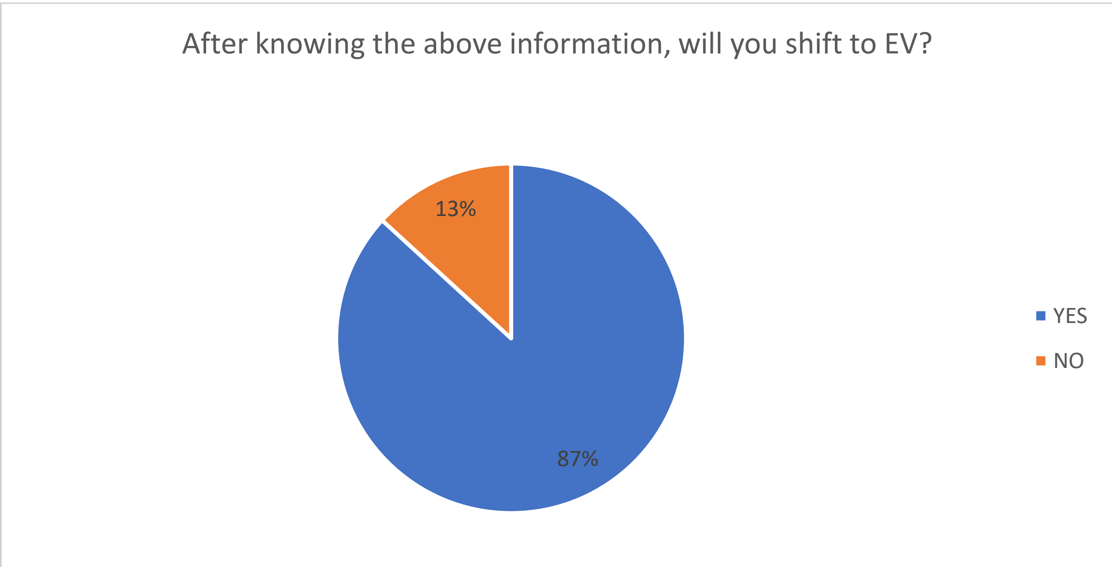

Is footpath available in your area?
41%
59%
YES
NO


Do you know about EV?
9%
91%
YES
NO


Do you know about the Government Benefits of Buying EV?
45%
55%
YES
NO



Under the 'Gujarat Electric Vehicle Policy 2021', the state government will provide a subsidy of up to Rs 20,000 on electric two-wheelers, Rs 50,000 on electric three-wheelers and Rs 1.50 lakh on electric four-wheelers. The policy will benefit nearly 2 lakh electric vehicle buyers. The subsidy will be credited to the buyer's bank account through DBT. The electric vehicle will reduce the pollution of the city.



It has been observed from the questionnaire responses that 47% people have two two-wheelers and 79% people have atleast one car. 52% of respondents does not use public transport and also 57% do not use cycle. 78% people prefer walking for shorter trips but 58% people said they have no footpath availability. Responses related to EV were as, 91% people have knowledge about the EVs and 9% do not have any knowledge or information. 45% people does not know the government benefits for buying an electric vehicle which inappropriate. Also, 49% people does not have information related to the subsidy provided by the government for electric vehicle. It is necessary that proper awareness should be there among the people about the electric vehicles to shift to low carbon transportation.

When the respondents were given the information about the subsidy given by government for electric vehicles, and asked that whether they would shift to electric vehicles or not, 87% people said yes to shift to electric vehicle from conventional modes. Hence, the low carbon scenario will be feasible and low carbon transport could be achieved to a great extent with electric vehicles.

Through this survey, it was observed that for achieving low carbon transport, proper pedestrian network is required for promoting NMT modes, the public transportation needs to be more efficient and ICT platform can be used to upgrade the public transportation. As it is observed that in order to make the transportation low carbon, major shift to EV will be required. But the city should be able to provide the required EV infrastructure that is charging stations. Future city planning should consider low carbon scenario and plan accordingly providing adequate infrastructure to city.

CHAPTER 5

5. STRATAGIES AND POLICIES

This chapter includes the policies and mitigation measures which can be taken to promote the low carbon transportation in the city. There are several policies and strategies through which low carbon transportation can be achieved. Below are some strategies and policies to reduce the transport emissions.

5.1 A-S-I Framework

The ASI strategy framework widens the focus of transport development beyond conventional technologies to include solutions that consider the policies and behaviours driving the demand for transport. Utilizing the ASI strategy framework enables stakeholders to think about more sustainable transport solutions and thus more effectively achieve their strategic low-emission transport development objectives. The ASI strategy framework can guide economies to avoid the demand for transport, shift transport systems to less carbon intensive modes, and improve transport infrastructure, technology, and policies. To achieve a cost effective shift to low emission transport development, one must assess opportunities under all three facets of the ASI strategy framework.

AVOID: Avoid passenger trips and freight movement or reduce travel distance by motorized modes of transport through regional and urban development policies, integrated transport and spatial planning, logistics optimization and travel demand management.

SHIFT: Shift passenger and freight travel to more environmentally and socially sustainable modes, such as public transport, walking and cycling and EVs.

IMPROVE: Improve the energy efficiency of transport modes through low carbon fuel and vehicle technologies, increased vehicle load factors, and better managed transport networks, with non-petroleum, low carbon fuels playing a more significant role.

