DEVELOPMENT OF SUSTAINABLE TRANSPORT STRATEGIES FOR A LOW CARBON URBAN ENVIRONMENT

Ph.D. THESIS

by

POOJA SINGH

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE 247667 (INDIA)
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DEVELOPMENT OF SUSTAINABLE TRANSPORT STRATEGIES FOR A LOW CARBON URBAN ENVIRONMENT

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POOJA SINGH

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE – 247 667 (INDIA)
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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"DEVELOPMET OF SUSTAINABLE TRANSPORT STRATEGIES FOR A LOW CARBON URBAN ENVIRONMENT"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from December, 2011 to July, 2019 under the supervision of Dr. P.S.Chani ,Professor, Department of Architecture and Planning and Dr. M. Parida, Professor, Department of Civil Engineering ,Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institution.

(POOJA SINGH)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(P.S.Chani)
Supervisor

(M. Parida)
Supervisor

Date:

EXECUTIVE SUMMARY

Unchecked growth of urban population has put forth tremendous demand for infrastructure and resulting in mismatch between demand and supply of transport infrastructure leading to delays, fuel loss, air and noise pollution , accidents and loss of productive time and energy. On account of this growth, it is very critical to develop a sustainable transport solution, which can create value for all stakeholders in a sustainable manner through creating and adopting safe, reliable, fast, economic and environmentally friendly transport options for all sections of society.

The objectives of present research are (1) to assess existing condition of the transport system and impact of socio-economic characteristics and user behaviour on sustainable transport strategies, (2) to develop a multi criteria development method (MCDM) framework for evaluating alternative sustainable transportation strategies for a city, (3) to evolve an emission estimation framework for road transport vehicles and identify strategy to reduce carbon emission through scenario analysis, (4) to suggest proposals, policy measures and improvement schemes to achieve environmentally and socially sustainable transport system. The capital of Uttarakhand, Dehradun has been chosen as a case study for the development of sustainable transport strategies for low carbon urban environment. Dehradun, a city with the population of 5.68 lacs in 2011, ranked 31th most populated city in the world (WHO, 2018) and urban transportation is the major factor for contributing in pollution; exceeding the limit of ambient air quality index in most of the city areas.

Due to its location advantage, there is a considerable influx of population from the surrounding regions. Being home to a number of prestigious institutions and with its large tourism potential, the existing transport infrastructure of Dehradun requires substantial augmentation. The stress on transport infrastructure is causing congestion, reduced mobility, and rising air and noise pollution levels. Therefore, analysis of projects/ programs/ plans needs to be carried out before implementation to ensure that it will not in any way harm the environment, society on a short or long-term basis.

Through comprehensive literature review, the concept and definition of sustainable transportation, the issues, and challenges for sustainable urban transport and sustainable transport practice in India and worldwide were identified with available approaches and models for evaluation and estimation of strategy.

In order to assess the existing condition of the public transport system in the city, relevant data required was collected as per the guidelines of the Service Level Benchmarking (SLB) handbook issued by MoUD (Ministry of Urban Development). The data could either be taken through previous studies, secondary sources or captured through specific primary surveys, and to understand the existing condition of the present transport pattern and human behavior, the data on various qualitative parameters affecting the urban mobility has been collected objectively and subjectively. The objective data collected in terms of observation survey and subjectively based on the questionnaire survey. A random survey has been conducted on 300 stakeholders. The study investigates relationships between people's perception of the influencing parameters of the strategies. The result proves that when parameters are judged on a rating scale, the user behavior towards sustainable transport is revealed. The study supports the need to frame strategies to evaluate in a sustainability framework.

The study develops a hierarchy framework to improve urban mobility using a Multi-Criteria Decision Method (AHP) to generate priorities from experts for various criteria and sub-criteria that affects the sustainable choice of urban mobility. Out of 6 identified alternate strategies, enhancement in public transportation in the city is the most sustainable strategy followed by transit-oriented development and non-motorised transport.

The study estimated the emission in present and 4 proposed scenarios in Dehradun city. The best possible emission reduction scenario is proposed for the city. The proposed methodology for emission estimation is developed by Central Pollution Control Board (CPCB) and used in various researches to estimate the emission load in the urban area. With the help of the proposed methodology, the effect on existing transport and proposed transport or scenarios has been estimated. A questionnaire survey has been carried out on a selected corridor to know the percentage of mode shift to proposed mode/scenario through which emission has been calculated against each scenario and compared it with the base scenario. The study recommended personal rapid transit in the study area. It would cover major routes and cater to the need of student, shopping and work trips. It will work as a feeder service as well to the Mass transit system in the future.

Sensitivity analysis has also been carried out to determine the emission changes in different percentage of commuter shift, the effect of fuel type and vehicle technology.Genetic algorithim (GA) has been used to predict number of different categories of vehicles and their distribution in order to minimise CO_2 emission in the city.. It will help to determine the policy to reduce the carbon footprint in the city.

Finally, the study proposes various measures and recommendations for sustainable mobility in the city. Paltan Pazar should be developed as a pedestrianized zone.To reduce the encroachment on road, pathways are provided with a guardrail to reduce access to it. Crosswalks are proposed for pedestrians at all intersection. Grade separate crosswalks are proposed where space is limited. This research shall helps urban and transport planner to analyse the impact of the project before implementation.

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I dedicate this thesis to all those who are striving towards achieving a sustainable transport system for improvement in user comfort, safety and quality of life and thus enhance the national economy.

(Pooja Singh)

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LIST OF ABBREVIATIONS

SL. NO.	ABBREVIATION	FULL FORM
1	**AAQ**	Ambient Air Quality
2	**ADB**	Asian Development Bank
3	**AHP**	Analytical Hierarchical Process
4	**ANN**	Artificial Neural Network
5	**ARAI**	Automated Research Association of India
6	**ASIF**	Activity Structure Intensity Fuel
7	**ATIS**	Automated Travel Information System
8	**AVL**	Automatic Vehicle Location
9	**BRT**	Bus Rapid Transit
10	**BRTS**	Bus Rapid transit system
11	**CBD**	Central Business District
12	**CDP**	City Development plan
13	**CNG**	Compressed Natural Gas
14	**CMP**	Comprehensive Mobility Plan
15	**CPCB**	Central Pollution Control Board
16	**CO_2**	Carbon Dioxide
17	**CO**	Carbon Mono Oxide
18	**CST**	Center For Sustainable Transport
19	**DIMTS**	Delhi Integrated Multimodal Transit System
20	**EMFAC**	Emission Factor
21	**ERP**	Electronic Road Pricing
22	**FAR**	Floor Area Ratio
23	**FHWA**	Federal Highway Administration
24	**FRI**	Forest Research Institute

25	**FSI**	Floor Space Index
26	**GDP**	Gross Domestic Product
27	**GIS**	Geographic Information System
28	**GOI**	Government of India
29	**GPS**	Global Positioning System
30	**HC**	Hydro Carbon
31	**HOV**	High Occupancy Vehicle
32	**ITDP**	Institute For Transport And Development Programme
33	**IPT**	Intermediate Public Transport
34	**ITS**	Intelligent Transport System
35	**ISBT**	Inter State Bus Terminal
36	**JnNURM**	Jawaharlal Nehru Urban Renewal Mission
37	**LOS**	Level of Services
38	**LPG**	Liquid Petroleum Gas
39	**LRTS**	Light Rapid Transit System
40	**MCD**	Municipal Corporation of Dehradun
41	**MDDA**	Masoorrie Dehradun Development Authority
42	**MGI**	Mckinsey Global Institute
43	**MLCP**	Multi Level Car Parking
44	**MoUD**	Ministry of Urban Development
45	**MORTH**	Ministry of Road Transport and Highway
46	**MRTS**	Mass Rapid Transit system
47	**NAAQ**	National Ambient Air Quality
48	**NIMHANS**	National Institute Of Mental Health And Neuro Sciences
49	**NMT**	Non Motorised Transport
50	**NO_2**	Nitrogen Oxide
51	**NUTP**	National Urban Transport Policy
52	**PM**	Particulate Matter

53	**PRT**	Personal Rapid Transit
54	**PT**	Public Transport
55	**PWD**	Public Works Department
56	**ROW**	Right Of Way
57	**RSPM**	Respirable Suspended Particulate Matter
58	**RTO**	Road Transport Office
59	**RTV**	Rugged Terrain Vehicle
60	**SLB**	Service Level Benchmark
61	**SUTD**	Sustainable Urban Transport Development
62	**STU**	State Transport Undertaking
63	**TDM**	Transport Demand Management
64	**TOD**	Transit Oriented Development
65	**TSM**	Traffic System Management
66	**UN**	United Nation
67	**USPCB**	Uttranchal State Pollution Control Board
68	**UEPPCB**	Uttarakhand Environment Protection and Pollution Control Board
69	**VMT**	Vehicle Miles Travelled
70	**VKT**	Vehicle Kilometer Travelled
71	**VQS**	Vehicle Quota System
72	**WHO**	World Health Organization
73	**WCED**	World Commission On Environment And Development
74	**2W**	Two wheeler
75	**3W**	Three Wheeler
76	**4W**	Four Wheeler

CHAPTER-1
INTRODUCTION

1.1 Introduction

Urban transportation system is under huge stress due to rapid growth in urban population and structural changes in urban settlement (Pred, 2017). Further higher expectation of the worldwide economy puts additional pressure on urban transport system (Black, 2018). Rise in urbanization leads to increase in economic growth, employment opportunities (Sinclair, 2017), better infrastructure, and education reforms that provides a better quality of life (Zhang, 2016). On the other hand urbanization process leads to exponential rise demand for infrastructure (Criqui, 2015; Madon & Sahay, 2017). However, this demand cannot be easily fulfilled leading to mismatch between demand and supply of transport infrastructure. This further results in traffic jams, congestion, waste of time, loss of fuel, pollution , accidents as well as loss of productivity and energy. The traffic situation, particularly in city core area, is quite frustrating

Transport sector is one of the crucial elements of any country's economy and is also responsible for CO_2 emission (Shahbaz et al, 2016). This sector's contribution to CO_2 emission is around 24 percent worldwide (Ben Jebli & Hadhri, 2018). India which is soon to be the country with highest population of world is not an exception to the trend of urbanization. The country road transport energy consumption is about 75 to 80% and from transport mode perspective India's share is about 10%. Delhi alone is responsible for 56-71% of carbon emission every day.

Eventhough there is differences in circumstance across various cities of India, however the basic trends like considerable rise in urban population, income, industries and commercialization display similarity across all the cities. These rising trends have led to increase in demand for transportation which most of the cities of India are unable to handle.

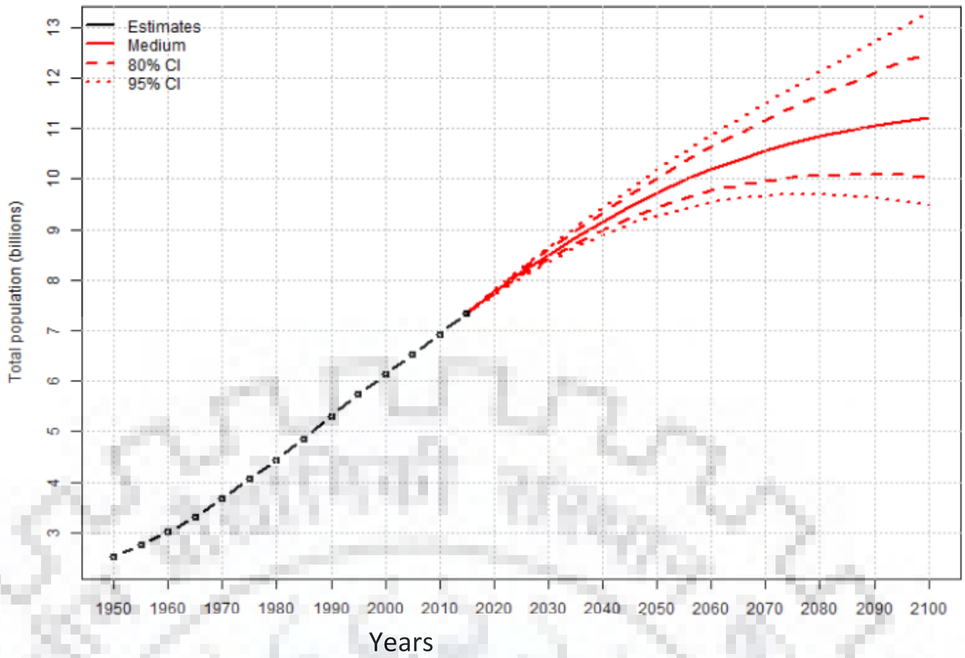
There exist a long term imbalance in modal split, lack of infrastructure and insufficient use of existing infrastructure. Due to these issues the public transport is not able to meet the increasing demand of transportation over past few decades. The impact on bus services is quite high. Due to high demand the services are deteriorated and their output is reduced; as public who uses these services opt for other forms of transport. This other forms of transport include use of personal vehicle, intermediate transport like three wheelers and taxis, which furhter adds to the traffic congestion on road. This congestion further impact bus services. Issues and challenges of the urban transportation can be resolved by making use of latest cutting edge technology. With the use of technology a state of art transportation system can be developed that will be innovative, sustainable, safe and secure, highly effective in terms of functionality and cost, and reliable. Such a system will dramatically improve the current status of transportation.

Sustainable development offers holistic approach that takes into consideration efforts which reduce the negative impact of all the parts associated with system that deal road infrastructure and transportation. Sustainable transportation system also takes into consideration interconnectivity within social, economic and environmental areas. Extreme environmental impacts on the cities due to global warming clearly define the requirement of sustainable transport solution.

1.1.1 Global Urbanization Scenario

Due to industrialization, there is substantial migration from the countryside to cities for employment opportunities and better quality of life. Urbanization is a dominant process in the growth of national economy and is considered as an unavoidable phenomenon. In 1990 the population living in the urban area is 751 million i.e.15% of the total world population whereas presently 55% of the world population is living in urban areas and expected to be 68% by 2050 (UN, 2018).

It can be seen in Figure 1.1 that the world urban population is growing 1.24 % annually. An additional one billion people would increase in world population within the next 15 years. It is forecasted that by 2030 it will reach 8.5 billion and further expected to reach 9.7 billion by 2050.It means the urban population is increasing at a faster pace. More people are moving towards cities for a better quality of life.



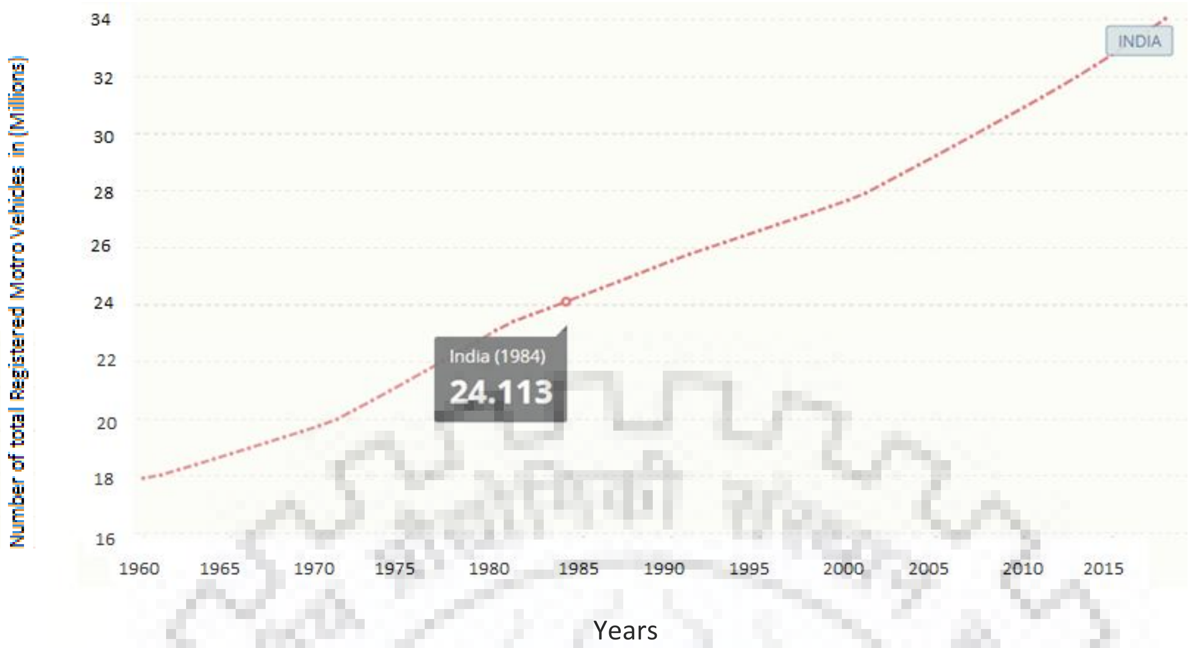
Source: UN, World Population Prospect: 2015 Revision.

Figure 1.1: World Population Estimates and Projection During (2015-2100)

1.1.2 Urbanization in India

The urban population of India ranks second in the world. Figure 1.2 below represents the trends of urban population growth in India as per the data provided by World Bank report (Worldbank.org, 2018). The urban population growth displays a consistent growth since 1960 and has displayed 4 fold increase as compared to total population over the century. The data reveals that there is 2.76% annual increase in urban population from 286.1 million in 2001 to 377 million in 2011 census. The phenomenal growth of urban settlement is clearly seen from the fact that 31.15% population dwelled in cities in 2011 where as this figure was 27.82% in 2001 & 25.7% in 1991. (MoUD, 2016).

A large number of statutory town and census town has increased during the decades.242 statutory towns and 2530 census towns have increased from 2001-2011 (Handbook of Urban Statistics, 2016).



Source: World Urbanization Prospects: 2018 Revision.