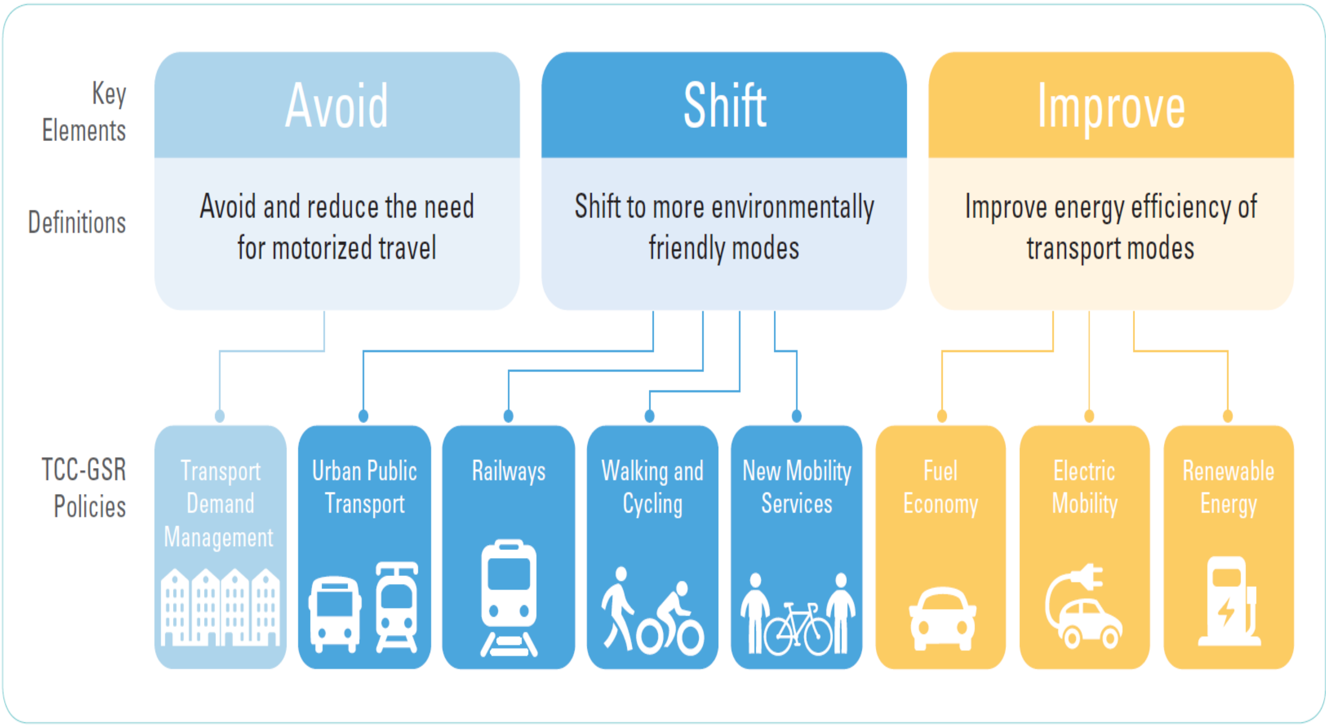


Figure 5.1 A-S-I Framework

Source: Transport and climate change report 2018

5.1.1 AVOID Strategy

The AVOID strategy has been mainly attained by land use planning as both technological and regulatory instruments to make urban forms more compact to reduce unnecessary travel demand. Land use control may be the most traditional approach to control urban expansion to protect greenspace and secure access to countryside at the early stage of urban growth. As the cities grow, their built up area needs to be expanded, but urban form can be kept compact by concentrating development around transit corridors. Transit corridor development is led by both, land-use planning and mass-transit development for urban trunk lines. However, these measures may also control urban sprawl at later stages of urban growth. Thus, it becomes necessary to make the expanded cities more compact by promoting development around transit stations, as transit-oriented development.

Integration of Land Use and Transport Planning

Tying together land-use and transport planning has long been a worthwhile goal of sustainable transport practitioners, urging a holistic approach to urban planning and transport. Concepts including compact cities, transit-oriented development (TOD) and new urbanism stem from this effort, as well as SUMPs. Setting the basis for compact cities, which could allow for efficient integrated energy, landuse and mobility planning, might need stronger regulations, or in some cases for counter-productive regulations to be amended. For instance, regulations that could be relaxed to promote compact cities and allow for higher density include minimum lot size, maximum floor area ratio, minimum parking requirements and prohibition of mix land uses.

Bringing land-use and transport planning together is essential for sustainable cities and SDG 11(Make cities and human settlements inclusive, safe, resilient and sustainable). Adding energy planning would increase the overall system efficiency. Travel activity can be reduced when various forms of land use such as residential houses, shops, public services, etc. are mixed and located in the close proximity of one another. Density of an area is crucial for reduction in the emission. Where low density leads to substantial dependence on private vehicles and higher energy demand, areas with higher density reduce travel needs and emissions. Demand of transportation in the high density centre is more easily served by public transport as it is cost effective due to reasonable load factor or occupancy ratio. Appropriate land use planning can also provide for pedestrian footways and cycle paths and encourage the use of NMT modes.

Implement transit-oriented development

Transit-oriented development (TOD) is a kind of urban planning that clusters jobs, housing and amenities around public transport hubs. It creates vibrant communities and delivers benefits for local economies, air quality and congestion. Cities should form a city owned and long-term vision for TOD. Align land use, planning and transport strategies and introduce the regulations for more dense, affordable, mixed-use, and walking and cycling friendly development close to transit stations. Reallocate road space to buses, cyclists and pedestrians.

Promoting use of Alternatives to Travel

Use of communication and information technologies can help to avoid or reduce the need to travel. For example, introduction of the 'Easy Bill' facility in Delhi and some other cities has helped citizens pay most of the utility bills at nearby centres at convenient hours. Similarly, in Bangalore, the government of Karnataka has set up one stop facility for citizens of Bangalore to access information and pay all government and municipal bills. Some corporate organizations, especially in developed countries, have 'work from home' programmes which helps in reducing the travel demand. However, in order to implement these initiatives successfully, well-knit information and communication networks should be put in place on a priority basis.

Regulatory Instruments

Regulatory instruments can be used to avoid or reduce travel or deny access to certain traffic or vehicles. Some regulatory measures include:

- Physical restraint measures: The city authorities can implement physical restraints like restricting access for certain private vehicles.

For example, restriction on plying of vehicles on certain days, depending on their registration plate number. This benefits in reduction in congestion, increase in speed, and saving in fuel consumption.

- Traffic management measures: Traffic management measures are used to smooth traffic flows, improve fuel efficiency and reduce emissions. Among traffic signal systems, area traffic signal is the most efficient where in signals are coordinated across a whole network. In developed countries, traffic management has achieved emission reduction around 2–5%. In developing countries, this measure can help in achieving higher reduction in fuel consumption and emissions. It has also been estimated that effective land use planning together with better traffic management schemes (like the Intelligent Transportation System) an bring about energy savings of 20–30 per cent or public transport due to better planned trips and smooth vehicle movement.
- Regulation of parking: Restriction of parking space supply can discourage the use of cars and will encourage modal shift. Planning authorities can also involve the employers and commercial institutions in reducing private parking space reserved for their employees or customers. Citywide initiatives which involves private entities are likely to be more successful compared to restrictions imposed only on publicly provided parking.
- Speed restrictions: To reduce GHG emissions, governments may propose minimum and maximum speed limits for vehicles.
- Inspection, maintenance, and certification: A proper inspection and certification programme coupled with driver training and adequate maintenance can bring about 2–17 per cent reduction in fuel consumption and GHG emissions.
- Enact a low emission zone to target vehicle emissions: Frame the area to suit the local priorities. Existing examples include 'low emission zones', 'clean air zones', and 'congestion charge zones.'

Set strict vehicle emissions standards within the zone and charge vehicles that don't meet them for entering, or ban them from entering, in order that cars and heavy motorized vehicles become fewer and cleaner. Strengthen these standards over time.

Economic Instruments

The main objective of economic instruments is to discourage the use of private vehicles and encourage more efficient use of transport through imposing charges or taxes.

Various economic instruments are discussed below:

- Road pricing and congestion charging: The road pricing increases the cost of running a vehicle and thereby will encourage the use of alternate modes of travel. The implementing agencies usually have two options: (1) introducing national road pricing where charges will be applied on long distance highway use, and (2) introducing local road pricing schemes which covers only the city centre areas. To reduce the peak hours traffic, road pricing rates can be fixed at a higher rate for peak hours of traffic. This can prove to be highly effective in reduction of emissions.
- Fuel taxation: Fuel taxes can increase the cost of travel and will consequently affect the individual's travel behavior. This can also help in reducing the number of vehicle kilometer travelled. As fuel taxation is proportional to fuel consumption, this can provide an incentive to purchase fuel efficient vehicles. Either way, it will help in reducing the emissions. However, care must be taken to remove any distortions that may exist in the fuel taxation system that discriminates against any particular fuel leading to pricing differences or generate persistent incentives.
- Vehicle taxation: Vehicle taxes can be considered as an 'access fee' to use the road network. Charges can vary with the vehicle type,

vehicle size or emissions, and noise levels. If tax rates are differentiated according to fuel consumption of vehicles, this will encourage the sale of fuel efficient vehicles. However, this tax will not necessarily ensure efficient operation of the vehicles. Further measures would be required to promote energy efficient vehicles through levy of fuel taxation. However, care needs to be taken to see that the axe of vehicle tax does not fall on the public transport system as that would frustrate the very objective of moving towards a low carbon transportation.