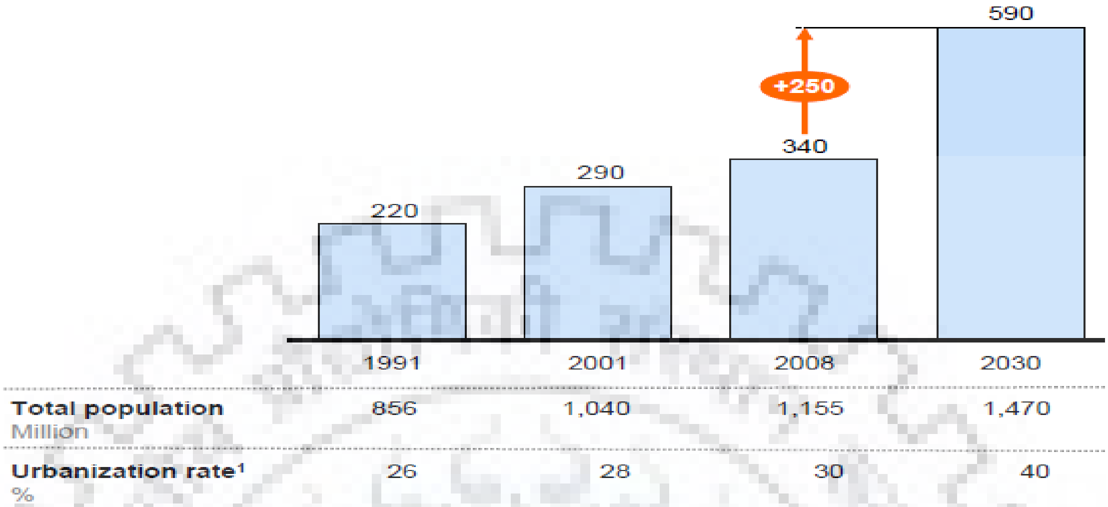
Figure 1.2: Growth Trends of Urban Population in India

The numbers of large cities display a continual growth trend. Table 1.1 below presents the data of number of megacities (>5m) and metropolitan cities as per the latest Sensex of 2011. The numbers in the Table 1.1 clearly indicate 3 fold rise in megacities and metro cities in last 30 years. This clustering of population in mega and metro cities is a phenomenon of primacy and disturbs the balance of Indian urban system (Luthra, 2011).

Table 1.1: Number of Large Cities in India

Year	Size of the city		
	>5m	>1m	>0.5m
1981	3	12	41
1991	4	23	55
2001	6	35	74
2011	9	50	94

Figure 1.3 envisages that by 2030 more than forty percent of Indian population will dwell in cities. (Mckinsey, 2010).



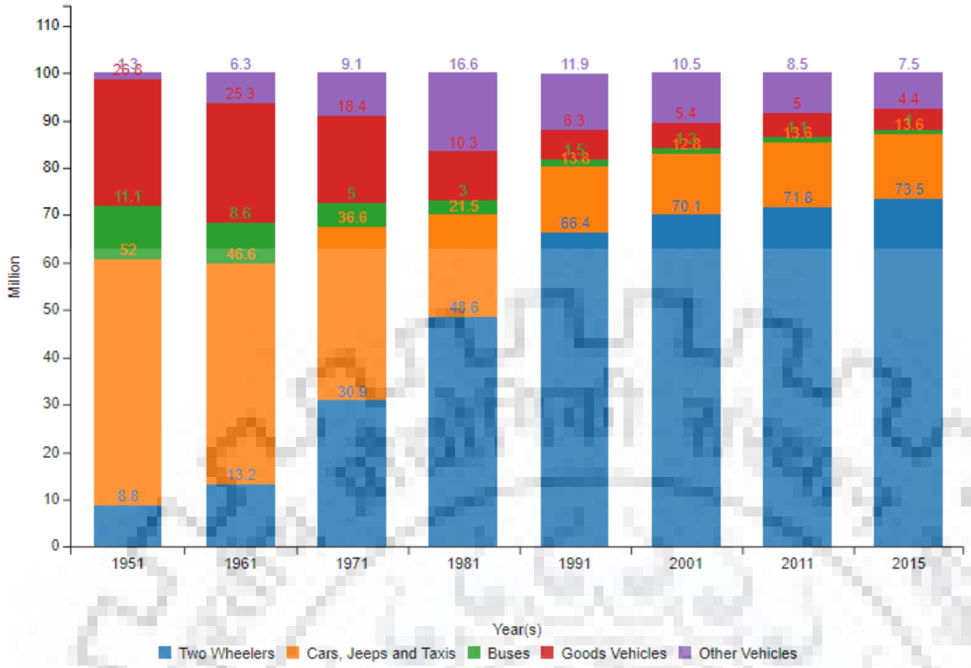
(*Source- Mckinsey, 2010)*

Figure 1.3: Urbanization Growth

On account of this expected rate of growth, it is very critical to develop a sustainable transport solution, which can create value for all the stakeholders in a sustainable manner by providing safe, reliable, fast, economic and environment friendly transport options for all categories of society. Current transport scenario in India is responsible for growing challenges like congestion, deteriorating environment quality, and rising road fatalities. This scenario led to the urgent need for promotion of more sustainable urban transport technologies and strategies for mitigation of negative environmental impact.

1.1.3 Urban Transportation Scenario

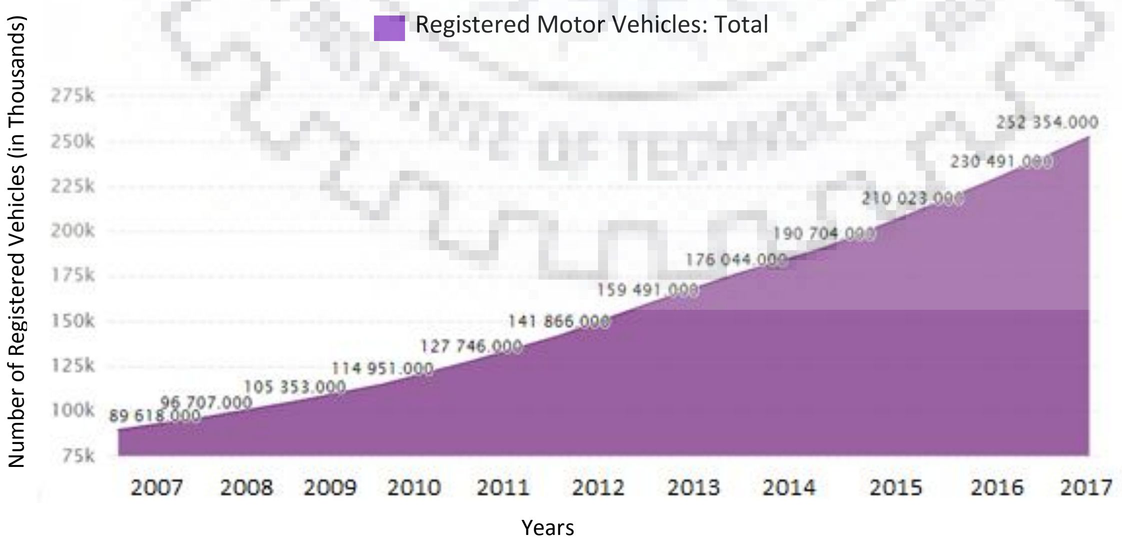
Population growth, transport demand has substantially increased over the years. As mentioned earlier there is a steep rise observed in the population of urban areas in India which has led to increase in vehicle population as well. The level of motorization in Asian cities is lower compared with the cities in Western and European countries, but the rate of motorization is high. Figure 1.4 below presents the composition of vehicle population between 1951 to 2015.



Source: Ministry of Road Transport and Highways

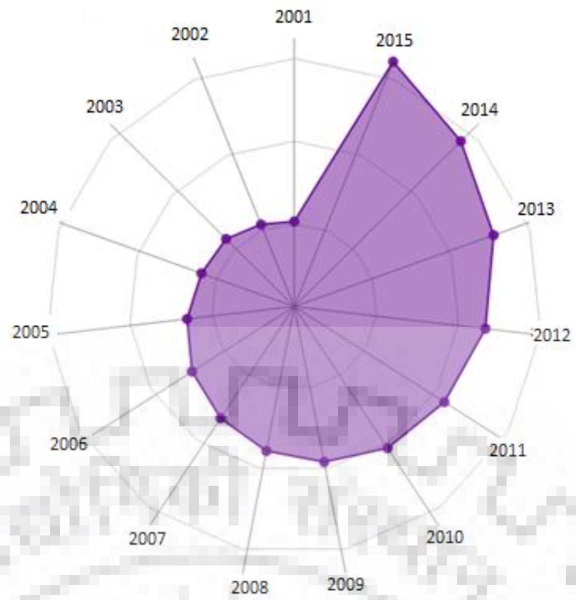
Figure: 1.4: Composition of Vehicle Population Between 1951 to 2015

As reflected in Figure 1.4 that Indian roads are dominated by two wheeler constituting approx. 73.5 % of total registered vehicle in 2015 (community.data.gov.in. 2015). Total of 252,354.000 units were sold in Mar 2017 (CEIC.com, 2018).



Source: Ceicdata.com (2018)

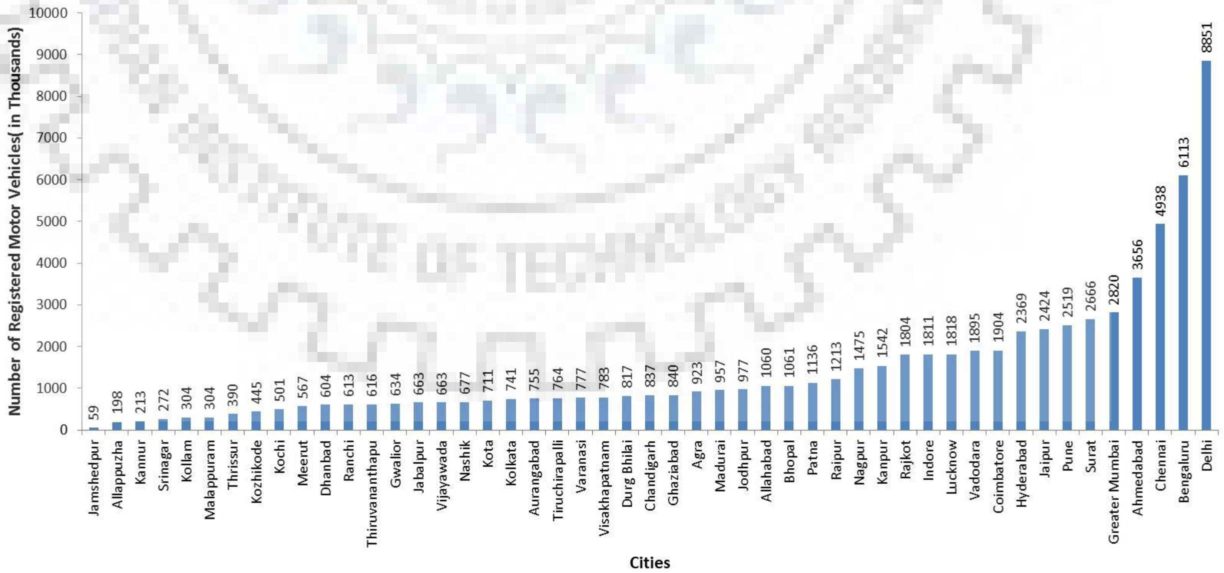
Figure 1.5: India's Registered Motor Vehicles: Total from 1951 to 2017



Source: Community data.gov.in (2016)

Figure 1.6: Total Registered Motor Vehicles per Thousand Populations

As shown in Figure 1.6 the number of registered motor vehicles per 1000 population increased by 35 percent between the period of 2010 to 2013. This increase in trend of registered motor vehicles display continues growth and as it reached the milestone of 150 in the year 2014 for the first time.



Source: Ministry of Road Transport and Highways

Figure 1.7: Registered Motor Vehicles in Million-plus Cities as on March 2016

Choice of mode varies with size of cities as apparent from Figure 1.7 prepared on the basis of the analysis of 50 million-plus cities data (MoRTH, 2017). Figure 1.7 envisaged that Delhi, Bengaluru, Chennai, Ahmedabad, Grater Mumbai and Surat are having highest growth rate of vehicles. The “slow, unreliable, unsafe, and overcrowded” public transport in most of the Indian cities is leading to use of personal vehicles (Pucher et al.2005).The core aspect, accessibility to public transport contributes to the effectiveness of the system, leading to increased modal share of public transport (Tuan et al.2015). An amendment in policy measures is required for effective control of private transport and sustainable transport development in developing country. (Tuan et al.2015).

1.2 Need of the Study

Transportation involves mobility of people, goods and the delivery of services, and has an important role to play in supporting regional & local development and enhancing the quality of life. From the perspective of a developing country like India, transport infrastructure has a key role in economic development and up-gradation of quality of living. From the point of view of environmental sustainability, transport development has the potential to give rise to significant adverse impacts. This is because transportation is material intensive, and its use has implications on carbon emissions, local air quality, noise, and health and well-being. Strategies that help in lowering the carbon emission is required to ensure that the adverse effect of transportation could be reduced. A strategy or framework to reduce the carbon emission from transport is the need of hour. Current, data and tools to reduce CO_2 emission in transport sector are inadequate to address emerging needs to tackle the adverse effect especially in urban areas. This research therefore attempts to present a low carbon transportation system to reduce carbon emission from transport sector without compromising the mobility need and confirming to environment sustainability.

The research is undertaken in urban context; the area chosen for the study is Deharadun.Due to its location advantage, there is a considerable influx of population from the surrounding regions. Being home to a number of prestigious institutions and with its large tourism potential, the existing transport infrastructure of Dehradun requires substantial augmentation. The stress on transport infrastructure is causing congestion, reduced mobility, and rising air and noise pollution levels. Therefore, evaluation analysis of projects/ programs/ plans needs to be carried out before implementation to ensure that it will not in any way harm the environment, society on a short or long-term basis.

1.3 Aim

The main goal of the research is to achieve a low carbon transportation system to reduce carbon emission from transport without compromising the mobility need and confirming to environment sustainability.

1.4 Objectives

To accomplish the goal, following objectives were planned to be addressed in thesis work;

1. To assess the existing condition of transport system and the impact of socio economic characteristics and user behavior on sustainable transport strategies.
2. To develop a multi-criteria development making (MCDM) framework for evaluating alternative sustainable transportation strategies for a city
3. To evolve an emission estimation framework for road transport vehicles and identify strategy to reduce carbon emission through scenario analysis.
4. To suggest proposals, policy measures, and improvement schemes to achieve environmentally and socially sustainable transport system.

1.5 Scope

The study aims to assess the factors that lead to the occurrence of air pollution, and accidents and responsible for deteriorating environment and reduces the quality of life. This study will make use of evaluation and emission estimation for planning a low carbon transport system. The scope of this research is limited to

- Assess the existing condition of responsible factors.
- Demonstrate the methodology, a data set extracted from sources and survey to estimate the carbon emission for different scenario.
- Develop a framework to evaluate the low carbon strategies to reduce the adverse impact on the environment.

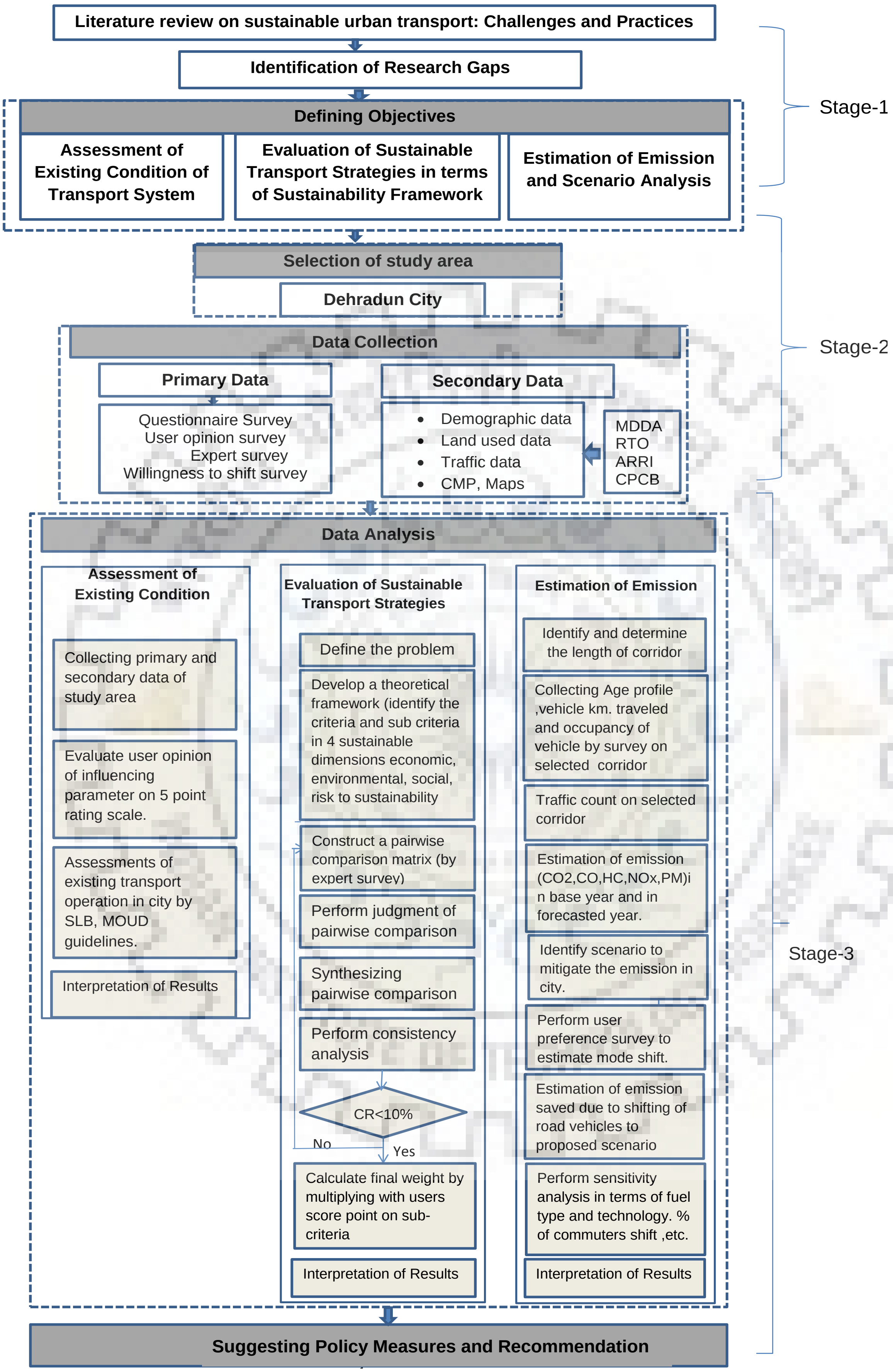


Figure 1.8: Flow Chart of Methodology

1.6. Methodology

The study methodology comprises of 3 stages. In the first stage the literature review is done on various sustainable practices and Impact evaluation tools used in India and worldwide. In second stage data is collected from primary and secondary sources. The secondary data is collected from various government institutions, reports and maps, and primary data collection is done by various field surveys against each objective. In third stage, data is analyzed for each objective, where identified strategies are evaluated in the sustainability framework and a multi-criteria decision method (AHP tool) is used to develop a hierarchical framework to evaluate the strategy. Post strategy evaluation the most sustainable strategy is identified for the estimation of carbon emission in different scenarios. The most optimal scenario is chosen as first priority to implement in the study area. Based on the data analysis and impact assessment result, various policy measure for physical planning are formulated and recommended for the study area to meet the goal of the study. The full step-wise research methodology involved in achieving the objectives of the present study is given in the Figure 1.8.

1.7 Thesis Organization

The thesis is divided into 8-chapters which cover the following content in brief as described below:

Chapter 1: Introduction

In this chapter, aim, objectives, scope, and methodology of the study have been discussed. It prepares a background for the project within the given context. The chapter also discusses the need of the study and uniqueness of the proposal and gives a clear idea of the outcome's structure.

Chapter 2: Literature Review

This chapter deals with the concept of the sustainable mobility, its character, benefits and its adoption around the world. This chapter segmented into following sections like issues & challenges, possible sustainable transport strategies and practice in India and worldwide. Then impact assessment tools to evaluate the strategies and various emission models to estimate the road transport emission have been discussed.

Chapter 3: Dehradun: City Profile

This chapter develops a brief background of the city profile. The demography, economy, growth trends, current traffic, and transport characteristics have been discussed briefly. The issues and problems of mobility in the city are studied through reconnaissance survey and user survey. This chapter deals with the traffic and transport issues in the city, its road network characteristics, etc.

Chapter 4: Assessment of Existing Traffic and Transportation Characteristics

This chapter discusses the assessment of the existing condition of public transport operation in the study area. The level of service of public transport operation in Dehradun city has been calculated by service level benchmarking (SLB). It also discusses the impact of socioeconomics characteristics and user behavior rating on sustainable transport strategies.

Chapter-5: Evaluation of Sustainable Transport Strategies

This chapter develops a framework for evaluation of strategies against 4 sustainability (economic, social, environmental and risk to sustainability) criteria. A multi-criteria decision making (MCDM) framework (AHP tool) is used to evaluate the strategies against 4 criteria through expert opinion and priorities the strategies.

Chapter-6 Estimation of Emission and Scenario Analysis

This chapter evolves a framework to estimates the carbon emission in the study area by road transport and calculate the improvement in emission by enhancing the public transport in different scenarios. Sensitivity analysis of each scenario by fuel and technology change and the commuter shift has been discussed and revealed the result from this.

Chapter 7: Detailed Proposal and Recommendations

This chapter presents a list of initiatives and guidelines in order to achieve sustainable urban mobility at the city level. It also comprises of a detailed proposal which needs to be implemented in the study area.

Chapter 8: Conclusions and Future Scope

This chapter summarizes the salient findings of identified objectives of the study. It discussed the contribution and limitation of the research. Future scope of the research also has been discussed to extend the research.

1.8 Summary

This chapter depicts the growth trend of urbanization globally and in India. Various statistics are discussed that reveal the current condition of the urban mobility in terms of population growth, travel demand, etc. This chapter gives a brief about the need and scope of the study along with their objectives. In the end, thesis organization is discussed which navigate the thesis to the reader.

CHAPTER-2
LITERATURE REVIEW

2.1 Introduction

Before arriving at the stage of making plans for sustainable mobility of a city, it is imperative to develop understanding about the term sustainable Urban Mobility , challenges and issues to achieve this, and all the related regulatory guidelines and laws along with all the government initiatives and worldwide strategies to cope up with these issues. Therefore, this chapter briefly discusses about the concept of Sustainable Urban Mobility, its purpose and path in India. Further different initiatives and practice in India and worldwide has been discussed. Various methods and models are also discussed to evolve an understanding to develop a structure for evaluating the strategies to mitigate and estimate the carbon emission in city.

2.2. Concept of Sustainability

2.2.1 Sustainable Development

The concept of sustainability or sustainable development has been around since the 1972 United Nations Conference on the Human Environment in Stockholm. The definition used most widely originates & published by the United Nations (UN) World Commission on Environment and Development (WCED) which reads;

"*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs",* (WCED, 1987).

The term "sustainable development" is seen by researchers as a tool with the potential to facilitate balanced economic development, good social atmosphere and protection of environment (Vidyarthi et al. 2017). For sustainable development an efficient and adequate transport system is required. This system should be economically acceptable to the society and environment friendly (Dua, 2012 & Dua, 2014).

2.2.2 Sustainable Transportation

Many researchers have derived the definition of sustainable transportation from “The Brundtland Commission’s” report that was published in 1987.(McVoy et al.2010; Gilbert 2006; Zietsman & Rilett 2002).

According to Black (2010) sustainable transportation means the transportation that is able to fulfill the current transportation requirements of the society without negatively impacting the transportation needs of future. From this perspective sustainable transportation is in line with the concept of sustainable development.

Other definitions related to transport policy developed by academicians and organizations offer good deal of comparisons. Along with other aspects it also takes into considerations like environmental integrity, improved quality of life, economic viability, offer social justice and increased urban resilience (Kenworthy, 2006; Haghshenas & Vaziri, 2012).

According Schiller et al. (2010) a sustainable transport system permits accessibility and promotes the development of people, organizations and society by safely meeting their needs. The process used in meeting these needs do not negatively impact health of ecosystem or humans and equity is promoted and transferred to next generation. Yigitcanlar et al. (2010) say that sustainable transport system should be affordable, with fair operations capacity that works efficiently by offering options of transport mode that is competitive in nature and leads to balanced development. According to Mihyeon & Amekudzi (2005) the ideal system controls emissions and waste and keeps it to the point that can be easily absorbed by the planet. Further the systems make use of renewable resources and emphasize on development of renewable substitutes without impacting land usage and reduce the noise pollution. Aastho (2009) also took into account the three basic factors (social, economic and environmental) while suggesting the solution to issues of transportation and providing infrastructure that is sustainable in nature.

Yigitcanlar et al. (2010) studied elements of Sustainable Urban Transport Development (SUTD) from economic, environmental and social factors perspective and found that urban form, transport, infrastructure and community domains are important element of Sustainable Urban Transport Development (SUTD). The domains also help in identification of the planning responsibilities from with respect to intervention and regulation for reaching desired sustainable future. Specifically, focus is given to the critical study of important factors that are associated with transportation activities that are unsustainable. Some of these unsustainable activities include harmful greenhouse gas emissions, pollutants that have ill effect on health, usage of nonrenewable fuel, traffic jams, and accidents. According to Christopher et al. (2005) for achievement of more sustainable transportation four pillars needs to be established. These pillars are: land use and transportation should be effectively governed; funding should be fair and sufficient; effective investment strategy in infrastructure; and higher focus on neighborhood design. “The Centre for Sustainable Transport (CST) in Toronto sees sustainable transport as a system that Is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development”.

2.2.3 Purpose of Sustainable Urban Mobility Plan

The main purpose to create a sustainable urban transport system is to ensure things enlisted below:

- The transport system should be accessible to everyone.
- It should have improved safety and security.
- It should help in reduction of emission of CO_2, greenhouse gas, air and noise pollution, and fossil fuel consumption .
- It should provide cost effective and efficient transportation of people as well as goods.
- Enhance the aesthetics and quality of urban design and environment.

2.2.4 Low Carbon Development

There is a dire need of strategy that facilitates low carbon emission in Transport sector and this strategy is especially requited in cities that are developing. Low carbon development strategy will help in making transport sector in cities sustainable

Qureshi &Lu (2007). Low carbon urban development model is the pathway towards reducing the emissions (Stanley, 2010; Dhar et al.2013).

There is a lot of variation observed in the definition of low carbon cities inspite of the fact that all the definitions emphasize on need of reducing carbon and its impact on social aspects like employments, quality of life and earnings. Skea & Nishioka (2008) mention that low carbon city must take actions that incorporates principles of sustainable development. It must ensure that the development needs of all the members of society are met. It should make equal contribution towards the worldwide efforts to reduce carbon dioxide and other greenhouse gases and keep their concentration to the level that do not lead to global warming or dangerous climate change. The low carbon city must display higher level of efficient energy usage and makes use of sources and technologies that promote low carbon usage. Lastly the authors say the cities consumption patterns should be consistent with low level of greenhouse gas emissions. Wang (2010) mentions that low carbon city should "ecologically innocuous with slashed CO_2 emission and urban sustainability". Further he comments that the city must make use of energy and environmental technology of elimination of carbon dioxide emission thereby gaining the economic advantages that will lead to rise in employment and income.

2.2.5 Sustainable Path for India

Increasing number of trips, longer trip lengths, increasing vehicles, less walking trips, reduced public transit usage, decreasing air quality and increasing accidents is the current urban scenario in India. The problem needs to be addressed at source, by reducing the demands for mobility, reducing number of trips, and also the length of trips. Like many other cities across the world India needs to adopt the "Avoid, Shift and Improve" strategy in transport planning in order to be sustainable.

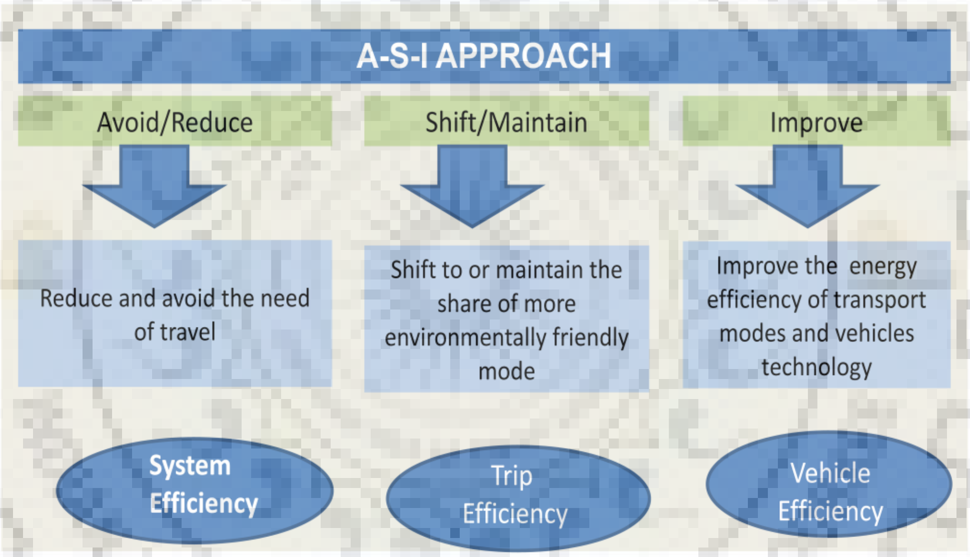
2.2.5.1 Avoid Shift and Improve

The "Avoid-Shift-Improve" strategy requires strong and effective leadership that prioritizes environmental concerns and social equity above short term economic growth (rather than long term losses).

As at international level issue of climate change has been accorded high priority this calls to urgently act for development of effecting and efficient solutions that are capable or working on big scale for transport sector of Asia. One of the useful conceptual tool that is capable of guiding work both at country and regional level is the "avoid–shift–improve" approach. (sutp.org)

The A-S-I approach, designed to tackle increasing transport demand and especially demand for car based travel, includes three main avenues:

- Avoid /Reduce,
- Shift / Maintain,
- Improve.



Source: Urban Transport and the Environment Module -8,(2012)

Figure 2.1: A-S-I Approach

Avoid: This strategy aims towards reduction of trip distances and avoiding unnecessary travel. It promotes measures that appropriately integrates transport planning and land use and also promotes mixed development.

Shift: Here the strategy is made to woo and educate passengers to adopt a transport mode that is more sustainable in nature.

Improve: This strategy pays attention to the regulation and polices that are made for the improvement of practices and technology in transport sector.

Even though "the Avoid, Shift, Improve approach" most commonly have the three strategies mentioned above, "the Bangkok 2020 Declaration" also recommends a fourth strategy that focuses on "people first" approach. This strategy will offer a humane touch for the delivery of sustainable urban transport policies. Policies that deliver health benefits and cause reduction in the negative impact of air and noise pollution and effectively tackle climate change. The effective participation of stakeholders play an important role in climate change (Samaddar et al. 2015); Samaddar et al. 2019).

Nakamura & Hayashi (2013) also used **"**AVOID, SHIFT and IMPROVE "policy. They set out 3 steps for tackling and reducing carbon dioxide emissions in the transport sector. In today's scenario where the passenger's demand for transportation is very high and many people own car due to rising incomes that leads to development of mega cities. A more effective way to control road congestion is to invest in rail transit system rather than in road system. This step further reduces CO_2 emissions in transport sector.

Mitigation options for Indian cities

I. Avoid: *Land use planning*

II. Shift:
- Public Transport
- Non-motorized transport
- Discouraging private motorized transport
- Traffic management measures

III. Improve:
- Improve vehicle technology
- Alternative fuel type

"CUTE (comparative analysis of urban transport and environment) matrix" is used to capture trends and classify measures that impact low carbon transport systems globally. Further the work on mitigation of CO_2 is studied by reviewing the empirical studies.

Then, their prospective effects on CO_2 mitigation are discussed by reviewing empirical studies. Nakamura, & Hayashi, (2013) also used this policy with four categories viz; technology, regulation information and economy to meet the need of sustainable transport.

For promotion of sustainable transportation (Singhal, 2010) the Government of India has taken following steps

- In 2006 National Urban Transport Policy was issued.
- In coordination with Global Environment Facility started demonstration projects that has strengthened the institution.
- Started capacity building programme
- Supported and improved both road and rail based "mass rapid transit (MRT) facilities"
- Creating stricter emission norms and offering improved quality fuel.

2.2.5.2 National Urban Transport Policy (NUTP)

National Urban transport Policy was issued under Jawahar Nehru National Urban Renewal Mission (JNNURM) in the year 2006 to rejuvenate the urban transport scenario. With the objective " to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within our cities". The objective of this policy was to do efficient planning for people rather than vehicles. In 2014 the new set of objectives were rolled out.

- Incorporating urban transportation as an important parameter at the urban planning stage rather than being a consequential requirement.
- Bringing about a more equitable allocation of road space with people, rather than vehicles, as its main focus
- Public transport (PT) should be citywide, safe, seamless, user friendly, reliable and should provide good ambience with well-behaved drivers and conductors.
- Walk and cycle should become safe modes of Urban Transport.

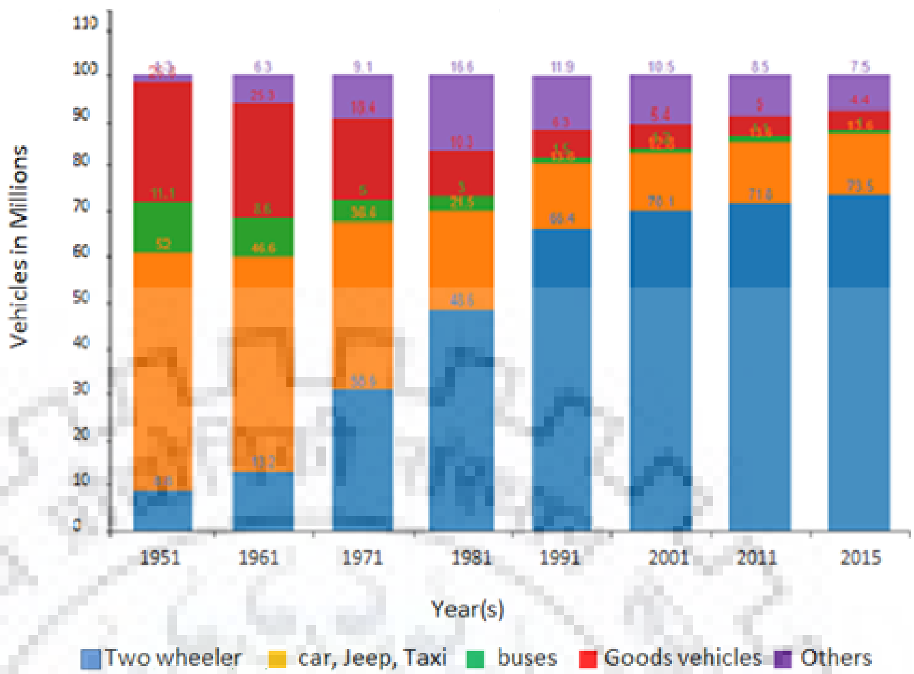
- Introducing Intelligent Transport Systems for traffic management
- Addressing concerns of road safety and trauma response
- Raising finances, through innovative mechanisms
- Establishing institutional mechanisms for enhanced coordination in the planning and management of transport systems.
- Building capacity (institutional and manpower) to plan for sustainable urban transport and establishing knowledge management system that would service the needs of all urban transport professionals, such as planners, researchers, teachers, students, etc. (National Urban Transport Policy, 2014, pg 2-3)

2.3 Urban Transportation Scenario: Issues and Challenges

Transportation planning is a process of preparing systematic basis for solving the traffic problems and meeting the travel need of inhabitants by providing appropriate transportation facilities in an urban area/urban agglomeration with a view to attain cost effective, safer , comfortable and environmentally sound transportation option for movement that enhance accessibility and mobility of all the people in the settlement. But Indian transportation scenario is almost opposite to it. Urban settlement, especially bigger settlement is facing variety of transportation problems and issues in different proportion and magnitude. Verma et al. (2015) has studied the factors responsible that are responsible for the prevailing trend of transport mobility in five Indian cities.

2.3.1.1 Vehicular Growth

India has observed drastic increase in number of vehicles as observed from the fact that the number has increased from 0.31 million in 1951 to about 252 million in 2017(MoRTH.2018) given in Table 2.1.Two wheelers have the highest share and constitutes 73.6% cars, jeeps and taxis share is 13.5%, buses take just 1 % share, 4.3 % is taken by goods vehicle and other vehicles takes 7.6 % share. Figure 2.2 below displays the consistency in the growth of two wheelers however share of buses and heavy vehicles display decline. Initially cars, jeeps and taxis share declined however between 2001 to 2015. The share gradually increased (MoRTH, 2016).The Figure 2.2 shows the mode wide vehicular growth in last decades.



(*Source: MoRTH, 2016)*

Figure 2.2: Composition of Vehicle Population in India from 1951 to 2015

The Ministry of Urban Development (MoUD) study highlights some characteristics of Indian cities:

- Walk trips are significant in all cities.
- Many cities do not have public transport and in these cities IPT plays an important role.
- Cycle trips are minimal in hilly cities.
- In smaller cities the number of walk trips are high. Kolkata and Kochi's walk share is less than 20%. One of the reason behind lower percentage is presence of public transport (PT) in these two cities. The percentage of Walk trips in all other metro cities are in range of 19- 25%.
- Cities like Gangtok, Bikaner, Raipur, Agra, Amritsar, Patna, Varanasi and Surat do not have public transport.
- Kolkata has the highest public transport share (54%), followed by Kochi (51%). Both the cities have public transport share above 50%. Delhi and Mumbai have almost same public transport share.
- Kolkata and Mumbai record the lowest two wheeler share of trips.