- Parking pricing: This will increase the cost of using a vehicle by raise in the cost of parking. It will help to substantially reduce parking demand compared to a free parking system.

Information Instruments

Information instruments will include measures such as awareness campaigns, mobility management, and driver education and training. Promotion of sustainable transport system requires public awareness and acceptance of the negative impact of certain transport systems and practices. Hence, there arises need for information instruments to spread these messages. For example, Colombia and Mexico have implemented 'car free days', banning cars from entering the city on certain days. This can be linked with the promotion of alternate mode choices such as public transport, cycling and walking. Education through schools or propagation of information through places of employment can also be useful in raising awareness. Improving the fuel efficiency is also possible through education and training of drivers that will facilitates behavioural change with regard to speed, braking and acceleration, engine idling, carrying capacity, and vehicle condition. Estimates shows that the fuel savings through this measure are in the range of 10–15%.

5.1.2 SHIFT Strategy

As the key mode of public transport, developing mass-transit systems, such as railways and buses, is the starting point of reducing the car dependency. This is required at the early phase of urban growth so the city do not become irreversibly car dependant. According to urban growth, the public transport system grows to cover a wider area, by improving the accessibility of using feeder transport modes, such as trams and buses to access mass-transit stations. Nevertheless, the improvement of public transport systems is insufficient to resolve issues of traffic congestion caused by motorisation, which also requires stronger controls on car use. Traffic exclusion is a traditional approach of traffic control that can be introduced around a mass-transit station to promote public transport use, and it can be complemented by feeder transport systems to improve levels of local mobility. Emission standards can be integrated with traffic control and road pricing by targeting vehicles with higher emissions. If urban growth of the city comes with significant technology advancement then advanced information technologies in public transport systems can result in substantial increases in the quality of services and levels of use.

Improve the Share of Public Transport

The growth of public transport in the form of large capacity buses, light rail transit, and suburban rail or metro is a feasible option for transport sector. The IPCC recognizes the preservation and augmentation of the market shares of low emitting collective transport modes as a worldwide mitigation option. Though, public transport should be accessible, affordable, and reliable if it is to replace private vehicles. Improvement of public transport is possible through expansion of systems or services and/or improvement in operation of systems and services pertaining to public transport. The expansion of services may include dedicated lanes, express bus services, and local bus services. Operational improvements may include splitting of routes, increased vehicle frequency, coordination of routes through integrated ticketing. Services may also be enhanced through provision of passenger amenities.

The public transport scenario includes Non-Motorised Transport (NMT), as any public transit trip includes a component of NMT for access and egress. Improved bus service with compatible pedestrian and bicycle infrastructure, the assumption here is that bus infrastructure and operations are improved so that reliable bus service is available, at least along all arterial roads. Moreover, initial ideas on operational interventions like better routing and scheduling, improved frequency, better bus stop design, improve bus speed, overall safety and bus user comfort should also be incorporated. The option of providing para-transit modes on the sub arterial and connecting roads should also be considered. This will help to limit the access/egress trip length to less than 1 km. The provision of access and egress support infrastructures should also be stressed for walking and cycling. The above-mentioned changes should be used to check the preferred mode choice of respondents, stated in the household survey. This will help to compute the increased demand for public transport in a scenario where public and non-motorised transport infrastructure is sufficiently improved.

Promote NMT

Shorter trips are best performed by NMT. Promote walking and cycling as zero emission transport options. These modes can be promoted and encouraged through provision of cycling and walking tracks and through road safety measures; appropriate pricing of individual vehicle use and fuels; regulation of polluting motorized modes; and use of information and awareness campaigns. These improvements can better accessibility and safety, and user experience of pedestrians and bicycles. Focus messaging on what the city will gain from increased road space for walkers and cyclists, instead of what car users will lose. Designate pedestrian and cyclist only areas and build a walking and cycling network that connects with other public transport networks. Improve walking and cycling infrastructure in the city, such as segregated bike lanes and wider sidewalks, and improve cycle hire facilities.

The scenario also considers campaigns to improve awareness of citizens with respect to beneficial impacts of cycling on the environment, health and CO2 emissions. Reducing barriers and obstructions on roads to improve bicycle safety is another aspect considered. Reduced conflicts between non-motorised and motorised modes on roads can result in a moderate increase in bus speed.

Shift the vehicles left on the roads to electric

Attain only zero-emission buses, taxis and municipal vehicles from 2025, or earlier. Build electric vehicle (EV) charging infrastructure, led by benchmark ratios on EVs per charger and the mix of charger types set in leading city markets, and encourage other stakeholders to invest. To encourage EV public uptake, financial incentives such as vehicle tax exemptions and convenience perks like reserved parking spaces can be introduced.

5.1.3 IMPROVE Strategy

There are a series of instruments to improve fuel economy and emission intensity for the IMPROVE strategy, which are differently implemented by country rather than by city. The types of tools for IMPROVE depends mainly on the level of available technologies in each country, which may be improved in line with urban growth. An emission standard to control the levels of emissions from vehicles is the most traditional approach, which is applicable even to countries at early developing stage where technology availability for Low-Emission Vehicles (LEV) is limited. As more technologies for LEVs are available, their standards become firmer, which can encourage further development of LEVs. They can also indirectly endorse LEVs in combination with other regulatory instruments, such as traffic control on non-LEVs. Economic growth makes it probable to implement more economic instruments to promote LEVs with help of emission standards. These economic instruments include not only direct ones, such as subsidies and tax discounts in vehicle purchase, but also indirect ones, such as discounts in road pricing and the carbon markets. When industries that can promote the development of vehicle technologies become strong, more investment can come into the industries for further development of advanced integrated transport systems, which can also lead to LEV promotion.

LEV development

Even though technology advancement is not a measure in itself, it does offer the opportunity to develop Low-Emission Vehicles (LEVs). LEVs reduce their emission intensity mainly by improving fuel efficiency with new vehicle technologies and shifting the fuels used by vehicles from gasoline to lower carbon ones, particularly electricity. Fuel shift is expected more to contribute to CO2 mitigation in LEV development. Hybrid Vehicles (HV), which use less gasoline by generating electricity as complementary power, have presently played a major role in LEVs, which leads the share of LEVs and they are competitively priced. While Electric Vehicles (EV), which only use electricity, have not been wide-spread, car industries have progressively invested in developing EVs and promoting them in the market. More technologies have been under development for new types of LEVs like Fuel Cell Vehicles (FCV), which use a fuel cell to produce electricity. While EVs are expected to become the next generation of LEVs and so replace the HVs, the emission intensity of EVs depends on the type of power generation.

Moreover, electrification has increasingly been introduced into feeder transport modes, such as electric motorcycles. Smaller- sized feeder transport modes need less power and, thus, are advantageous for electrification. In China, electric motorcycles have been wide-spread as they are officially regarded as bicycles, which do not require driving licenses. The development of such electric feeder transport modes can significantly contribute to low-carbon transport through lower levels of emissions particularly in Asian cities where feeder transport modes, such as para- transit and motorcycles, are popular.