Table 2.1: Number of Registered Motor Vehicles in India :Transport and Non Transport as on 31st March 2018

Year	Buses	Taxis	Light Motor Vehicles(Passengers)	Goods vehicles(a)	Two-wheelers	Cars	Jeeps	Miscellaneous(b)	Grand Total
1	2	3	4	5	6	7	8	9	10
2001	633900(b)	634357	1777130	2948300	38556026	5297219	1126148	4017946	**54991026**
2002	635006	688204	1878261	2973740	41581058	5748036	1177245	4242787	**58924337**
2003	720696	825416	2113781	3491637	47519489	6594166	1180057	4562042	**67007284**
2004	767593	901889	2167324	3748484	51921973	7267174	1282113	4661385	**72717935**
2005	678521	939738	2337264	3877622	58799702	8072650	1307926	5488296	**81501719**
2006	762341	1039845	2492726	4274984	64743126	9109855	1376744	5818646	**89618267**
2007	1098422	1042347	2697449	5118880	69128762	10146468	1460364	6014568	**96707260**
2008	1156568	1201862	2903821	5600938	75336026	11200142	1547825	6405672	**105353854**
2009	1205793	1307805	3146619	6040924	82402105	12365806	1638975	6843006	**114951033**
2010	176642	3615086	3615086	6431926	91597791	13749406	1760428	7552876	**127745972**
2011	1238245	1789417	4016888	7064495	101864582	15467473	1974253	8045441	**141865607**
2012	1296764	2011022	4242968	7658391	115419175	17569546	1987098	8866332	**159490578**
2013	1418763	2216453	4718672	8596762	132550294	20503389	2132893	9768046	**182445229**
2014	1468010	2109348	4638377	8697541	139409778	21671515	2216888	9778764	**190703971**
2015	1527396	2256619	5028312	9344464	154297746	23807986	2546731	10474886	**210023289**
2016	1384740	2341375	6392010	10516156	168975300	25634824	2265488	12048062	**230030598**
2017	1395290	2491420	6653010	14816256	184976795	26644679	2357590	13018960	**252354000**

Source: Transport Research Wing, Ministry of Surface Transport

2.3.2 Rising Traffic Densities and Congestion

Rising number of vehicles on road and non-proportionate road network has led to rise in traffic densities and congestion of roads. This congestion leads to reduction in the speed of journey and wastage to energy, productivity and time. A comparative study of effect of motor vehicles volume on four lane roads has been carried in India and Thailand (Sinha et al. 2012) where relationship of speed volume is used for capacity estimation.

2.3.3 Inadequacy in Public Transport System

Barring the large cities metropolitan public transport system is either absent or awfully inadequate resulting in serving the transportation needs by Para transit modes or private vehicles. This inadequacy has led to use of private transport to meet transportation needs. Almost 70 % of transport needs are taken care by private modes.

Insufficient mass transport facility leads to traffic congestion. Most of the cities have city buses as the main mode of transportation and some of metro cities have suburban rail or metro rail as public transport. Many cities, including a significant number of million plus cities do not have a proper bus system. Gangtok, Bikaner, Raipur, Amritsar, Patna, Agra and Varanasi do not bus service therefore transport need in these cities is taken care of mini- buses and by IPT mode. Table 2.2 represents share of public transport city category wise in 2007 and in comparison with 1994.

Table 2.2: Public Transport Share Comparison with 1994 Study

City category	Population range in lakhs	WSA,2007 %	Rites ,1994 %
1	<5	0.0-15.6	14.9-22.7
2	5.0-10.0	0.0-22.5	22.7-29.1
3	10-20.0	0.0-50.8	28.1-35.6
4	20.0-40.0	0.2-22.2	35.6-45.8
5	40.00-80.00	11.2-32.1	45.8-59.7
6	>80.00	35.2-54.0	59.7-78.7

Source : Road Transport Year Book of MoRTH, 2011

2.3.3.1 Poor Performance, Unpredictable and Unreliable Public Transport system

The route planning is unscientific and the depots too are not properly planned this leads to increase in dead mileage that causes losses both on energy and financial front (Jain, 2009). When the mass public transport system is not reliable then this leads to people opting for private transport modes to fulfill their travel needs (Luthra, 2011).Due to Lack of cleanliness , comfort, and safety, passenger ridership in busses are less that put performance index of PT on lower side.

2.3.4 Lack of Inter Modal Integration

Urban settlement witness variety of transport modes on their roads. Heterogeneity of traffic tends to slow down the speed and leads to accidents to great extent. But it is important to notice that lack of public transport system integration results to loss of energy, time, and fuel and environment inefficiency. Except for some scanty efforts in bigger cities hardly any efforts are made to establish integration amongst different components of transportation. Rather different transportation systems are operating in competition to each other instead of complementing each other. No efforts have been made for development of common infrastructure for different transport system existing in cities (Jain, 2009 ; Luthra, 2011).

2.3.5 Deteriorating Environment Condition

The deterioration of the environment due to traffic has been causing serious concern. Some environmental issues of traffic are :(Kadiyali, 2014)

- Safety
- Noise
- Air pollution
- Vibration
- Visual intrusion and degrading aesthetics
- Severance

2.3.6 Rising Vehicular Emission and Climate Change

Carbon emission and GHG (Green House Gas) emission in atmosphere is responsible for Climate Change which increase in the Earth's average temperature. Urban transport represents one of the fastest growing sources of greenhouse gas emissions that contribute to global climate change.

Transport is the second largest sector contributing 23% of global carbon dioxide (CO_2) emissions from fossil fuel combustion as shown in Figure 2.3. Out of which road transport alone accounts for 73 % of emission , (UNEP,2010)

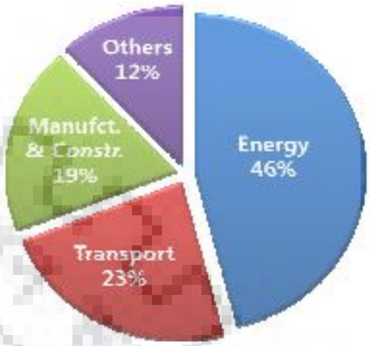


Figure 2.3: Global CO_2-Emission by Sectors

Environment is a global concern these days and role of vehicles in deteriorating the environment has been widely recognized. According to the International Energy Agency (IEA) transport sector contribute 23% CO_2 emission in the world. It is estimated that CO_2 emission will increase from 1 billion tones in 2006 to 2.3 billion tons by 2030 (Schipper et al. 2009_a).Whereas Indian transport sector is responsible for 12.9 % of the country's GHS emissions (Luthra, 2011). CPCB (Central Pollution Control Board) New Delhi, mentioned that 56-71% CO_2 emission is contributed by road vehicles every day. As per CSE (Center for Science and Environment) study vehicle speed is reciprocal of three major component (CO, NO_x, & hydrocarbon) of pollution means at the speed of 75kmph emission of CO_2 is 6.4grm/vehicles. Which increase by five times at the speed of 10km/hours (Singh, 2005).

Table-2.3 envisaged that large cities emitted maximum CO_2 emissions(64%), Medium size cities(2-4 millions) emitted 3-4 times less CO_2 emission & Small cities (0.5-2 millions) emitted minimum CO_2 emission as these cities are based on para transit modes (motorized and non-motorized).

Table 2.3: Population & CO_2 Emission Distribution by City Size

City categories (population in million)	Total number of cities	% of total Population	% of total CO_2 emission
<0.5	4208	53	0.2
0.5-1.0	39	10	6.4
1.0-2.0	88	10	11.7
2.0-4.0	6	6	5.2
4.0-8.0	4	8	12.3
>8.0	3	15	64.2

Sahbaaj et al. (2016) found that urbanization and CO_2 relationship is in U shape i.e initially urbanization decreases the carbon di oxide but after a thresh hold it increased CO_2.

2.3.7 Urban Poor

The mobility linkages to shelter and livelihood are very crucial to the urban poor. High costs of travel (time and money) to jobs, schools, and health clinics impose large economic burdens on the poor, many of whom reside on the urban periphery. The time freed up, and the reduction in fatigue, can increase productive capacity of this population, especially women and valuable time (school, play, study time) for children. Furthermore, vulnerable population like children, women, person with disability, and senior citizens need have to be taken into account in the transport planning process (SUTP/GIF, 2012).

2.3.8 Urban Sprawl

Overall population increase, lack of effective planning and land-use controls have encouraged sprawl rapidly in all directions, in all the Indian cities, mega, big and small. Public policies in an attempt to decongest the core city centers have historically restricted the Floor Space Index (FSI) in Asian city centers is within the range of 5-15 whereas in India, it is 1.6 (Bertraud, 2002). Government has also taken steps to permit higher floor space/land area ratios in suburban developments, thus further inducing firms to decentralize.

2.3.9 Energy Inefficient Transportation System

Heterogeneity of traffic and traffic congestion of city roads make the transport system energy inefficient. According to an estimate, bus transport consumes about 5-15% of fuel energy and 85-95% is consumed by other vehicles. In large cities 50-60% by private modes, 17.33 % by bus and about 4% is by auto rickshaw. Large amount of energy is consumed by private automobiles due to their rising number (Luthra, 2011).

2.3.10 Lack of Parking Facilities

The significant road space is being encroached by parked vehicles in Indian cities. Parking is one of the critical problems faced by the city, which is becoming serious due to distortion in land use, unauthorized encroachment, longer trip length accompanied by higher private vehicle ownership due to poor public transport and easy financing of private vehicles. Approximately 40 % of the commercial vehicles which enter inside the city, have no business in the city. Parking of truck at the outskirt of the city due to restriction to enter in the city is also a concern (MoUD, 2010$_a$).Hence there is a dire need to revise parking norms and arrangement.

Figure-2.4 shows inadequate parking place at GMCH Chandigarh. Due to absence of organized parking space, vehicles are parked on roadside which choke the road capacity and become the reason of congestion.

(htttp://www.tribuneindia.com)

Figure 2.4 :Parking Condition in the City

2.3.11 Poor Mobility

Mobility of all is one of the main objectives of transportation planning but the existing transportation system in different cities hardly plans for all. Except in few bigger cities, no provision has been made for physically challenged, elderly, children and females. In few bigger cities like Bangaluru and Delhi, low floor busses are recently introduced (Jain, 2009; Luthra, 2011).

2.3.12 Inappropriate Transport System Management

In most of the Indian cities the transport system management measures are either nonexistent or inappropriate. Neither the authority nor the public having concern for meeting the travel need in planned manner. The Impact has been chaotic traffic scenes, frequent jams, conflict, accidents, increased vehicular emission etc. The central part or the cities are worst affected by such condition (Chandra & Sinha, 2003).According to Kumar, (2003) road information system should be GIS based so that chronic transport situation can be reduced.

2.3.13 Ineffective Traffic Regulation

Traffic control and regulation provided in Motor Vehicle Act, 1988 and rules prepared as per requirements of the local transport condition are either inappropriate or ineffective. Also improper execution of suggested traffic regulation by the competent authority are not obeyed and respected.

2.3.14 Lack of Inter-Agency Coordination

Planning, development and enforcement works on different aspect are performed by numbers of agencies in the urban settlement. Each agency is responsible for a job which can be performed on others agency's jurisdiction as well. Although, about 15-20 agencies related to transport system, (roads, rail, terminals or traffic control and regulation) are working in different area of traffic and transportation yet all these agencies work independently and hardly any coordination is visible amongst them.

Lack of coordination amongst different agencies is responsible for absence of an integrated approach to urban transportation planning and development**.**

2.3.15 Inappropriate Funding and Financing Option

One of the most important causes for leisurely progress in the improvement of the urban transportation system is lack of funds. How to finance and fund urban transportation is still unclear to people leading the projects. However there has been some improvement in the bigger cities; the smaller cities and towns are neglected

2.3.16: Air Pollution

India stands third in carbon dioxide emission after China and the United States, according to a report release by Centre for Science and Environment (CSE) in November 2017. According to Global Health Report of 2014 on air pollution published by World Health Organization, it has estimated that Indian has become 9th largest industrial nation but at the same time it has become the most polluted nation in the world (Kumar, 2015_a).Urban transport contributes substantially to poor air quality, posing environmental and health risks, although it should be stressed that motorized traffic is not the only emission source of air pollutants. (Kumar et al. 2018). Pollution of the atmosphere by fumes and smell emitted by the motor vehicles make the urban street extremely unpleasant, with further growth of the vehicle population, the problem is bound to assume serious proportion (Kadiyali, 2014).Driving behavior of motorcyclist also affect the fuel consumption and emission in the city (Kumar & Saleh, 2015). As per WHO, 6 major pollutant that cause significant health effect are ground level Ozone, Carbon mono oxide, sulphur di oxide, nitrogen oxide ,lead and particulate matters. These emissions damage health, especially of pedestrians and persons living or working in open area near main road. Long-term exposure to polluted air causes diseases such as respiratory inflammations and infections, cancer & cardiovascular dysfunctions. This is widely accepted by Rumana et al. (2014), Yamamoto, (2014), Zhang, (2014) hence, air pollution is responsible for millions of death globally each year (Biggeri, 2004, Kan et all. 2010).In current situation vehicles contribute 60%-70% of the total emission in urban areas. Transportation sector is accountable for about 50% of the emissions of nitrogen oxide and 90% of the carbon monoxide**.** Table 2.4 given below shows the various pollutants and its effect on the person's health

Table 2.4: The Pollutant and Health Effects

Pollutants	Effects on health
CO (Carbon mono oxide)	Harmful for the heart, nervous system impairing physical coordination, vision and judgment, causing nausea, dizziness and headaches, reducing productivity and increasing discomfort.
NOx(nitrogen oxide)	Responsible for respiratory problems. Causes lungs inflammation, bronchitis, coughing and wheezing
SO_2(sulphur dioxide	It is linked to cardiovascular dieses and respiratory problems.
SPM and RPM (Suspended particulate matter and repirable particulate matter	Fine particulate matter may be toxic itself or may carry toxic trace substance and can alter the immune system. Fine particulates penetrate deep into the respiratory system irritating lung tissue and causing long term disorders
HC(Hydrocarbon)	Potential to cause cancer.

Source : Shrivastava et al. (2013), Kampa & Castanas(2008)

The air quality index is a national index for 5 pollutant that tells us condition and quality of air surrounding us in outdoor. CPCB publishes the annual air quality data base called National Ambient Air Quality Status that includes data for criteria pollutants including particulate matter, NO_2, SO_2 that are routinely monitored. Toxics and CO were monitored on a rudimentary scale in a few cities. The National Indian Ambient Quality standard is envisioned in Table 2.5.

Reducing the pollutants at the sources, by improving the vehicles design and maintenance, using of small cars instead of bigger ones, using alternative fuels, and exhaustive use of public transport system. Measures to reduce peak hour traffic and reduce road pollution:

- By introduction of staggering hours,
- Instituting parking restraints to encourage the use of public transport
- Using road pricing tools to restrain traffic and
- Construction of ring roads and bye-passes to reduce traffic in town are some measures to mitigate emission in the city .Kadiyali, (2014).

Table 2.5: Indian National Ambient Air Quality Standards

Pollutant	Time Weighted Average	Concentration in ambient air	
		Industrial, Residential ,rural and other area	Ecological sensitive area
SO_2 (µg/m^3)	Annual* 24 hours** 1hr	50 80 -	20 80
NO_2(µg/m^3)	Annual* 24 hours**	40 80	30 80
PM10(µg/m^3)	Annual* 24 hours**	60 100	60 100
PM2.5(µg/m^3)	Annual* 24 hours**	40 60	40 60
Ozone(µg/m^3)	8 hours** 1 hour *	100 180	100 180
Lead(µg/m^3)	Annual* 24 hours**	0.5 1.0	0.5 1.0
CO(µg/m^3)	Annual* 24 hours**	2000 4000	2000 4000
Ammonia(µg/m^3)	Annual* 24 hours**	100 400	100 400
BENJENE (µg/m^3)	Annual*	5	5
Arsenic(µg/m^3)	Annual*	6	6
Nickel(µg/m^3)	Annual*	20	20

*Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Source: National Ambient Air Quality Standards, Central Pollution Control Board , 2009

2.3.17 Road Traffic Injuries

Motor vehicles endanger the safety of many pedestrians. In most of the accident pedestrian, cyclist and motorcyclist are the victims. According to (WHO, 2018) road accidents account for 1.35 million deaths globally every year. (NCRB, 2007, Mohan ,2009) say that 1,14,444 people died in road accidents in India in 2007. This number increased to 1,37,423 fatalities and 469,900 injured in road mishaps in 2013 (Singh, 2017,NCRB,2013).In last ten year fatalities have increased by 5% per year. All over the world India is the only country which faces more than 53 injuries and 15 fatalities every hour as a result of road crashes (Singh, 2017). WHO (2008) reports that if initiatives or efforts are taken the figures of road accident deaths will reach 250,000 by 2025. BY 2030 road related deaths will be the third highest cause of overall death and the will account for approximately 5% of global disease burden.

Singh (2017) analysed that though the population of the country has increased at the rate of 1.4% every year but the rate of accidental deaths has increased by 5% in the last 10 years. Fatality risk in India is rising from 7.9 deaths per 100,000 in 2003 to 11.2 in 2013 (Singh, 2017). Fatalities increase with increased motor use and higher speeds & violation of traffic rules. Usually, fatalities are more in the peripheral areas, than in the city centers in India, especially pedestrian fatalities (Nguyen & Taneerananon ,2012). Human errors are the main cause of traffic accident, where driver fault account for 78% of total accident and 76.5% of total injury. Age and gender is another factor for accident Singh (2017) mentioned that number of male fatalities has increased by 64.3% while female fatalities are increased by 53.1% during 2003-2013.

2.4 Sustainable Transport Strategies

2.4.1 Integration of Transport and Land Use

The relationship between urban transport and land use has long been recognised. The urban structure and form affects the need and selection of transport system. It is necessary that transport planning and integrated land use go together according to National Urban Transport Policy (NUTP, 2014)

Hickman and Banister (2005) suggest the use of integrated land and transport planning, with an emphasis of the reduction of car use. A mixed land use development and transport strategy combined will reduce travel demand and trip length and further with supportive compact urban form of city, reduces the travel demand (SUTP Toolkit MoUD, 2013) . In order to achieve a sustainable transport the influence of landuse planning and transport supply and commuter behavior have to be understood thoroughly (Furlonge & Cudjoe (2017). According to study of

Gupta (2010), where he elucidates that emission is directly proportional to urban radius.i.e compact city is good for low emission. Good land use planning can reduce the need for highway expansion and increase focus on sustainable transport and healthy lifestyle **(**Litman 2011, Litman 2016).The benefits of land use transport integration are; reduction in travel length , reduced vehicle dependence and encourage PT and NMT ,improved access to job and facilities, reduce GHG /pollution and at last affect land value and affordability. As per Naess et al (2019) workplace are responsible for car choice means if the job is in CBD, the public transit is preferred as it take less commuting time and for jobs in peripheral areas employee prefer to use car.