Improving Vehicle Technology and Energy Efficiency

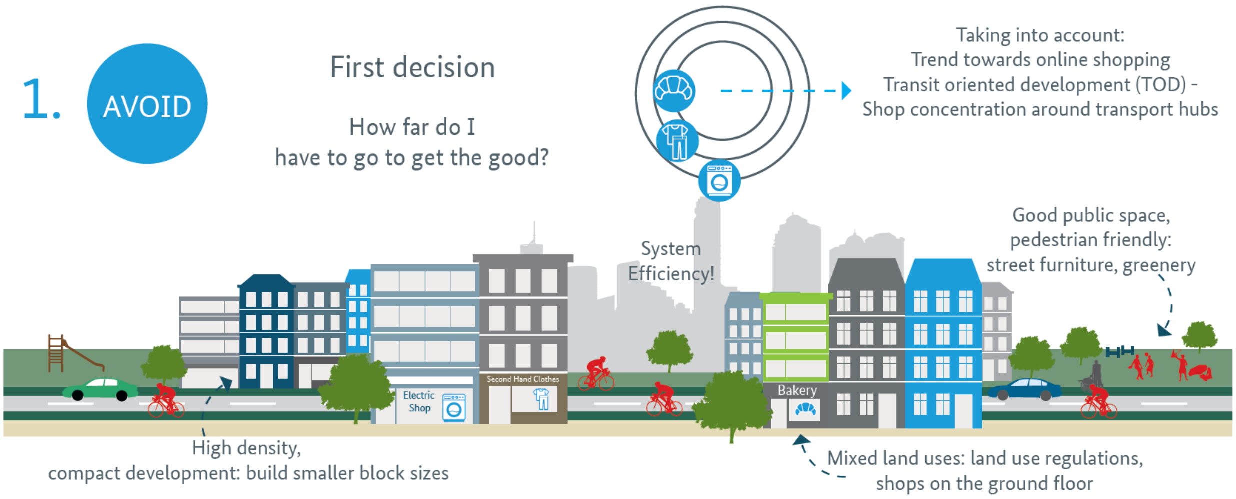
Variation in GHG emissions is contingent upon the nature of fuels and technologies used. Thus, technology solutions for vehicles usually underscore two possible areas of improvement with respect to GHG emissions:

1) reducing the carbon content of fuel by altering the mix of fuels actually used and/or 2) by influencing the intensity with which fuels are used. This can be achieved by promoting and providing incentives for using road-friendly and fuel-efficient vehicles by introducing appropriate fuel efficiency standards; making superior quality fuel sufficiently available for transport vehicles; and putting in place suitable regulatory policies to check fuel adulteration. However, in order to tap the full potential of technological improvements, especially in passenger transport, these measures should be supplemented with policy instruments that focus on promoting modal shifts and reducing overall travel time Further, from a low carbon perspective, electric vehicles (EVs) and hybrid electric vehicles (HEV) should be promoted in India on a priority basis as they are cleaner than diesel and gasoline powered vehicles despite the fact that electricity generation in India would take long to become less GHG intensive. In fact EVs are already being produced on a mass scale in India in the form of two-wheeled bikes and scooters and the four wheeled light duty vehicles are expected to catch up soon. Globally, HEVs (using both petrol and electric propulsion systems) compared to EVs are expected to capture the

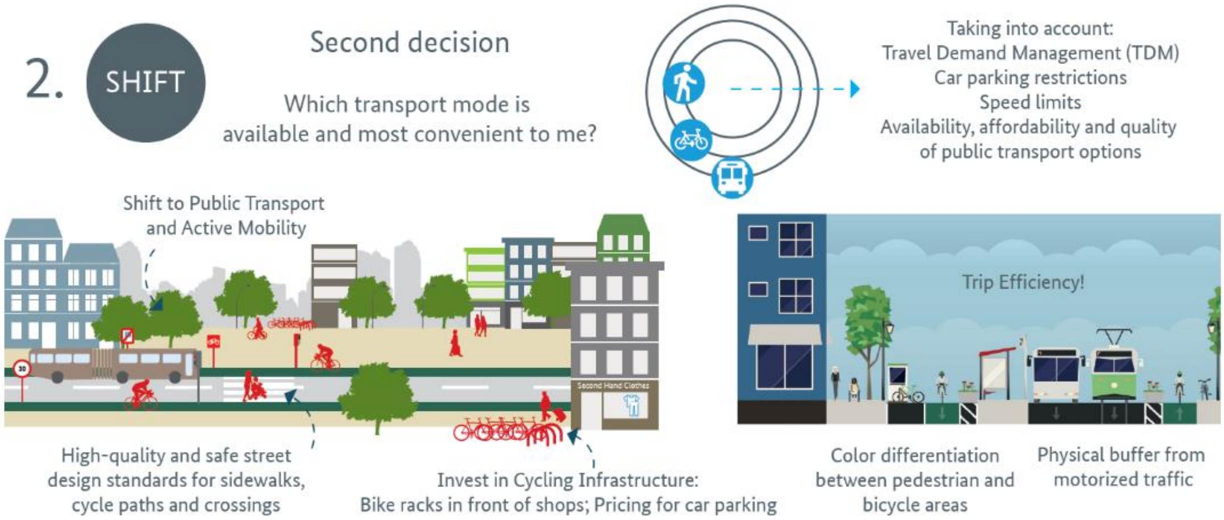
market sooner as these vehicles do not require refuelling or charging infrastructure. Although both EVs and HEVs have great potential in India, policy support is crucial for making them cost-competitive. Expanded use of EVs and HEVs would require better understanding of consumer needs and desires. Measures to influence greater penetration might include fiscal and purchase incentives besides influencing the driving range, which presently is a major restraint with electric two-wheelers and four-wheelers. Moreover, continuous support needs to be provided for research, development, and demonstration so as to reduce battery cost and ensure adequate supply of materials for battery manufacture. Industry and governments must also work in tandem towards prioritizing international collaboration that can facilitate research programmes aimed at accelerated deployment of smart grids and vehicle-grid interface for fuelling electric vehicles.

Example of A-S-I-F Approach

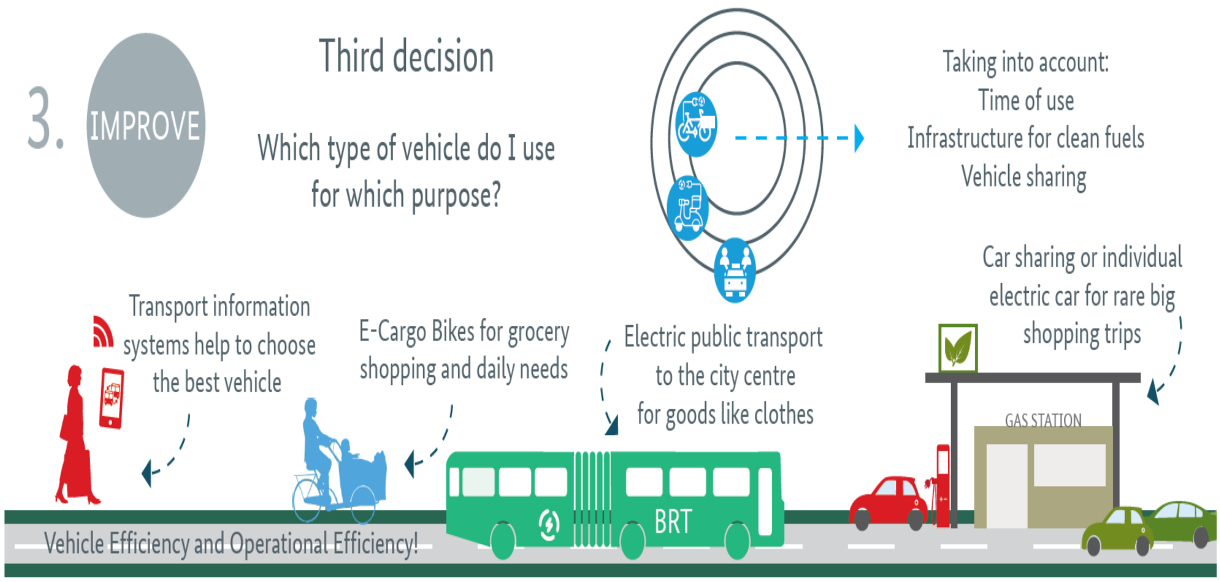
An Example: Buying Goods



AVOID: By implementing an integrated land use planning policy and fine-grained urban fabric (high density and mixed land use areas with shops on the ground floor) travel distances to go shopping can be reduced



SHIFT: Short travel distances can be more easily undertaken by active transport or public transport. By increasing the operational efficiency and infrastructure of public transport, as well as safety, design and infrastructure for active transport, the individual may regard these modes as more convenient for the daily shopping trip.



IMPROVE: In the medium/long term the individual may consider reducing the car size or using vehicles with improved energy and carbon efficiency. Innovations in transport information systems, priority schemes for public transport (BRT/LRT), electrical bicycles or car sharing will further improve the transport sector. Subsidies and a good charging infrastructure can encourage people to use the electric version of a vehicle.

Source: (Sustainable Urban Transport: Avoid-Shift-Improve(A-S-I))

5.2 POLICIES

Policies are needed to implement the strategies in the city. Some policies are explained below that how will they promote the low carbon transportation.

5.2.1 Promoting NMT

To promote the NMT mode in the city, the pedestrian network in the city should be proper. The city should be more accessible and walkable. For promoting the NMT mode, footpath plays a major role. Footpath allows the people to walk freely without any vehicles obstructing. But the conditions and quality of the footpath is not upto the mark and hence it demotivated people to use them.

The map below shows the condition of the existing footpaths.

It is observed from the map the that footpath in good condition is very less. 55km road length have greater than 1.8m width footpaths, 106km road length have less than 1.8km width footpath and 295km road length does not have footpath at all.

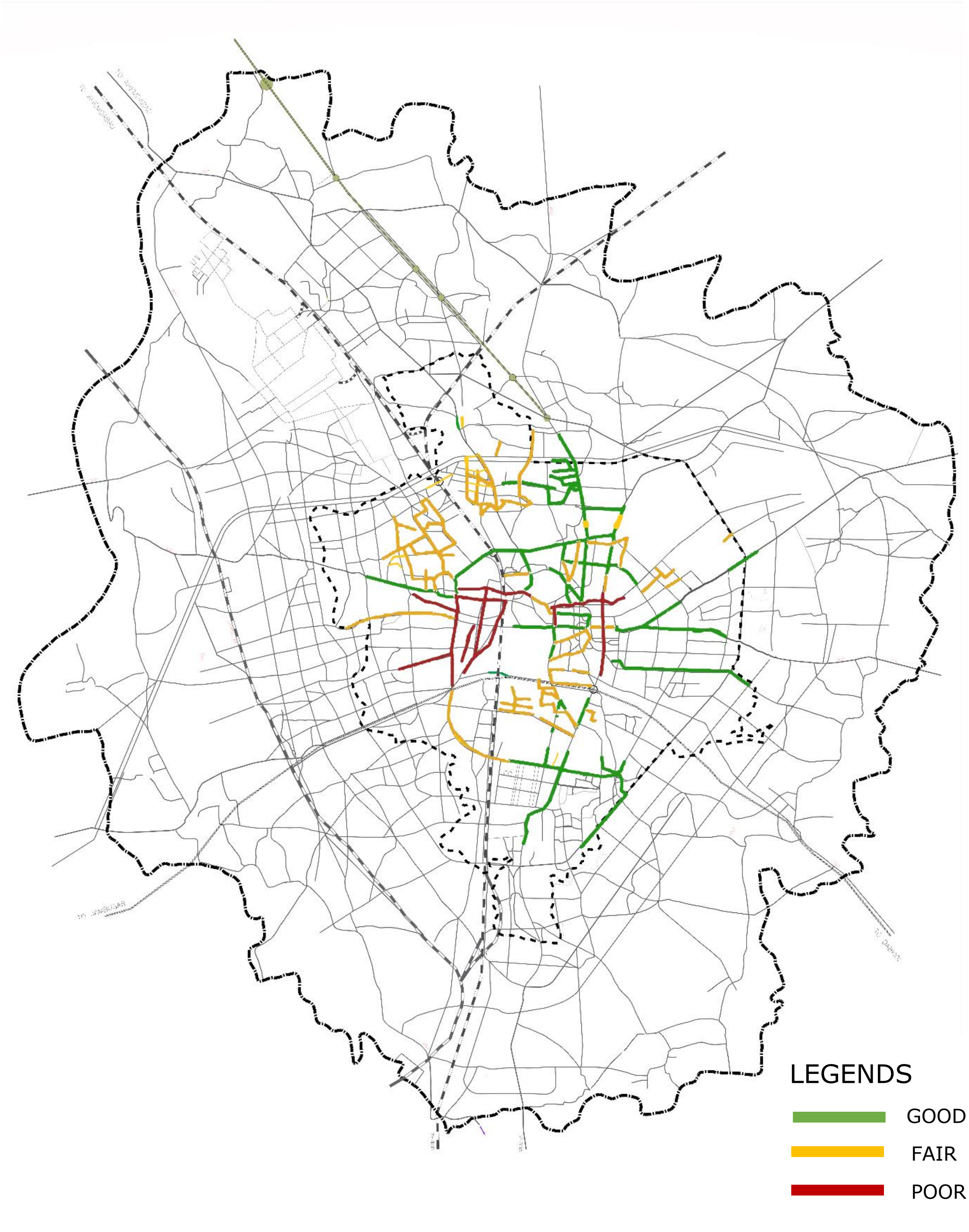


Figure 5.2 Condition of Footpaths

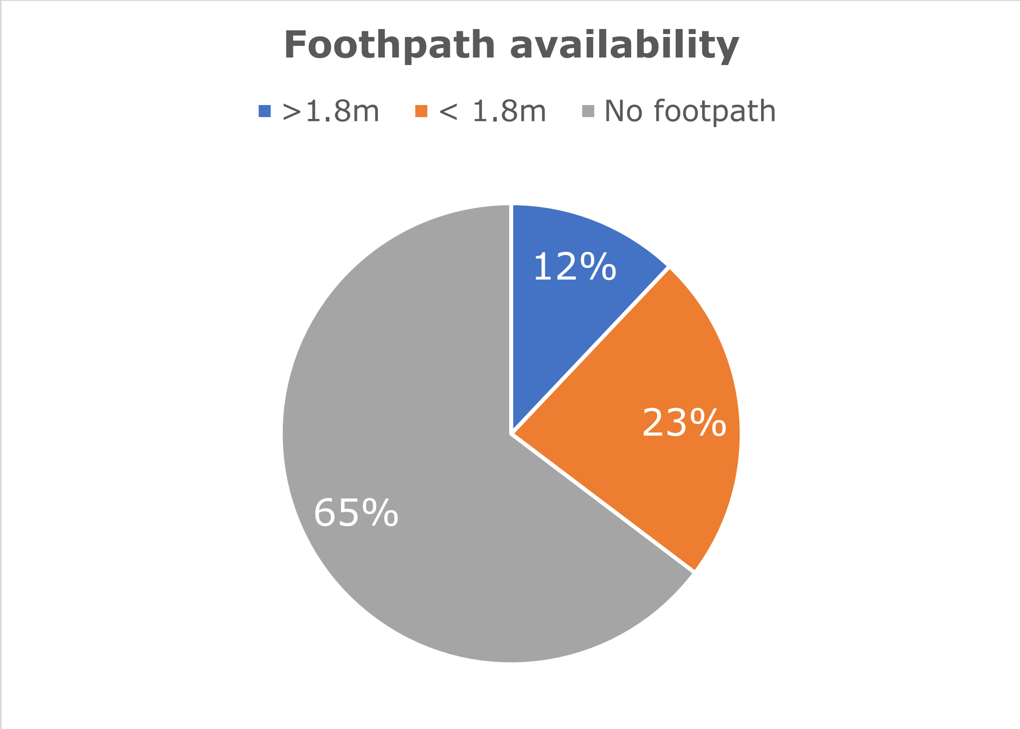


Figure 5.3 Footpath Availability

Hence, 65% of road length in the city does not have footpath which reduces the share of NMT and needs to be improved.