2.4.2 Transit Oriented Development (TOD)

Transit oriented development is defined as high density mixed land-use development near the transit station. The concentration of high density development near the station makes transit more accessible and encourages ridership Tong et al. (2018) expressed the correlation between transit oriented development, land use catchment area and surrounding environment. Figure 2.5 depicts the concept of Decentralized: the work areas are distributed to mitigate the demand for transport. At the same time the length of the trip is also reduced considerably and encourages use of public transport. All the major center shopping and hospitals should be near to transport route that reduce the travel length

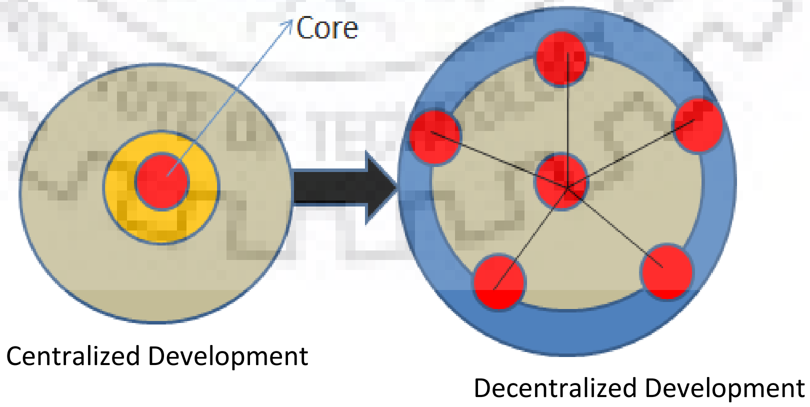


Figure 2.5 :Concept of Decentralization

Reduced trip length and travel time in turn leads to lower pollution including lower GHG and particle emissions. It is estimated that by implementation of TOD approximately 27 million car trips per annum have been reduced due to the modal shift to the BRT and around 2.1 million passengers travel on BRT route daily (ICLEI, 2011). Gunnarsson & Löfgren (2001); Pushkarev et al. (1977); Ewing and Cervero, (2010);Dou et al. 2016 believe that urban densities have strong influence on transit ridership, whether for rail systems or bus-based. That's why transit should be provided along high densities or mixed land use (Cervero & Dai, 2014) and transit should be at 5 to 10 minute walkable distance. Cervero (2014) expressed that BRT Ahmdedabad and BRT Bagota have failed to leverage TOD, so to improve the effectiveness of TOD,implementation tools were used Ann S. (2019) applied an approach of multimodal last mile connectivity when explore the TOD as urban planning.

2.4.3 Travel Demand Management

The main aim of Travel Demand Management (TDM) is to optimise the efficacy (GTZ, 2009) of the urban transport systems by reducing the use of unnecessary private vehicles and introducing more effective, environment friendly and healthy modes of transport, i.e. public transport and non-motorized transport.

It is in order to increase the efficiency of transport systems and achieve specific planning objectives linked to sustainability of mobility systems. (VTPI, 2011) and to understand the pattern travel behaviour in urban environment trip distribution models are used. (Hassan et al. 2016).

TDM measures should motivate people to: shift to transit modes — cycle, rideshare, walk instead of driving; do several things in a single trip, shop online, do telework, shop locally, avoid peak hours or congested routes, drive efficiently. (FCM, 2008)
Typically, TDM measures are implemented with the aim of achieving the following goals:

- Reducing traffic congestion
- Improving road safety
- Reducing energy consumption
- Reducing environmental pollution
- Improving quality of life

- Ensuring equitable distribution of road space

Various studies have been carried out on travel demand management fiscal measures to achieve sustainable goal. Some TDM measures are: vehicle quota system, road pricing and road tax. High fuel and parking pricing, congestion charges, pedestrianisation and bicycle improvement, car sharing and compact land use, high fuel charges etc. are being practiced worldwide.

- Controlling vehicle population has been done by adopting two measures: car usage restriction measures and car ownership restraints.
- Restrict vehicle usage: By adoption of policies used in Singapore such as introduction of:
    - Parking fee,
    - By road pricing
    - Registration fee
    - FUEL tax etc.
- Vehicle Quota System (VQS**)** to control vehicle population: Here the number of new vehicles is predetermined. Prospective owners have to bid for Certificates of Entitlement (COEs) to buy a car**.**
- Giving priority to shared mobility and buses.
- Employers must provide incentives to the employees for using public transport.
- Provide park and ride facility (Buchari, 2015) and integrate the personal or IPT mode to public transport to reduce congestion on roads (Buchari, 2017).

2.4.3.1 Vehicle Ownership Control

Vehicle quota system: This policy has been tried and tested successfully by Singapore. In this policy, the government decides the annual growth in vehicle population for each category of vehicles and then releases monthly quota (suppose the number of cars allotted for a month is X) of new vehicles that can be added on to the roads which then bided. Price is determined by the bidding market and the bidding is open. Car owner aspirants would then bid for the license to own the car; the top X bidders are then selected and asked to pay the lowest bid (quota premium) among them to obtain the license to own a car. Only if you have this license can you buy a car and register it.

In Singapore (Lee, 2009), person has to pay additional taxes and fees to buy a vehicle i.e. Total Cost of vehicle **=** Open Market Value+ Good and Service Tax + Import Duty + Registration Fee; **+** Additional Registration Fee + Annual Road Tax + Certificate Of Entitlement

This measure will discourage the vehicle ownership to great extent. The government fixed the number of COEs (certificate of entitlement) is valid for 10 years only; while the price is determined by the market. (i.e., "Vehicle Quota System" (VQS)) (Lee, 2009).

Tax : Many cities have adopted higher taxation to control vehicle growth by increasing the cost of owning a car. These taxes are in different forms in different cities and they are explained below.

Registration fees: Registration is generally a one-time process that identifies you as the person legally responsible for your vehicle. A registration fee comprises the registering fee of a vehicle. Hong Kong have first registration fee and in Singapore vehicle owner has to pay additional registration fee.

Road tax: Road tax is basically a tax that you have to pay for a motor vehicle before you can use it on the public roads

Car Acquisition Tax: This is a form of tax that is adopted by the Japan government where regardless of whether the car is new or second-hand, acquisition tax is charged. This tax is paid along with the registration of the car. Nearly 5% of the cost of the car comprises of acquisition cost. The payment of this tax is compulsory and without which you cannot register your vehicle.

Car Weight Tax: This is a form of tax that is adopted by the Japan government where the tax is paid after a mandatory automobile inspection once every two years. The amount of tax to be paid is directly proportional the weight of the car. The weight tax for cars with engine sizes up to 2 litres is about 56,700 yen. The payment of this tax is compulsory and without which you cannot register your vehicle.

Fuel taxes: A high fuel taxes can be imposed to discourage excessive use of vehicles and encourage fuel conservation that may contribute to congestion and pollution. In many countries road taxes have been kept high to discourage car use for environmental causes.

2.4.3.2 Vehicle Usage Controls

These policies/ measures aim to control the usage of private vehicles on the roads by altering the travel behaviour of motorists by different methods like congestion pricing, area licensing, electronic road pricing, shared mobility. The basic concept behind this is that you pay for using the road space. In area licensing, vehicles purchase a license when operated within a defined area. In road pricing, it is basically pricing which charges vehicle users for using/passing through a certain route or using a specific road way. Shared mobility is another alternative to cut down the share of personal vehicles. There are some policies which stimulate the travelers to optimize the usage of car, shift to public transit mode and therefore protect the environment in return.

a) Area licensing scheme (Singapore)

It is a road pricing scheme where each car is charged which gives contribution to the congestion in central business district (CBD).It is based on cordon pricing where daily a licence was required of cost S$4 to enter into restricted vicinity. This was a manual paper based, where observers/ officers have to verified licence manually at the entry posts..At the same time, to discourage the use of private vehicles (car) in the restricted zone, parking charges was raised and additional surcharge was levied on private parking operators to discourage car use (Dhakal, 2002). Apart from congestion the major advantage of ALS was on energy saving and air pollution reduction.

b) Road pricing in Singapore

After ALS in Singapore, the manually operated Road Pricing Scheme (RPS) was first implemented on 1 June 1990 along congested sections or 3 major expressways (Menon & Guttikunda, 2010). The scheme was introduced at congested points outside the restricted zone. Major drawback of ALS and RPS are, both are manual so it has major chances of error and there is big rush after restricted hours.

c) Electronic road pricing (ERP) (Singapore)

In 1998, these 2 schemes were transformed to an electronic scheme called Electronic Road Pricing: Under the proposed system, the rate that the motorists to be charged for using each road section would be dependent on the congestion level of the road section. It is hoped that such a pricing system will help to reduce the congestion level and discourage the travel by private cars, and by choosing less congested road sections, thereby optimizing the utilized capacity of the road network. (Menon & Guttikunda , 2010; Rizal et al. 2018).

Through the use of sophisticated technology, time and spatially varying charges is possible reflecting the true cost of vehicle uses in central business districts using electronic gantries at the entry points to the cordon area and in-vehicle units. This system uses short wave radio frequency link between ERP gantry and In-vehicle Unit, which deducts the charge automatically from your smart card (Cash Card). Charges are different for motorcycles, cars, good vehicles, taxies and buses etc. and therefore different IU units are installed in each category of vehicles.

d) Congestion charge (London)

The charge was imposed for driving or parking vehicle on public roads within the congestion charging zone at the centre of London (22km^2) between 7:00 a.m. and 6:30 p.m. from Monday to Friday. Payments for entering into the charge zone are paid in advance, on a daily, weekly, or annual basis, or on the day of travel. A variety of payment modes are available, including retail outlets, kiosks, by telephone, over the Internet, and by text message using cell phones. Individuals submit their vehicle registration number when paying the congestion charge and this number is then entered into a database for trips within the charging zone (Leape, 2006). A network of video cameras within the zone record the licence plate numbers of vehicles entering, leaving Litman (2011).Similarly Seoul, Korea introduced congestion charge on 2 main roads in Seoul as a means to reduce the congestion in the roads leading to the CBD. HOV (3+), buses, taxis and trucks are exempted from the pricing and this led to increased use of carpooling, buses and taxis. Sydney, Australia: Sydney has zero parking requirements in its office buildings in the CBD area compared to the non-central areas61 to reduce the number of car trips.

e) Priced parking and time limits for parking

The pricing of parking in on street residential areas and on street and off street parking, public buildings, etc. in the urban areas can help increase the cost of using a car and discourage people from using cars. Cost-based parking pricing typically reduces vehicle trips 10-30% compared with unpriced parking.

f) Shared mobility

Shared mobility is referred as short term access to transport mode on “As needed” basis. It can be classified as; car sharing, scooter sharing, bicycle sharing, on demand ride services etc.as per study on shared mobility in Delhi 29% of vehicles reduction has been observed after shifting to shared mobility. By which 426 kg/km of CO and 1262kg/km of PM emission reduction has been observed in a year (Roy & Gupta 2018).The main issues in shared mobility are safety and waiting time. Causes of these concerns, women are less inclined towards shared mobility.

2.4.4 Improvement in Vehicle and Fuel Technology

The technology Improvement in engine design of two wheeler “replacing the 2 stroke engines with 4 strokes” will make the automobile environmentally cleaner and energy efficient as well. Various studies envisaged that use of alternative fuel like compressed natural gas (CNG), liquid petroleum gas(LPG), solar energy, electricity and synthetic liquid fuels derived from hydrogenation of coal, proved to be less air polluting and energy efficient. According to CSE, 2010 the CNG vehicles give various health benefits and reduce emission in Delhi and Mumbai.

2.4.5 Provision of Non-Motorized Transport and Bicycles

According to Singhal (2010), walking is the most sustainable mode of commuting. It does not consume fuel, causes no air and noise pollution and is good for environment and health. A study of 30 cities in 2008 indicates that on the average, almost 28% are walking trips and 11% are bicycle trips. However, walking and cycling are in a decline due to growing city size, increase in trip lengths and safety concerns. According to the studies, there are 45 million cycles in India against 1.5 million cars. The ratio is 1:30, but in term of its transport contribution, it is meagre as compared to other cities in China, where 80% of the trips are by bicycle (Luthra ,2011).It is flexible and accessible to narrow streets.

NMT play an important role in transportation of goods in city and core commercial area. However increasing vehicular growth, congestion and parking space constraints hamper the movement of NMT (Gupta, 2017). Integrated urban transport solutions should make provision for non-motorized transport infrastructure together with dedicated bikeways, pedestrian zones and walkways, segregated cycle paths, and bicycle parking and rental programs (Jain,(2009), Shrivastava et al. (2011). Cycle stand are provided near transit stops and shopping area. Secured and shared bike service are provided in many countries as shown in Figure 2.6,2,7 & 2.8)

Figure 2.6:Secured and Shared Bicycle Services at Guangzhou, China

Figure 2.7 : Secured and Shared Bicycle Services at Hangzhou, China

Figure 2.8: A Shared Bicycle System in Seville, Spain

Figure 2.9: On-street parking facility, Ahmedabad, India

Figure 2.10: Bicycle lanes installed near Lajpat Nagar Metro Station, New Delhi

Figure 2.11: Separation of Bicycle and Pedestrian Space

2.4.6 Improving Public Transport

Promoting public transport system in cities through introduction of world class transportation system like MRTS, LRTS and BRTS in the cities to make it attractive for the single vehicle users. By having a quality public transport system which sustains the transportations need of all commuters and which offers a viable alternative to cars is desperately needed in cities. This move will go a long way in the reduction of vehicular emission and energy requirement to a great extent (Jain, 2009). By moving more people with fewer vehicles, public transportation can reduce greenhouse gas emissions.

2.4.6.1 BRTS: Bus Rapid Transit System

"Bus Rapid Transit System" (BRTS) can be defined as innovative, ,flexible , low cost high capacity public transport solution to improve the urban mobility rapidly(Levinson et al. 2003) and offer a promising future by providing many advantages like less fuel consumption, lesser congestion n lesser pollution.(Kadiyali,2014) .Bus Rapid transit system (BRTS) is an exclusive dedicated lane with intelligent transportation system and off board fare collection for buses .It could be at median or on left side. If it is median then station or stop can be built in the median. BRT systems also commonly include: (Swamy et al. 2019;Deng et al.2011).

- Means of quick boarding and alighting
- Efficient fare collection
- Comfortable Bus stops;
- Integration of modes;
- Customized marketing identity;
- Excellent customer service

The first Bus Rapid Transits started in Curitiba, Brazil in 1974. By1990s, the model gained acceptance in Quito, Equador (1996), Los Angeles USA (1999) and Bogotá, Columbia (2000). The Transmilenio project of Bogotá flagged off in in 2000 was a huge success and drew attention of the world as an example of the state of the art BRTS shown in Figure-2.13. Figure 2.12,2.14,2.15,2.16 give a glance of BRTS in Curitiba, China, Beijing etc.

Figure 2.12 :Curitiba Metrobus –Tube Station

Figure 2.13: Bagota Transmilenio-Median Busways and Station

Figure 2.14: Guangzhou (China) BRT

Figure 2.15 : Beijing ,Median Bus ways

System.

Figure 2.16 : Accommodate Physically Handicapped

a) Bus Rapid Transit System in India

In India eight cities (Delhi, Ahmedabad, Bhopal, Indore, Jaipur, Pune, Vishakhapatnam, Hyderabad and Nagpur) have implemented BRTS. Kumar (2011) & Kumar (2009) discussed the driving pattern in Delhi BRTS and evaluation of emission by different categories of vehicles. Shihora, 2018 evaluate the performance of various BRTS in Indian. Figure 2.17, 2.18, 2.19, 2.20 show the present operating BRT system in India.

Figure 2.17: Ahmedabad BRT

Figure 2.18: Ahmedabad's Janmarg system is one of the top BRTs in the world.

Figure 2.19: Pune BRT

Figure 2.20 : Low Floor Busses in Bangalore

2.4.6.2 CNG Buses

CNG based Low Floor busses with ITS features like: LED Sign Board, audio visual passenger information, GPRS smart card ticketing machine. Delhi has largest CNG Bus fleet in the world.

2.4.6.3 Light Rail Transit (LRT)

(LRT) is referred as urban rail public having low speed and low capacity than heavy rail and metro systems, but it has high capacity and speed than traditional street-running tram systems or BRT System. The light-rail trains run on electricity. LRT is popularly known as tram. It is relatively cheaper than conventional suburban rail system. Some of the cities which have LRTS are: Boston, Buffalo, New Orleans, New York, Philedelphia, Sanfranssisco, Montreal, Toronto, Singapore, Oslo etc.

Kolkata tram system is the only tram system presently running in the India. Calcutta Tramways system (CTC) started operating electric trams from 1902 in India. Presently there are 125 Tram vehicles runs in the city. It uses 550 DC Overhead catenary for supply.

Figure: 2.21-Kolkatta Tramways

2.4.6.4 MRTS (Mass Rapid Transit System)

MRTS means of rapid transit along high density corridors. They can be elevated ,on surface or underground(Tang,2016).The system originally used light rail vehicles but has the characteristics of a rapid transit system and later on upgraded to a medium capacity system. In 1987, Mass Rapid Transit in Singapore opened. It was the world's first heavy rail system. Surface rapid transit plays the main role in Bombay, Chennai and Delhi. The lines are electrified. In Kolkata 16.4 km long underground system has been built from DumDum to Tollygunge. (Kadiyali 2014). India is looking to create a world class infrastructure with its existent Kolkata and Delhi Metros with the addition of Mumbai, Bengaluru, Hyderabad, Chennai, Jaipur, and Kochi metros in the next few years while proposals for MRTS for Pune, Chandigarh, Ahmedabad, Kanpur, Ludhiana, Bhopal, Indore and Faridabad are being chalked out. India is looking to create a world class infrastructure with its existent Kolkata and Delhi Metros with the addition of Mumbai, Bengaluru, Hyderabad, Chennai, Jaipur, and Kochi metros in the next few years while proposals for MRTS for Pune, Chandigarh, Ahmedabad, Kanpur, Ludhiana, Bhopal, Indore and Faridabad are being chalked out. The Table 2.6 presents the comparative analysis of metro project from different level.

Table 2.6: Comparative Analysis of Metro Project from Different Level

Sl no	Mode of transport	Capacity PHPD*	Project time Estimate	Approx. cost(Rs.Cr /KM)	Approx user fee/km
1	Metro underground	75000	5-6 years	500	3.5
2	Metro elevated	75000	4-5 years’	250	3.5
3	Metro surface	75000	4-5 years	100	2.5
4	monorail	25000	2 years	125	3.0

*PHPD: Per hour per direction at three- minute frequency

Source: The Economic Times on 23 Feb, 2012)

It can be observed from the above Table 2.6, the cost of construction in case of Metro rail on surface is significantly lower than Metro at elevated and surface level therefore the preference shall be given for this option and it will enable the government to provide more coverage at low budget. (Singh, 2016). The 10 best metro system in the world are Athens metro, Seoul metropolitan subway, Stockholms tunnel rail, Mooscow metro, Tokyos subway, New york city MTA, Paris Metro, Singapore MRT, Hongkong MRT, London underground etc. The metro system with the longest route length is the Shanghai Metro; the busiest one is the Beijing Subway; and the one with the most stations is the New York City Subway.