Other issue in the footpath is the encroachment of footpaths. Maximum Footpaths are observed to be encroached in the city by street vendors or parking or roadside activities. Footpath is present on only 160km of road network and out of which 80% of the footpaths are encroached.

Hence it is necessary to improve the footpath network for better pedestrian connectivity in the city. The map below shows the proposed footpaths.

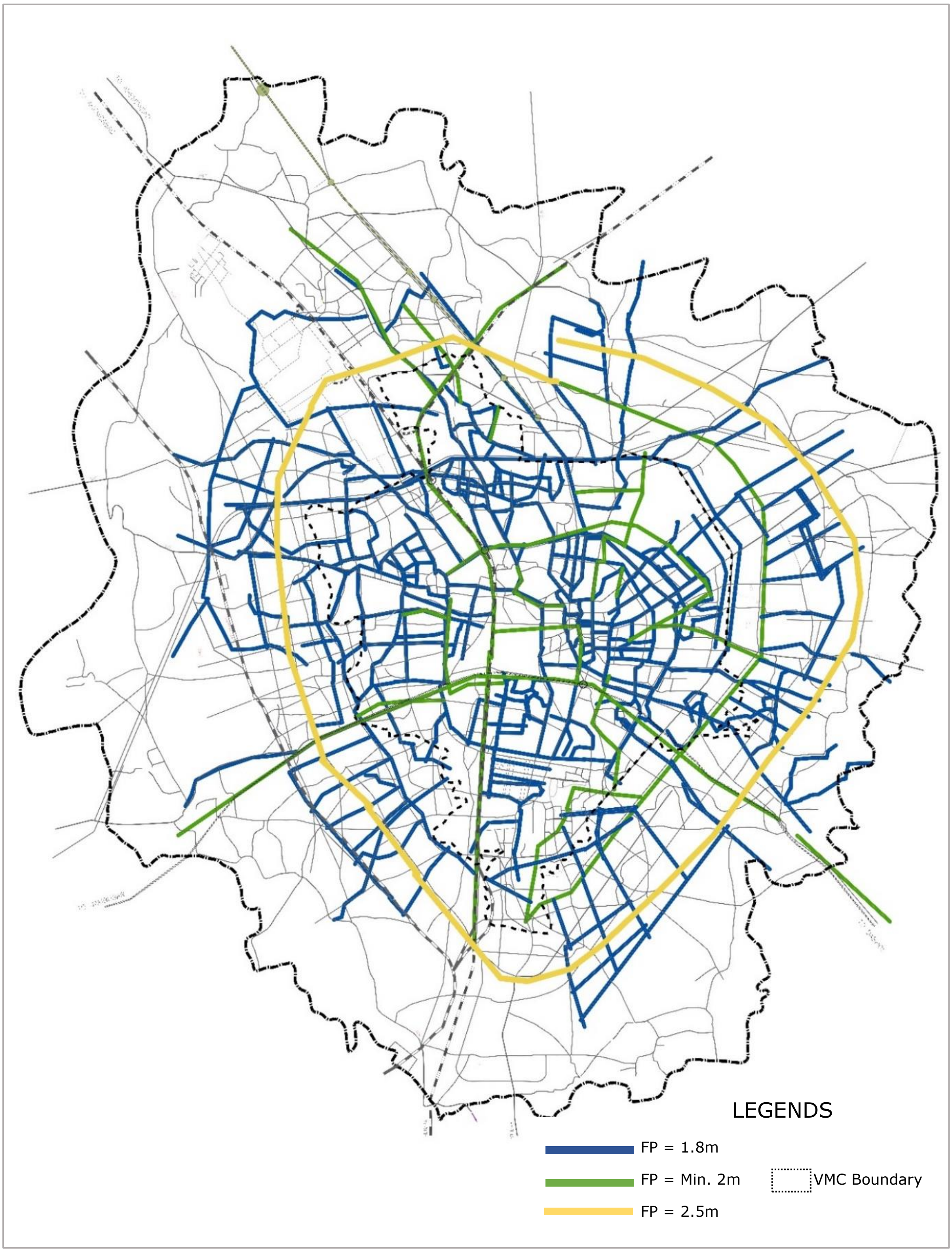


Figure 5.4 Proposed Footpaths

In the existing footpath network, 50% of the footpaths need to be upgraded to 1.8m width, 16% of the footpaths need to be upgraded to 2m width.

The footpaths which are not connected and are discontinuous needs to be joined and new footpaths are needed to be proposed on the roads which do not have footpath at all.

Also, new footpaths can be proposed on the proposed road network of the city. This will increase the mode share of NMT and will result in low emissions in the city as there are no emissions from NMT mode and it can also increase the health of the people.

5.2.2 Parking Regulations

Demand management is the application of policies and strategies to influence travel behaviour towards sustainable choices such as public transportation and non- motorised transportation. Instead of increasing supply of transportation resources in the form of roads and flyovers, demand management focuses on controlling the travel demand.

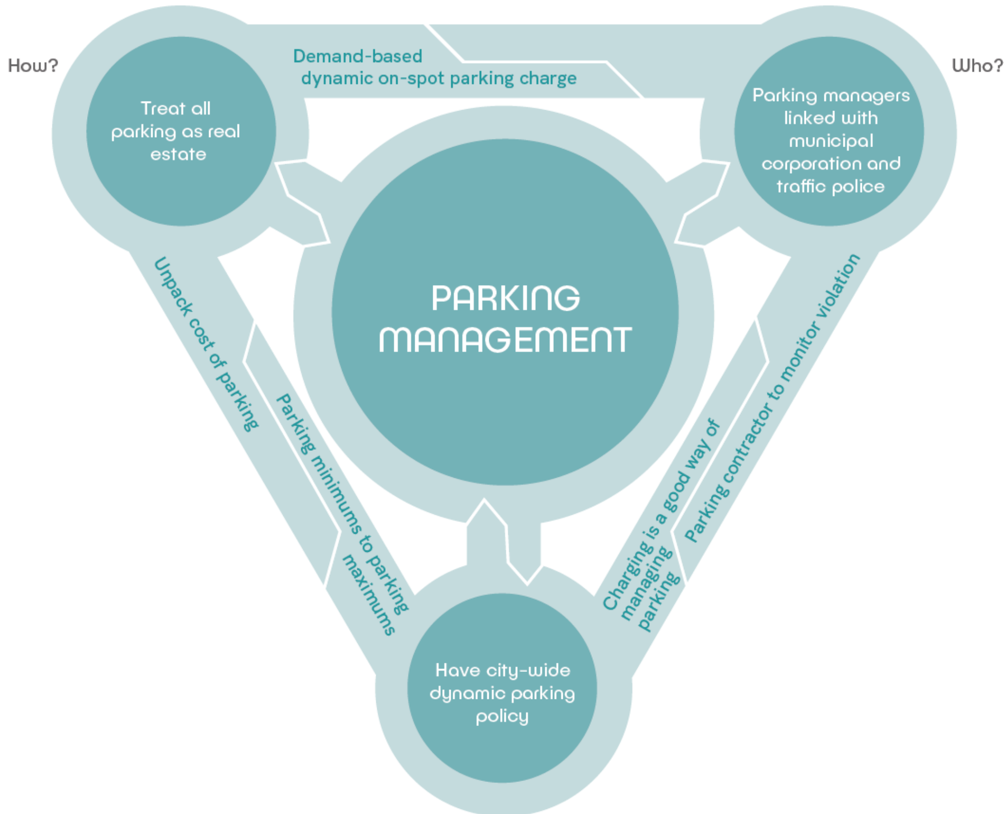


Figure 5.5 Parking Management

Parking management essentially is demand management for the consumption of space used for the parking of private motor vehicles. Sometimes due to economic constrains or limitations of space it is not possible to always keep increasing the supply of transport resources, in this case parking. In such cases demand management becomes a handy tool to efficiently organize parking at the area and city level.

Figure 5.6 Demand and Supply of Parking

The figure explains that when we provide free parking on the streets, people park their vehicles on the streets rather than parking in paid parking. This increases congestion on roads and decreases the walkability. The current planning regulations ensures higher supply of off-street parking while there is chaos on the street. Since, parking is a location-linked activity, high demand on street will not go away by providing more parking in buildings. Given the regulations, on-street parking is conflicting with street activities, while parking lots within buildings remain empty. Unless, we manage on-street parking well, we will not be able to improve the street or walkability.

Parking should be treated as real estate in the city. When we regulate parking and increase the charges it demotivates the people to use private motorised vehicles.

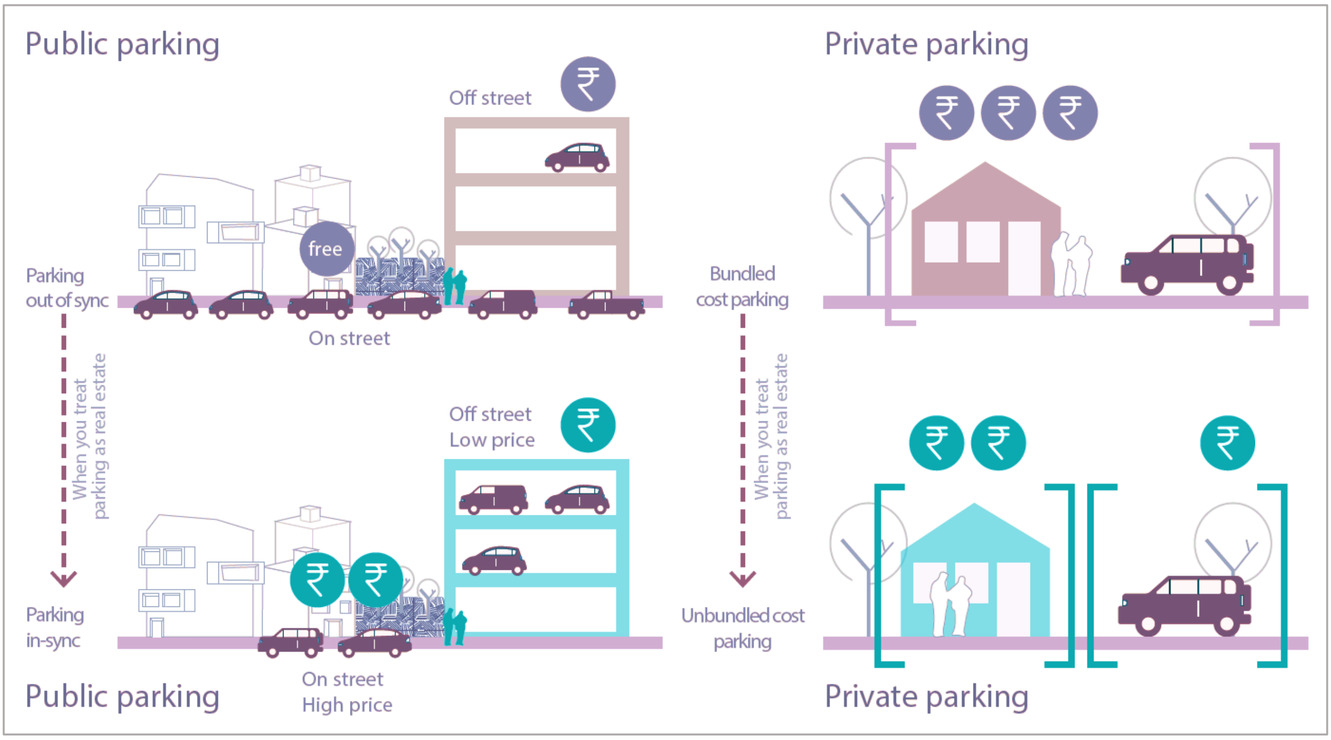


Figure 5.7 Policy for Public and Private Parking

An area should be demarcated in the city core around the transit node to implement on-street parking charges. And should be extend to major destinations, arterial roads and subsequently to secondary roads. Eventually can be also extend to suburbs and peripheries. A parking policy and pricing strategy should be developed based on demand-based dynamic on-spot parking charge. A pricing regime should be put in place for parking, both in building and streets. This will provide a priority to bus and non-motorized modes. Priority of intervention: Calibration – Unbundling-Minimums to Maximums

A link should be established between on-street and off-street parking. In Public parking the price the on-street should be higher than the off-street to reduce the pressure on the former. And in Off-street private parking, Separate the parking cost from the house cost to avoid burdening home buyers. Regulate off-street private parking.

5.2.3 Electric Vehicle Infrastructure

- As observed in low carbon scenario, for reducing the CO2 emissions, there needs a shift in electric vehicles to greater extent.
- Is the city prepared for the infrastructure for electric vehicles or not is a matter of concern.
- Charging stations for electric vehicles needs to be allocated as per the needs.
- The local government should make landbank of the land they deducted as 40% deduction for infrastructure development.
- From landbank, EV infrastructure can be laid up.
- The future planning of the city should be done by considering the scenarios for low carbon transport and the infrastructure needed.
- Charging Stations can be provided in the parking of the every apartment or else can be provided personal charging in the streets of colony.

CONCLUSION

So, this study demonstrates the future passenger mobility scenarios for Vadodara city. It is observed that various level interventions in the passenger transport sector itself has the potential to reduce CO_2 emissions to a very large extent. The various interventions could be of the following types.

Increased use of mass transit: It can be achieved through developing transit-oriented development zones, taxing private vehicles, extending the public transport network, improving quality of service, etc. Higher share in PT, reduces the share of private vehicles, thus reducing emissions.

Discourage Private vehicle use: Various policies and restrictions can discourage the use of private vehicles, rather shift to PTs and NMTs for commuting.

Support Non-Motorized transport: non-motorized transport has zero emissions associated with them. Greater use of non -motorized transport would therefore reduce emissions. It can be achieved by providing adequate and safe walkways and cycling tracks. Better PT network also supplements to the increased use of NMTs. Walking and cycling sometimes becomes a feeder service to the existing PT network. Better land-use planning with higher mixed use also leads to reduction of trip length and making areas walkable.