2.4.6.5 Personal Rapid Transit (PRT)

PRT is most environment friendly and energy efficient alternative to current public transportation so far (Singh, 2017). It also referred as automated pod cars which are operated in a network on dedicated guide ways with docking station to get in and get off. These guide ways can be suspended or on ground as shown in Figure 2.22 and Figure 2.23 and may form linear routes and network of loops.(Vibhuti,2009). It provide on demand service like taxi for individual user and small group of people (2-6 person) .It gives benefits of both public and personal transportation . PRT vehicle are computer controlled driverless vehicles runs at the speed of up to 40 -60 kmph and use a network of magnet embedded in the ground to navigate from point to point or can be suspended 4-10m above the ground from overhead rails .It is very flexible and lightweight system which can construct at low capital cost.

Figure 2.22: Suspended Pod

Figure 2.23 : Heathrow Rapid Transit System on Ground

The main benefits of this alternative are

- Reduce congestion
- Reduce accident
- Reduced travel time as it doubled the speed
- Provide safety and comfort than normal cars
- Reduce risk of assault as it is point to point service with no intermediate stoppage and under the surveillance of video camera inside and outside of pod.
- Require less road space for installation and operation.
- Reduce environment pollution as vehicles are electric and quiet.
- Driverless on demand operation service.

A research on alternative transportation methods was conducted by Don Fichter in 1953; thereafter concept of PRT has evolved (Anderson, 1996). In 1975 an operational PRT system was first introduced in West Virginia University in Morgantown, USA(Anderson, 1996). After 2011 when PRT operations began at Heathrow Airport Terminal 5 PRT got real existence (Sarkar et al. 2013). Since then the potentials of PRT system has realized and considered for public transport planning studies in various cities around the world. And slowly it is getting popular in Indian cities also to cope up the travel demand and traffic issues and challenges.

As of February 2016, – Masdar PRT, Heathrow PRT and Suncheon PRT are three modern PRT systems are operational worldwide (Gustafsson et al., 2013; ATA, 2016). In addition to these, some PRT are announced in India at Amritsar, Dwarka, Gurgaon, Varanasi etc. (Ultra Fairwood, 2009; Ultra Global, 2014; Jain, 2016 & Jain, 2017). Some successful operational PRT systems are described below.

a) Morgantown Single Mode PRT

This is the oldest Operated by West Virginia University in 1975; it connects the university's two campuses with downtown Morgantown. It is 13.2 km guideway with 5 stations. vehicle are having capacity of 20 perrson(8 seating and 12 standing)(Agarwal, 2011).

Figure 2.24: West Virginia University, Morgantown, PRT

b)The Heathrow Airport PRT (Agarwal, 2011)

The Heathrow PRT was commissioned in year 2011 with 3.8 km guide way at the Heathrow airport in London, UK, shown in Figure 2.25. Here 21 vehicles are operating to connect Terminal 5 of the airport to the business car park.

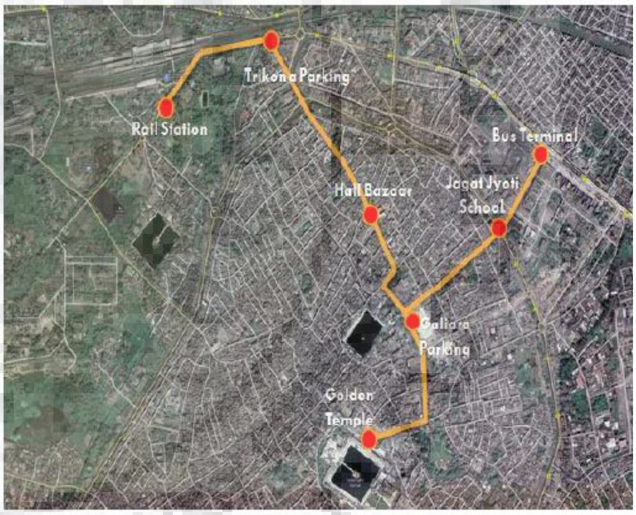
Figure 2.25 : Ultra layout for PRT system at Heathrow airport

c)Masdar City PRT, Abu Dhabi

Masdar city is designed with no fossil fuel cars. The city is pedestrian friendly with PRT for long distances.(Figure 2.26) The PRT is introduced in 2010 .It is 1.4 km long PRT provide connectivity to Masdar Institute of Science and Technology (De Graff, 2011,Courtesy of 2getthere)

Figure 2.26 : Masdar City P

d) PRT AMRITSAR *(Source: Ultra Fairwood Green Transport. (2009)*



This is the first urban PRT project in India. The Figure 2.27 represents the proposed 8.6 km long elevated guide way stretch with 7 intermediate stations. It focuses on taking daily tourist passengers from bus and railway stations to golden temple.

Figure 2.27 :PRT Amritsar

e) PRT Dwarka New Delhi (Jain ,2016; Jain,2017)

Recently a 18 km long stretch Gurgaon border-Rajiv chowk-Sohna road is proposed (Ref.Figure 2.28).It take I minute per docking station and 1100 pods are proposed with 5 person carrying capacity.

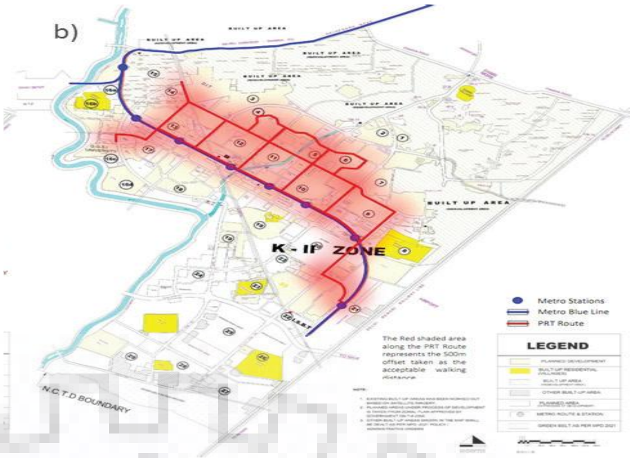


Figure 2.28 : Proposed PRT Route in Dwarka , Delhi

2.4.7 E- Mobility

E mobility is identified as Low Carbon environmentally friendly tool in Indian cities. Norway ,Netherland, Sweden, France, United Kingdom, US and China holds 6.39%,6.39%,1.46%,1.41%,0.91%,1.37% market share of EV respectively.(Gupta & Saini (2018).Currently EVs sales are low in India i.e only 22,000 units by the end of march 2016 .National Electric Mobility Mission Plan (NEMMP) ,2020 was announced in 2012 by the Government of India in order to mitigate the adverse effect of road transport on environment. Its target is to deploy 5-7 million electric vehicles in country by 2020. And lowering the carbon emission 1.3 % by 2020 (Pandit & Kapur ,2015). As per NEMMP, (2013) and NITI Aayog, (2017), all vehicles in India will switch to electric vehicles by 2030.

E-rickshaw has become an integrated part of urban mobility and provides last mile connectivity. Battery driven vehicles are more preferable than other IPT mode.(Rahim, (2013).It is environment friendly, reduce unemployment problems. It acts as feeder for PT and alternative to IPT and mode of transport for tourist places. In the last few years the number of E-rickshaw are rapidly increasing. Due to unplanned and unregulated system it creates congestion on road. Shukla et al. (2014) discuss the reduction of carbon in different electric vehicle scenario with comparison to BAU. Which reveal that CO_2 emission would increase 4 fold during

2010-2035 and by introducing EV , a reduction is achieved in carbon emission By using the solar powered electric vehicles (SPEA) (Reddy et al. 2017) the CO_2 emission can certainly be mitigated instead of conventional vehicles.

Singhal et.al. (2018) discussed the efficient way of management of E rickshaw which focuses on users safety and convenience.to ensure this vehicles should be Radio frequency identification (RFID) and Global positioning System (GPS) equipped. Thakur, (2018) estimated the emission by auto rickshaw plying in Bengaluru. And solar based hybrid engine driven vehicle feasibility analysis has been carried out in Bangladesh (Malik ,2017).Which reveals that EV is more environment friendly vehicle as compared to conventional vehicles. Various studies on electric vehicle operation in Delhi, Udaipur, Siliguri, Bangalore, and Kakinada, Bangladesh has been carried out and expected to grow in near future.

In order to encourage the E- mobility In India, urban planners need to evolve planning norms and standards for provision of charging station like any other physical infrastructure. To increase the sale of EVs, incentives has to be given to costumer in terms of exemption for road tax, purchase tax, registration charges and concession in income tax etc. (Gupta & Saini , 2018).

2.4.8 Pedestrianisation

Pedestrianisation is removal of vehicles from the streets. According to Hong Kong transport department pedestrian was defined as to restrict the vehicle usage to a street or area for pedestrian mobility (Nasim,2008). According to Nasim (2008), the pedestrinisation put impact on 3 sustainable dimension like environmental economic and social. It reduced the air and noise pollution by reducing the motorized vehicles in the area and further reduced fuel consumption as well. It increased pedestrians' safety and gave freedom to shop leisurely and enjoy without fear of vehicles. By promoting walking in the area it provide various physical health benefits and street scape encourages people for social activities. (Nasim , 2008).

2.4.9 Transport System Management

Jain,(2009) proposed various low cost TSM techniques to address urban transport problems .These solution include traffic signal management, carpooling, parking policy, park and ride policy, segregation of office hours and school hours, fixed carrying capacity of road. And better traffic monitoring and information to reduce the congestion, accident and at last improve environment quality too.

2.5 Carbon Emission Estimation

The estimation of CO_2emissions and other emissions related to transport infrastructure projects with different perspectives have been adopted in past literature studies. Transport modeling and an emission inventory provides a useful means to assess and simulate the dynamics, scale and magnitude of transport-related emissions and evaluating policy choice (Tiwari et al. 2011; Linton, 2015; Mishra et al. 2012; Kumar & Mishra, 2017) for air quality management .Grover et al. (2013) studied the reasons behind the increase in CO_2 emissions in transport sector in Asia. Many researchers (Krantz, 2017; Mishra et al. 2016 ; Shukla et al. 2010 ; Mishra and Goyal, 2015) predicted and assessed the emission of different pollutant from various categories of road vehicles by using emission models.

2.5.1 Available Approaches and Models

There are number of vehicle emission models which are available in developed countries to predict emission based on available vehicle type, fuel type, emission standard and vehicle kilometer travelled and various correction factors. All these models are very complicated because these require a huge input data of respective region. Application of these models in India is difficult due to non-availability of data (Nagpure, 2013).Some of the model available in various countries and region for emission estimation from transport sector are mentioned in Table 2.7.

Table 2.7 : The Models Available in Various Countries for Emission Estimation

Sl. No.	Transport emission model/methodology	Issue year	Country area	Organization	Soft-ware	Field	Reference
1	MOBILE 6	2004(first version 1978)	USA except California	US environmental protection agency(USEPA)	Y	Predict gram/ mile emission	Brzezinski and newwll,1998
2	Intergovernment alPanel on Climate ChangeIPCC	2006	Internatio nal	IPCC	Y	Emission inventory	IPCC,2006
3	Computer program to calculate emission from road transport COPERT 4	2007	Europe	Europeon Environmental Agency	yes	Calculate road emission	Bellasioa et al.,2007,
4	Emission Factor Model EMFAC	2007	USA	California air Resources Board(ARB)	y	Emission rate	EMFAC, (2007)
5	MOVES	2010	USA	(USEPA)	y	Replace mobile 6	
6	International vehicle emission model (IVEM)	2008	Internatio nal	USEPA	y	Emission estimation	IVEM ,2004,Guo et al,2008, Goyal et al.,2013
7	Vision model	2009	USA	Argonne national laboratory	Y	Emission forecasting	
8	Transport emission evaluation model for project (TEEMP)	2011	Internatio nal	Clean Air Asia &ITDP	Y	Project based emission analysis	Replogle et al.,2011

Although there are other methods (e.g., inverse modeling), as suggested by IPCC (Intergovernmental Panel on Climate Change) (IPCC, 2006). The top down approach during national communication of Gov. Submitted to UNFCCC used the following Equation 2.1.

Emission = Activity data X Emission factor…………….Eq (2.1)

Where fuel consumption is activity data and the mass of CO_2 emitted /unit of fuel consumed is the emission factor. REGMIF (2010) used this approach to calculate the CO_2 emission by modal shift. The bottom up approach (Schipper et al, 2009, Replogle et al.,2011) has been described by many authors as following Equation (2.2).

G= A x Si x Ii x F i,…………………………..Eq (2.2)

Where , G is the carbon emissions from transport, A is the total; activity of passenger travel in passenger km(Pkm)or vehicle km (Vkm), Si is the modal structure which is percentage share of PKm or Vkm by each travel mode, Ii is the model energy intensity inl/km or l/PKm and Fij is the carbon content of fuel in g/l of g/Pkm. Land use and form of city, income have an effect on travel distance or transport demand. Doll (2013) estimate the environmental co benefits of transport sector in Delhi. Sharma & Gangopadhya (2007); Sharma et al (2010); Sharma et al (2014) & Kumar (2009) also used the bottom up approach methodology for estimating emission load developed by CPCB as mentioned in Equation 2.3.

P(i , y) = ∑ (j) ∑(ky) N(j, ky).L.DF(i, j, ky) EF(i, j, ky).365.10^{-6} ………..Eq (2.3)

Where,

P(i, y)	=	Annual emission of pollutant i in the year Y(t/year)
N(j, ky)	=	No. of vehicles of a particular type j and age ky i the year y (Avg daily traffic)
L	=	Length of the corridor
DF(i, j,ky)	=	Deterioration factor for component i in the vehicle type j, age ky in the year y (dimentionless)
EF(i, j ,ky)	=	Emission factor” for component i in the vehicle type j, age ky in the year y (gm/km)

i	=	Pollutant component(CO,HC,PM,NO2)
J	=	Type of vehicle (2W,3W,4W,bus,truck)
Ky	=	Age of vehicle in year y

Nagpure and Gurjar (2012) have developed a Vehicular Air Pollution Inventory (VAPI) model to quantify the vehicle emission. Emission factor and vehicle utilization factor based approach as recommended by IPCC (2006) have been used for estimating emissions. A spreadsheet model (Microsoft Excel 1997/2003/2007) has been used for calculating emissions from transport sector using Equation 2.4.

$$Ei = \sum(V_{ehj} \times D_j) x\ Ei, \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq.(2.4)}$$

E_i = Emission of pollutant (i), Veh_j = Number of vehicles per type (j), D_j = Distance travelled by per vehicle in per year or vehicle utilization factor (j), Ei,j km = Emission of pollutant (i) from vehicle type (j) per driven kilometer. Nguyen (2011) predicted CO concentration in different scenario would be calculated by Urban Air dispersion model. To evaluate the air quality impact under different scenario the highest value of CO average hourly concentration in different scenarios were compared with BAU scenario and National air quality standard. By this we can frame the impact matrix which provides a quick indication of the problematic area to decision makers. Nguyen, (2011). Cities account for nearly 75% of the world energy consumption and contribute more than 80% to global GHG emission; therefore they attract initiatives aimed at energy conservation and reduction of emission. . Geurs & Wee, (2010) investigated 2 scenarios: business as usual (BAU) and environmentally sustainable transport (EST) to develop a sustainable transport scenario where they find an emission reduction of 80-90% by a back casting tool. EST is actually a back casting scenario.

Air pollution caused due to transportation activity can be mitigated by BRTS (Vincent, & Jerram, (2006). Change in fuel type and vehicle technology, improved public transport, pedestrian way and crossing. Grover (2013), Yedla & Shrestha (2003**)&** Shrivastava, (2011) identified some simple measures like banning of fossil fuel vehicles in identified areas, traffic signal synchronisation, correcting conflicting signals, improved tramcar services, parking, shifting junction of arterial road to main street, halting point of public vehicles etc. can reduce substantial emission in the city. Bhargava et al. (2018) estimated the emission from road transport in Chandigarh city using Vehicular Air Pollution Inventory (VAPI) model in two scenario; Business as usual (BAU) & Best estimated scenario (BES), which evolved that by transforming 30% private transport to public transport, 520Gg GHGs emission would be reduced. Wöhrnschimmel et al. (2008) measured the emission of different pollution before and after implementation of Bus Rapid transit (BRT) in Maxico city to evaluate the exposure of commuter to different pollutant.

2.6 Impact Assessment Tool

Sustainability indicators and composite index are increasingly recognized as a useful tool for policy making and public communication in conveying information on countries and corporate performance in fields such as environment, economy, society, or technological improvement. Environmental analysis of projects/ programs/ plans needs to be carried out before implementation to ensure that it will not in any way harm the environment on a short or long-term basis.

2.6.1 Environment Impact Assessment (EIA)

Environment impact assessment (EIA) was developed in the 1970s as a tool to assess and reduce adverse impacts on the environment caused by projects. Environment impact assessment (EIA) is the process of identifying and evaluating the potential impacts of the proposed projects on the environment prior to decision making. Canter (1996) defines EIA as "the systematic identification and evaluation of the potential impacts (effects) of proposed projects, plans, programs or legislative actions relative to the physical, chemical, biological, cultural and socio-economic components of the environment. It has been mainly performed by experts in social engineering, environmental law, ecology or in the use of specific impact-prediction technologies.(Nishikizawa, (2015).The three basic components (UNEP, 2002) of an Environment impact assessment (EIA) exercise are:

1. Establishment of environmental, socio-economic, and public health baseline data for the project site before construction.
2. Prediction and evaluation of potential – direct and indirect – environmental, socioeconomic, and public health impacts of the proposed project.

3. Identification of appropriate alternatives and mitigation measures to avoid, minimize, remediate or compensate for any environmental, socio-economic, and public health impacts resulting directly or indirectly from the project

2.6.2 Strategic Environment Assessment (SEA)

Strategic Environment Assessment (SEA) is different from Environment impact assessment (EIA) in terms of the scale of application and also, in its approach. Ideally, Strategic Environment Assessment (SEA) should be conducted well in advance in order to ensure selection of most environmentally suitable options. EIA, on the other hand, should be conducted at the scale of projects as discussed earlier. Strategic Environment Assessment (SEA) is broader in scope and used for strategic planning while projectlevel EIA addresses specific issues and impacts at specific locations EU commission (2001, 2002). Nguyen (2011) uses Strategic Environment Assessment (SEA) for sustainable transport related air quality process. Here Strategic Environment Assessment (SEA) was applied for an integrated assessment of environment, social and economic impact of wide range of scenario for air quality policies. The ultimate aim of Strategic Environment Assessment (SEA) is integration of environment to achieve the best possible strategic decision (João, 2007). To evaluate the environment impact in term of reduction of CO concentration urban air dispersion Model MUAIR was used as a qualitative tool. The stages involves in SEA process are shown in Figure 2.29.

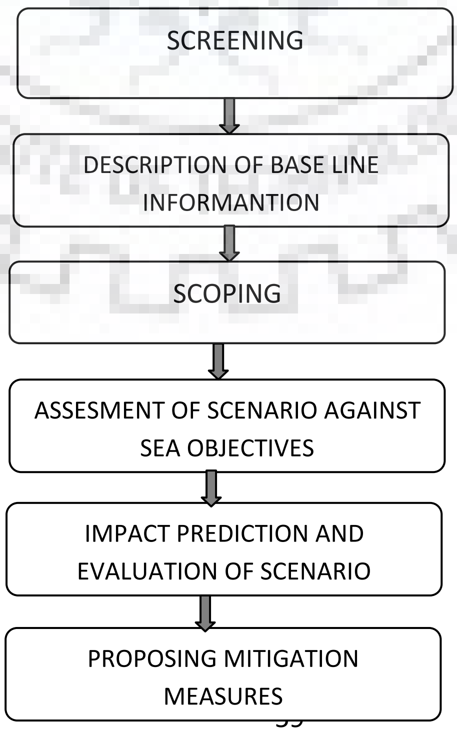


Figure 2.29 ; Stages in SEA

Fischer, (2010) gives a concise and well-structured book of Strategic Environment Assessment (SEA) as it is used today. Sheate, (1992); Sánchez, (2008); Fischer , (2006) used Strategic Environment Assessment (SEA) in the preparation of transport policies, plans and programmes. The logic of applying the principles of Environment Assessment at strategic decision-making levels as well as at project level is clear, especially as project environment assessment alone is clearly inadequate(Sheate, 1992). SEA objective for transport sector mostly refer to both sustainability and environment prediction objective (Duc, 2010).

2.6.3 **Level of Services (LOS)**

Level of services is the benchmarking service level to measure quality of infrastructure and services**.** Benchmarking is an important mechanism for introducing the accountability in service delivery .It can help urban local bodies and agencies in identified performance gap and effecting improvement by sharing the improvement and best practice, ultimately resulting better services to the people(MoUD, 2010) & Service Level Benchmarking Jaipur, 2012).On December,2009, MoUD launched a hand book on service level benchmarking. Service Level Benchmarking, which has advised all JNNURM cities to identified the Level Of Service . Service level/performance benchmark has been identified for the following area of intervention

1. Public Transport Facilities
2. Pedestrian Infrastructure Facilities
3. Non Motorized Transport (NMT) Facilities
4. Level of usage of Intelligent Transport System (ITS) facilities
5. Travel speed (Motorized and Mass Transit) along major corridors
6. Availability of parking spaces
7. Road safety
8. Pollution levels
9. Integrated land use transport system
10. Financial sustainability of public transport

Establishment of level of service (LOS) for each parameter Service Level Benchmarking identified 10 area of intervention. Then indicators are identified for each parameter. Data would be collected against each parameter and its indicator from primary and secondary sources. Analyzed and accordingly the performance of parameter would be assessed to generate the performance report card.

Typically, four levels of service (LOS) have been specified, viz. ‘1’, ‘2’, ‘3’, and ‘4’ with ‘1’ being highest level of service (LOS) and ‘4’ being lowest to measure each identified performance benchmark . Therefore, the goal is to attain the service level 1. Calculate the level of service (LOS) of each indicator and sum up the indicator and calculate the overall level of service (LOS) of each parameter. Parida & Parida (2007) used level of service (LOS) as a qualitative measure for qualitative evaluation of sidewalks. JiweshUjjal & Sinha , (2017) used this to benchmark the safety of highway using road side landuse.

Benchmarking is a widely used method of comparing performances and practices in order to learn from the best. This leads to a range of recommended initiatives to exploit the benefits of benchmarking for sustainable transport policy while avoiding some of the lurking pitfalls (Gudmundsson et al. 2005). There are few drawbacks in the service level benchmarking (SLB), as parameters and indicators for areas with different geography cannot be evaluated using common indicators, Intermediate Public Transport, Street Infrastructure condition and its availability, delay in intersection, which are key factors when evaluating the Urban Transport of any city is

not considered as an aspect by the MoUD. Intermediate Public Transport, Street Infrastructure condition and its availability, delay in intersection, which are key factors when evaluating the Urban Transport of any city is not considered as an aspect by the MoUD.

2.6.4 Scenario Analysis

Several researchers have used scenario planning approaches for examining potential of different mitigation strategies to reduce CO_2 emission in transport sector. Selvakkumaran & Limmeechokchai, (2015), Grover et al.(2013) have used scenario approach to analyze the effect of different policy option aimed at reducing CO_2

emission under annual average growth of passenger km for sustainable development in India.

Scenarios and scenario analysis have become popular approaches in organizational planning and participatory exercises in pursuit of sustainable development. However, they are little used, at least in any formal way, in environmental impact assessment (EIA). It's based on brainstorm session, expert involvement and comprises the assumption of high technology and capacity constraints scenario. Feng & Zhang, (2012) conducted a research on Beijing to predict the effect of different development alternatives on future energy consumption and carbon emission. A long range Energy Alternative Planning (LEAP) Model was built to analyzed the future trends of energy demand, energy Structure and carbon emission from the base year 2007 to 2030 under three scenario: business as usual (BAU), BP (basic policy), low carbon (LC).The result of this study provide insight into Beijing energy future and highlight possible steps to develop a Sustainable low carbon city. Cervero et al. (2009_a) studied VKT and emissions for three situations – current; BAU 2031 and TOD 2031.By this he got the tremendous saving of carbon by Strategy TOD. Selvakkumaran & Limmeechokchai (2015) create cluster of low carbon scenario for Thailand and after assessment of mitigation scenario, during 2010-2050, CO_2 can be reduced approximately 30% in comparison of BAU scenario.

2.6.5. Analytical Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. It was developed by Thomas L. Saaty 1980s and has been extensively studied and refined since then (Saaty, 2013). In planning a variety of discourse involves and social constructs influencing each other (Kumar & Pallathucheril, 2004).AHP is a multi criteria decision support tool which can be used to solve complex decision problems taking into account tangible and intangible aspects. Therefore, it supports decision makers to make decisions involving their experience, knowledge and intuition. Problem hierarchy construction is the first step of the analytic hierarchy process (AHP). The hierarchical structure used for multiple criteria decision problems is typically defined as a decision tree. Typically the first level represents the goal, e.g. for the best alternative selection, the second level includes groups of criteria, the third level includes all decision alternatives as shown in Figure 2.30

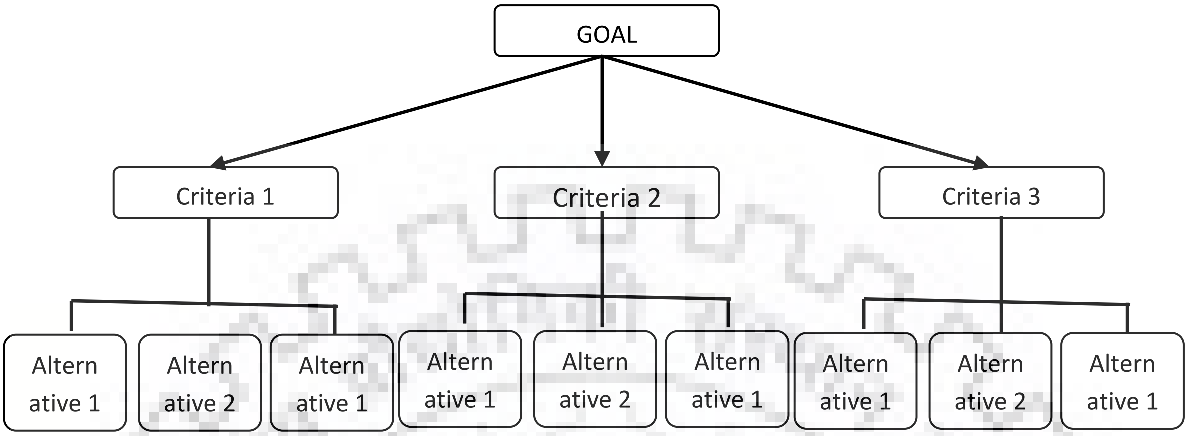


Figure 2.30: Conceptual Hierarchical Framework

1. The level with experts can be also included.
2. Local priorities or preferences developed in the second step of the AHP are calculated using pair wise comparisons. The consistency of these judgments has to be controlled.

   For computing the priorities of the elements, a judgmental matrix is assumed as follows:

$$A = [a_{11} \quad a_{12} \quad \dots \quad a_{1n}$$
$$a_{11} \quad a_{12} \quad \dots \quad a_{1n}$$
$$\dots \quad \dots \quad \dots \quad \dots$$
$$a_{n1} \quad a_{n2} \quad \dots \quad a_{nn}]$$

where a_{ij} represents the pairwise comparison rating between the element i and element j of a level with respect to the upper level. The entries aij are governed by the following rules: $a_{ij} >0$; $a_{ij}=1/ a_{ji}$; $a_{ii}=1$.

Following Saaty (1980, 2000), the priorities of the elements can be estimated by finding the principal eigenvector w of the matrix A, that is: $AW = \lambda_{max}W$

3. Expressing priorities as weights of decision alternatives is the third step. The best alternative selection is then based on synthesis of the weights throughout the

hierarchy. According to the hierarchy structure and AHP software support, the decision-maker can also analyse different results depending on priorities of states of nature or on the criteria.

Piantanakulchai & Saengkhao (2003) used analytic hierarchy process (AHP) in the decision process to reflect social preference. Impacts were estimated by the aid of Geographical Information System (GIS) and analytic hierarchy process (AHP) model developed. Environmental-friendly transport modes has been assessed as the best transport policy to reduce the adverse climate change impacts by Berrittella et al. (2007). Awasthi & Chauhan (2011), dictate an integrated decision-making approach based on Analytical hierarchy process (AHP) and Demster –Shafer theory (DST) for evaluating the impact of transport measures on city sustainability. The approach comprises of selecting evaluation criteria, data collection and information fusion, evaluation of city sustainability using a transport sustainability index (TSI) and Impact assessment of the proposed transportation measures. Sensitivity analysis is conducted to determine the influence of criteria weight in transport decision making. The main strength of this approach lies in its ability to treat heterogeneous, uncertain and incomplete data coming from multiple information sources. They demonstrate this approach by application on transport measure “Car sharing”. Sattayaprasert et al. (2008) used this tool for root prioritization.

Soltani & Allan (2012) has attempted to evaluate a set of travel demand management (TDM) policies and define their priorities through a bottom-up planning_for metropolitan where analytic hierarchy process AHP technique has been applied to find the most preferred policy for study area.

Yedla & Shrestha (2003) examined the impact of including various qualitative criteria for the selection of alternative transportation options in Delhi. Three alternative transport options viz. 4-stroke 2-wheelers, CNG cars and CNG buses are prioritized based on six different criteria-energy saving potential (energy),emission reduction potential (environment), cost of operation (cost), availability of technology (technology), adaptability of the option (adaptability) and barriers to implementation (barrier).This tree is made of three quantitative criteria (energy, environment, and cost) and three qualitative criteria (technology, adaptability and barriers). Each one of the quantitative criteria needs essentially a separate methodology for their quantification and subsequent prioritization. In the present case of hierarchy, alternative options provide the lowest level with criteria as an intermediate level and goal at the top level. As in analytic hierarchy process (AHP), the priorities attributed to the lower level of hierarchy adds to the prioritization of upper levels, prioritization of lower level is carried out first to attribute priorities to the alternative options with respect to each criteria. De Luca (2014) used analytic hierarchy process (AHP) to describe the public engagement in strategic transport planning to give the social sustainability as well. Nguyen et al. (2015) quantifying the complexity of transportation projects using the fuzzy analytic hierarchy process. According to Brozova & Ruzika (2010) AHP method used only the hierarchical structure of decision elements and their expert's preference estimation. Kumar (2015_b) used AHP to assess the sustainability of indicator for transport, feeder services and pedestrians in developing country. Whereas Ngossaha et al. (2017) used Multi criteria decision method to assess the sustainability of transport system with uncertainty. Al-Atawi et al. (2016) developed sustainable transport strategies for Tabuk city (Saudi Arabia) by AHP using travel data from Tabuk city. Where, as per user perception (Al-Atawi et al. 2016) the main aims of the sustainable transport strategy are: enhance environment quality, change travel behavior and shift to more sustainable mode, enforce congestion fee, road pricing and parking fee etc.

2.6.6. Transport Emission Evaluation Model for Project (TEEMP)

The TEEMP City Model, developed by Clean Air Initiatives for Asian cities and Institute for Transportation and development and funded by the Veolia Environment Institute, has been designed to look at long-term city-wide impacts of a combination of project interventions and policies with many transferable default values so it can be applied in cities with sparse existing data. This allows comparison of business-as-usual trends against one or more alternative project and plan scenarios that specify generalized investment types, such as building new bus rapid transit lines vs. building new highways.

The tool is based on the Activity Structure Intensity Fuel (ASIF) framework and although originally designed to measure environmental impacts, it is also able to quantify the current and future impacts of different transport interventions. The other impacts such as PM, NO_X, fuel consumption, traffic fatalities are also quantified (Replogle et al. 2012; Asia C.A. 2012).

2.7 Research Gap in Literature

In this chapter first the understanding of sustainable urban transport system, its challenges and issues of achieving the sustainable transportation system has been discussed. Great deal of literature focus on the unprecedented and unexpected growth of transport activity associated with air and noise pollution etc. which degrade the environment quality and quality of life. Further the literature and research in this domain also presents various sustainable transport strategies in India and worldwide.

There are many researches that explore different impact assessment tools where multi criteria decision analysis method is widely used as a tool to solve the complexity of attributes. However not a single study has been conducted in Dehradun. There are various challenges for urban and transport planner /decision makers for designing and selecting a framework for sustainable transport strategies with incomplete information and also there lack of data available on designing and selection of framework. Further the literature report discusses the available approaches for estimating the emission but all are very data invasive.so there is a dire need to develop an approach to calculate the emission in different scenario to judge the strategy and policy before implementation.

Although there are numerous studies that provide scientific evidence of negative impact of CO_2 emission by transportation section on human and business, only few studies focuses on approach or framework to tackle this issue. The nature of transportation industry is very fragmented therefore it poses a lot of challenges in making of a good framework. In order to meet the expected level of CO_2 transmission accurate understating of the emissions need to be done. There is a need of a framework that is more customized to the nature of the specific location. There are many different types of framework but they are still not able to fulfill the objective of reduction in CO_2 emission and greenhouse gases. There is a lack of consistent methodology, carbon emission assessment and non-availability of recent credible data that can be used to test the benchmarking of emissions available. Especially for the above mentioned inputs there are very few researches available in

Indian context. There are very few studies done on scenario analysis. Therefore in order to fulfill the gap in this area of research this attempts to present unique and practical focused framework that can help to reduce CO_2 emission.

2.8 Summary

The literature on sustainable transport, range of challenges and issues in India and worldwide for sustainable transport, worldwide practice of sustainable transport strategies in order to reduce congestion and pollution, further various impact assessment tool and carbon emission estimation models are discussed in this chapter. All these studies done so far in order to understand the need of the sustainable urban transport (SUT) and possible strategy. Further all studied model help to develop the framework for evaluation of strategies and for emission estimation.

CHAPTER -3
DEHRADUN: CITY PROFILE

3.1 Introduction

This chapter deals with the basic understanding of the profile of the city, which includes demographic details, tourist inflow in city, land-use pattern explaining broad level trip generation and attraction zones, vehicle registration data and accident data, information on existing road network, public transport (bus) and IPT (Intermediate Public Transport) operations their routing pattern and mobility issues in Dehradun city etc. This gave us a strong understanding of the existing condition of urban mobility infrastructure and traffic associated problems

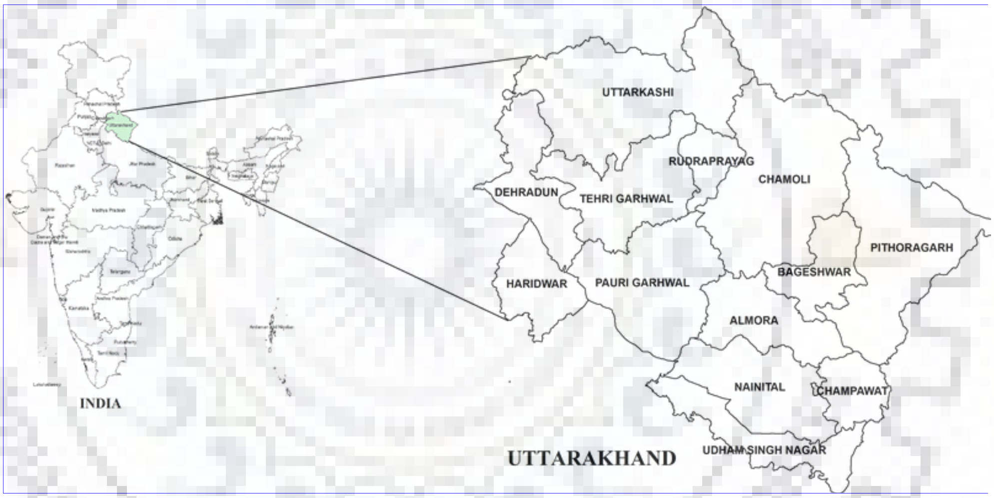


Figure 3.1: Dehradun on the Map of Uttarakhand

3.2 City Background

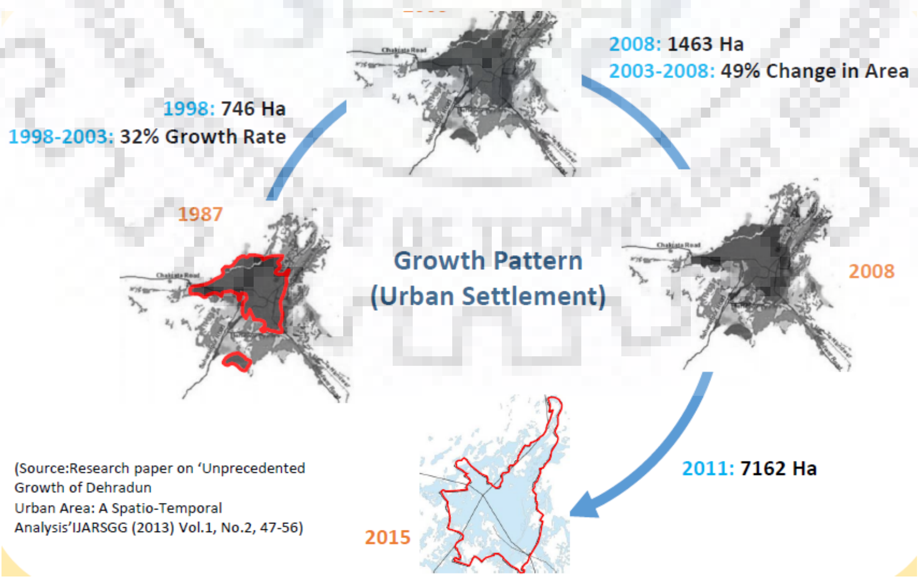
The city of Dehradun is the state capital of Uttarakhand and situated at the Himalayan foothills in the fertile Doon Valley. It is well connected by all modes of transportation (Road, Rail, and Air) and surrounded by regional towns (Uttarkashi, Tehri Garhwal, Pauri-Garhwal, Haridwar) and other states (Uttar Pradesh and Himachal Pradesh). Figure 3.3 presents the regional linkages of Dehradun district.