Increased efficiency of Vehicles: Increasing vehicular efficiency directly reduces the amount of CO_2 entering the atmosphere. Various vehicular efficiency norms can be implemented in order to achieve higher efficiency in vehicles.

Increase share of Electric Vehicles: Electric vehicles are another mode, which has zero emissions associated at the source. Though the electricity used to run these vehicles has CO_2 emissions associated with it, but it is comparatively lower than the conventional vehicles. Various EV policies can be implemented in order to encourage the use of EV as well as discourage the conventional vehicles.

Increasing the share of renewables in the main grid: electric vehicles which run on electricity from the main grid, may not be directly associated with emissions at the source but has emissions associated during generation. In India, the major source for electricity generation has been coal and petroleum, which has a very high emission associated with it. Incorporating renewables in the main grid would reduce the carbon intensity of the grid.

This study acts as a model case study of generating carbon inventory at city level. City level inventory would also help to understand the urban interventions in CO2 generation in a national level. This could also act as the base for a bottom-up inventory generation for a nation. In this study, a proper methodology has also been framed, which can be used to calculate emissions at urban level everywhere.

This study also provides with an understanding of how different actions impact differently in terms of CO2 emission reduction. And also, if combined, what is the added benefit. The business-as-usual scenario shows the trend in future that to what extent the emissions from transport sector would increase. And the low carbon scenario shows that the how the shift to EVs would help to a great extent to reduce the emissions.

Strategies and policies listed would help a city to great extent to reduce the transport emissions. As observed in the low carbon scenario, there will be a major shift to EVs in order to reduce the emissions hence the city need to be prepared for the EV infrastructure. Planning Authorities and the local governments should consider the concern about the need of the EV infrastructure in future and plan accordingly.

Also, the government should look forward to incorporate these low carbon mobility initiatives in order to meet the Paris Agreement 2-degree limit temperature goal and help coping up with the problem of climate change.

References

Bandyopadhyay, K. R. (2010). Reconciling Economic Growth with Low Carbon Mobility In India.

Banister, D. (2011). Cities, Mobility and Climate Change. *Journal of Transport Geography*.

CDP VADODARA. (n.d.).

CITY PATHWAYS TO LOW CARBON MODELS. (n.d.). *MOLOC*.

Creating Sustainable Cities through Low Carbon Freight. (n.d.). *ICLEI*.

Daniel BONGARDT, M. B. (2011). Beyond Fossil City: Towards Low Carbon Transport and Green Growth. *GIZ*.

Deborah Salon, A. M. (2008). City Carbon Budgets: Aligning incentives for climate friendly communities.

Decarbonising the Indian transport sector : Pathways and Policies. (2020). *New Climate Institute*.

Dhar, S., & Shukla, P. (2015). Low carbon Transport Scenarios in India: Cobenefit analysis . *Energy Policy*.

Dhar, S., Pathak, M., & Shukla, P. (2013). LOW CARBON CITY : A Guidebook for city planners and practitioners.

Energy Outlook 2019. (n.d.). *IEA*.

FICCI. (2020). India Roadmap on Low Carbon and Sustainable Mobility. *FICCI*.

Fritz Akhmand Nuzir, B. J. (2013). From Sustainable to Low Carbon City: Zero Emission Urban Mobility in Japanese.

India Roadmap on Low Carbon and Sustainable Mobility. (2020). *FICCI*.

Intergovernmental Panel ob Climate Change, IPCC. (2014).

Intergovernmental Panel on Climate Change ,IPCC. (2014).

Kazuki Nakamura, H. Y. (2013). Strategies and instruments for low-carbon urban transport.

Kazuki Nakamura, Y. (2013). Strategies and instruments for low-carbon urban transport: An internation review on trends and effects. *ScienceDirect*.

Litman, T. (2017). Smart Transportation Emission Reduction Strategies. *Victoria Transport Policy Institute*.

Maria J Figueroa, L. F. (2013). Avoiding, transforming, transitioning: pathways to sustainable. *ScienceDirect*.

Peterson, R. (2004). Landuse Planning and Urban Transport. *gtz*.

Promoting Low Carbon Transport in India. (2010). *UNEP*.

Promoting Low Carbon Transport in India. (2010). *UNEP*.

Reducing carbon Emissions from Transport Projects. (2010). *Asian Development Bank*.

Robin Hickman, O. A. (2011). Transitions to low carbon transport futures: strategic conversations from london to delhi.

Robin Hickman. Olu Ashiru, D. B. (2011). Transition to Low Carbon Transport futures: Strategic Conversation from London to Delhi. *ScienceDirect*.

Shrestha, T. a. (2009). Why Have CO2 emissions increased in transport sector in Asia.

SLoCaT. (2018). Transport and Climate Change Global Status Report .

Sudeep Grover, G. R. (2013). Low Carbon Mobility Plan: Case Study Of Ludhiana, India .

Sudeep Grover, G. T. (2013). Low carbon mobility plans: A case study of Ludhiana, India. *ScienceDirect*.

Sustainable Development Benefits of low carbon Transport measures. (2015). *GIZ*.

Sustainable Urban Transport: Avoid-Shift-Improve(A-S-I). (n.d.). *Federal Ministry of Economic Cooperation and Development*.

Switching Gears: Enabling Acces to Sustainable Urban Mobility. (2020). *Sustainable Energy for All*.

T V Ramachandran, S. K. (2009). Emissions from India's transport sector: Statewise synthesis. *Atmospheric Environment*.

T V RAMACHANDRAN, S. K. (2009). Emissions from india's transport sector: statewise synthesis. *Atmospheric Environment*.

Transitioning to Electric Mobility in Gujarat. (2021). *GERMI*.

Transport and carbon Dioxide Emissions. (2009). *Asian Development Bank*.

Transport and Climate Change Global Status Report. (2018). *SLoCaT*.

Transport and CO2 emissions. (2009). *ADB*.

APPENDIX

Questionnaire for feasibility check of Low Carbon Scenario:

Electric Vehicle Survey

1. NAME

2. AGE
   - ☐ below 18 year
   - ☐ 18 - 25 years
   - ☐ 25 - 40 years
   - ☐ more than 40 years

3. GENDER
   - ☐ MALE
   - ☐ FEMALE
   - ☐ OTHER

4. INCOME
   - ☐ below 15000
   - ☐ 15000-30000
   - ☐ 30000-50000
   - ☐ more than 50000

5. How many people are there in family?

6. How many two-wheelers do you have?
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ 4 or more than 4

7. How many four-wheelers do you have?
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ 4 or more than 4

8. Do you use public transport?
   - ☐ YES
   - ☐ NO

9. Do you use Cycle?

☐ YES ☐ NO

10. Do you prefer walk for short trips?

☐ YES ☐ NO

11. Is there facility of footpaths for walking in your area?

☐ YES ☐ NO

12. Do you know about electric vehicle?

☐ YES ☐ NO

13. Do you know about the government benefits for buying two-wheeler?

☐ YES ☐ NO

14. Do you know the subsidy provided for buying electric vehicle?

☐ YES ☐ NO

Under the 'Gujarat Electric Vehicle Policy 2021', the state government will provide a subsidy of up to Rs 20,000 on electric two-wheelers, Rs 50,000 on electric three-wheelers and Rs 1.50 lakh on electric four-wheelers. The policy will benefit nearly 2 lakh electric vehicle buyers. The subsidy will be credited to the buyer's bank account through DBT. The electric vehicle will reduce the pollution of the city.

15. After knowing the above information, will you shift to electric vehicle?

☐ YES ☐ NO