The valley is well known for its salubrious climate and natural beauty. It is due to this reason Dehradun has been one of the preferred residential cities and favorite tourist destination. It is also an important educational center of the country. Dehradun houses many governments organization and prestigious educational institution of high repute across the country namely Indian Military Academy(IMA), Forest Research Institute(FRI), Indian Institute of Petroleum, Survey of India, Oil and Natural Gas Corporation (ONGC) and Wildlife Institute of India, etc.

Dehradun is visited by a large number of tourists every year, many of them en-route to Mussoorie. There are several places of tourist interest in Dehradun and its surrounding area such as Gurudwara, temple, Sahastradhara, Robbers Cave, Dakpatthar, Tapkeshwar, Mahadeo temple, Malsi Deer Park, Raipur spring, etc. Jhanda Fair is held every year at the historic Guru Ram Rai Darbar situated close to River Yamuna on the way from Dehradun to the hill station of Chakrata. Rajaji National Park is situated at the edge of the sprawling Dehradun valley, comprises about 820 sq. km area.

3.3 Growth of the City

The city has grown outward towards the northern side. The core city area is still the same with negligible expansion in the city limit. Figure 3.2 presents the growth pattern of urban settlement. In 1998 the city comprised only 746 Ha which has increased to 7162 Ha by 2011 at the growth rate of 49%.



(Source: Gupta, 2013)

Figure 3.2: Growth Pattern of the City

(Source: CMP, Dehradun, 2012)

Figure 3.3: Regional Linkages of Dehradun

3.4. Demographic Profile

As capital of Uttarakhand state, Dehradun has strategic importance in the sustainable growth of the state, so it is important to understand its demographic profile in a more detailed manner.

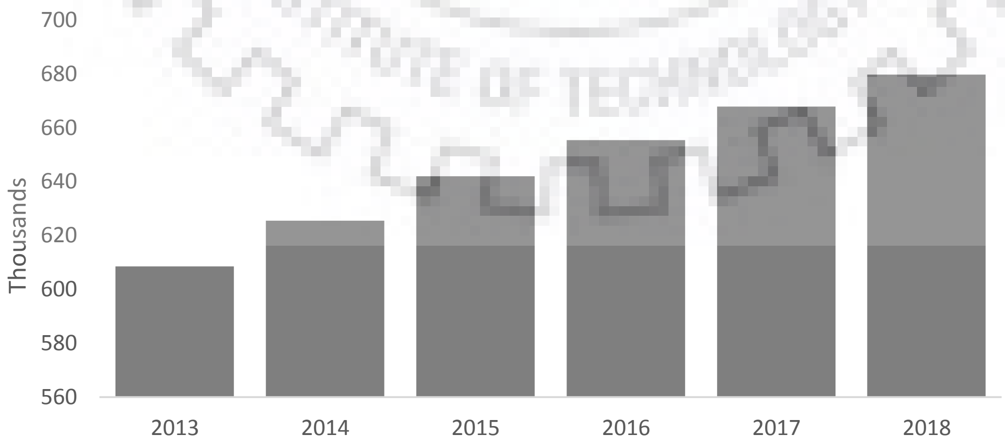
The decadal growth rate of Dehradun population from 1981 to 1991 was 27.11% and 27.96% respectively. From Table 3.1 it is seen that in next decade the growth rate has reached to more than double i.e. 65.93% explained by the fact that in this decade Uttaranchal was made a separate State with Dehradun as its capital in the decade 1991-01. In the period 2001-11, the population growth rate is 27.01% with a population of 5.69 lac in the urban area.

Table 3.1: Dehradun Population and Decadal Growth Rate

Year	Population (000' Person)	Decadal Growth Rate
1971	166	
1981	211	27.11%
1991	270	27.96%
2001	448	65.93%
2011	569	27.01%

Source: Directorate of Economics and Statistics, Government of Uttaranchal, Statistical Diary, Uttaranchal, 2004-05, page 9

The population of Dehradun in the most recent year is estimated around 679,730 and it has increased at an annualized rate of 2.3% in the last 5 years. (Figure 3.4)

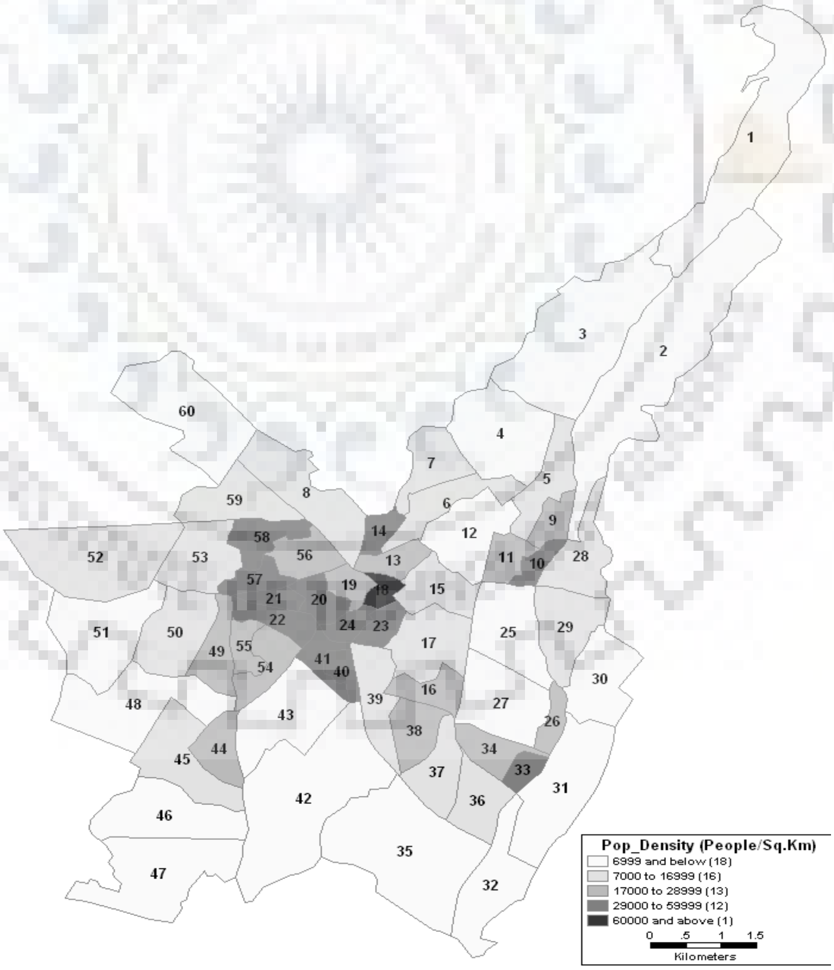


(*Source: http://indiapopulation2018.in*)

Figure 3.4: Population Growth of Dehradun City

As per Census of India 2001, the population of the city was 5.30 lakhs in the urban area (this includes population residing in the area under Municipal Corporation (4.26 lakh) and Cantonment and Clement Town Area (1.04 lakh). In 2011, the population residing in Municipal Corporation (MC) area has grown to 5.78 lakh, with an annual growth rate of around 3.08%. The total number of households in the MC area is 84, 0122 with an average household size of 5.07 persons/ household. The Master Plan (2025) projected a population of 1.530 million by 2025.

Dehradun has also shown an increase in economic development activities. The total area of Dehradun City is 87.4 sq. km (as mentioned in the Master Plan 2005-2025). The average literacy rate of the population of Dehradun is 85.2% which is higher than the state average of 79.63% and the national average of 74.04%. The population density of Dehradun Nagar Nigam, range from 2500-70,000 persons/ sqkm with most populated ward Kalika mandir as shown in Figure 3.5 below.



(Source: CMP, Dehradun, 2012)

Figure 3.5: Population Density (People/sq.km)

3.5 Tourist Inflow

The tourist inflow in Uttarakhand has perpetually increased from around 11 million in 2000 to 34 million in 2017. (Figure 3.6)

Source: Ministry of Tourism, Uttarakhand

Figure 3.6: Number of Tourists Visiting Uttarakhand

Dehradun with its scenic beauty, charismatic climate, and peaceful sociocultural and political environment is one of the prominent destinations for tourist. It is also a gateway to many other tourist destinations like Mussoorie, Rishikesh, Haridwar, Kedarnath, etc. Every year a large number of tourists have visited the city. The tourist inflow for the period 2005-15 is shown in Table 3.2 & Figure 3.7 below.

Table 3.2: Tourist Inflow in Dehradun

Year	Indian Tourists	Foreign Tourists	Total Tourists	Percentage Change (%)
2005	1013959	12012	1025971	
2006	1016058	18051	1034109	0.79%
2007	1369950	17766	1387716	34.19%
2008	1422578	18483	1441061	3.84%
2009	1558715	17051	1575766	9.35%
2010	1966942	20699	1987641	26.14%
2011	1978962	19864	1998826	0.56%
2012	2175851	21884	2197735	9.95%
2013	2383783	18202	2401985	9.29%
2014	2397197	18549	2415746	0.57%
2015	2374527	18722	2393249	-0.93%

Source: Pa Anil l, & Pal Brijesh (2016)

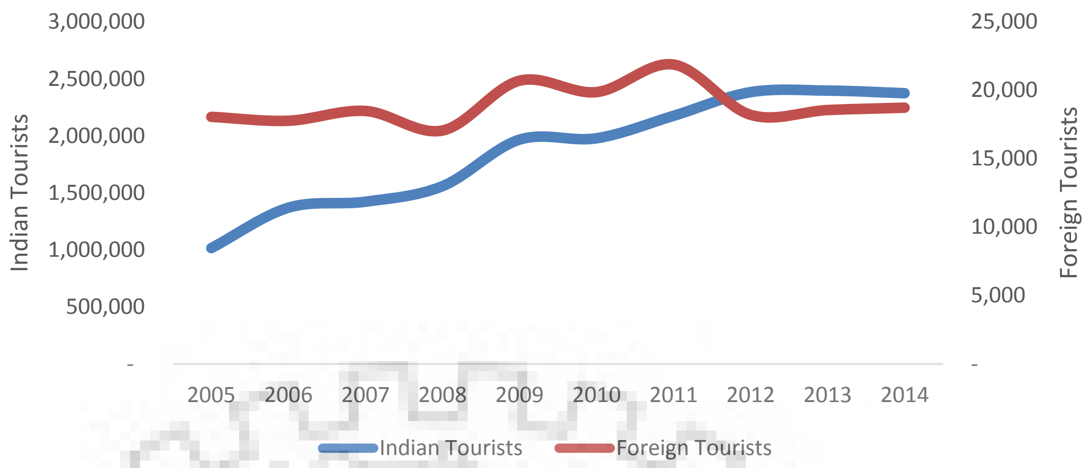


Figure 3.7: Indian & Foreign Tourists Visiting Dehradun

3.6 Land Use Distribution

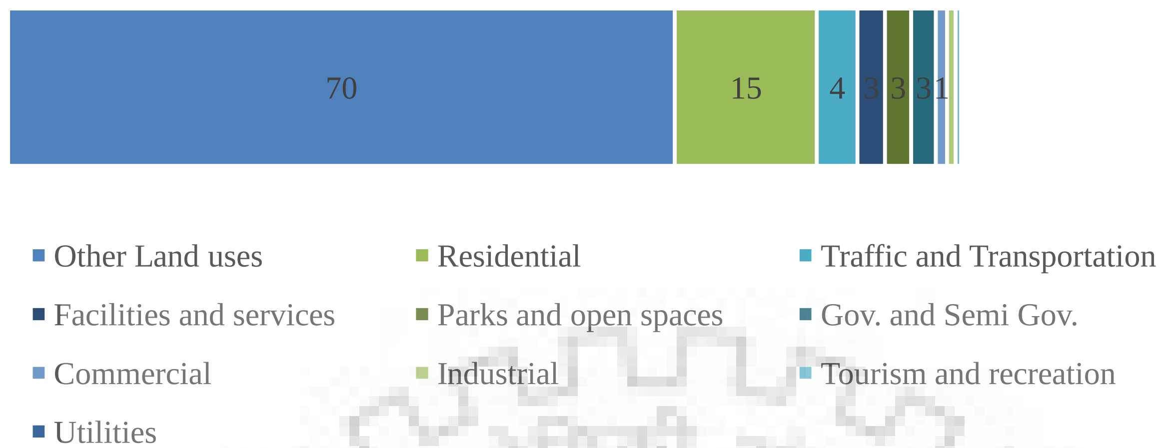
The master plan prepared for 2025 with a vision to govern the development of the city which is based on the survey carried out in the year 2003-04. The total area reserved for different land uses is approximately 35,867.20 ha which includes Dehradun Urban Agglomeration Area (9,698.97 ha), undefined area (3,058.82 ha) and 172 rural villages (26,168.33 ha). According to Master Plan (2025), the population is expected 1.530 million by 2025 (Master plan 2025).

Table 3.3 indicates the proposed different land uses with respective areas of land uses for Master Plan 2025

Table 3.3: Proposed Land Use as per Master Plan 2025

S.No.	Land Use	Area (In Ha)	Percentage of Total Area
1	Residential	5325.7	14.8
2	Commercial	423.3	1.2
3	Industrial	331.7	0.9
4	Gov. and Semi Gov.	926.0	2.6
5	Facilities and services	1030.5	2.9
6	Utilities	132.9	0.4
7	Tourism and recreation	202.2	0.6
8	Parks and open spaces	978.9	2.7
9	Traffic and Transportation	1517.8	4.2
10	Other Land uses	24998.3	69.7
	Total	**35867.2**	**100**

Source :Master Plan for Dehradun 2025, MDDA



3.7 Transport System in Dehradun

3.7.1 Road Network

Dehradun city has a dense road network and is well connected by road with other important towns in Uttarakhand. Dehradun city comprises of 493 km of road. Out of which 363 km are maintained by Municipal Corporation and 130 km maintained by PWD. The limited widths of the road, intense land use and encroachments on road, reduces the traffic carrying capacity which leads to congestion in the city. The city road network is shown in Figure 3.8 and important roads in the city are given below:

- Saharanpur Road (NH-72A)
- Haridwar Road (NH-72)
- Chakrata Road (NH-72)
- Rajpur/ Mussoorie Road (SH – 1)
- Raipur Road
- Haridwar Bypass Road
- Gandhi Road
- Eastern Canal Road
- Chakrata Road

(*Source: CMP, 2012)*

Figure 3.8: Dehradun Road Network

3.7.2 Vehicular Growth

Dehradun district has shown very high growth in the number of registered vehicles from 1994-95 to 2010-11. The data collected from the Regional Transport Office shown in Table 3.4 elucidate that two-wheelers have grown drastically in the district.2-wheeler also has shown a growth of more than 15% per annum after 2000. Overall the growth of registered vehicles in the district is more than 12% annually presents in Figure 3.9.

Table 3.4: Growth of Registered Vehicles in Last Decade – Dehradun District

Year	Car/ Jeep/ Van	Scooter /M. Cycle	Taxi	Auto /Tempo	Bus/ Mini Bus	Goods Vehicles	Others	Total
1994-95	4,852	66,104	348	211	1,028	1,958	552	75,053
1995-96	5,690	72,716	591	281	1,105	2,186	617	83,186
1996-97	7,419	80,415	875	375	1,146	2,602	708	93,540
1997-98	8,879	88,557	1,140	500	1,249	2,892	806	104,023
1998-99	10,426	98,566	1,337	666	1,300	3,163	934	116,392
1999-00	12,972	109,498	1,678	905	1,405	3,502	1,207	131,167
2000-01	15,262	121,678	2,135	1,567	1,461	3,835	1,427	147,365
2001-02	17,479	135,202	2,620	1,956	1,546	4,155	1,612	164,570
2002-03	20,214	150,296	3,041	2,187	1,621	4,658	1,754	183,771
2003-04	23,859	166,399	3,370	2,484	1,991	5,479	1,987	205,569
2004-05	28,242	183,851	3,722	2,559	2,314	6,329	2,866	229,883
2005-06	33,385	203,137	4,344	3,051	2,687	7,119	3,713	257,426
2006-07	37,799	225,413	5,200	3,267	2,857	8,084	3,942	286,562
2007-08	45,459	246,326	6,020	3,646	3,159	9,423	4,526	318,559
2008-09	52,746	266,777	6,576	4,790	3,571	10,308	4,973	349,714
2009-10	62,134	293,415	7,204	5,233	3,690	11,176	5,467	388,319
2010-11	74,389	324,810	7,997	5,793	3,899	12,348	5,972	435,208
2011-12	89536	361891	8442	5980	3965	12,694	5,978	488486
2012-13	104176	396916	8856	6094	4011	12,906	5,989	538948
2013-14	117159	434914	9185	6211	4025	13,063	6,022	590579
2014-15	131565	473861	9621	6317	4076	13,216	6,029	644685
Growth rate	15%	8.9%	9%	8.5%	5.2%	10%	12.69%	12%

Source: Regional Transport Office, Dehradun.

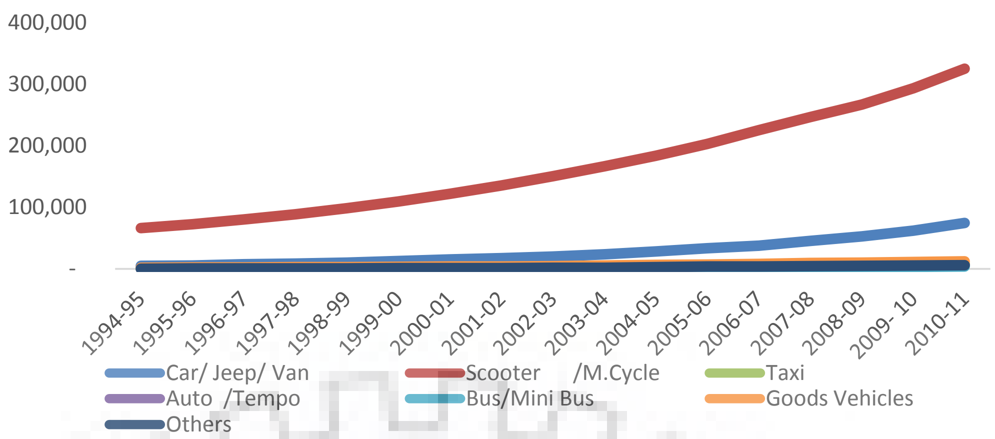


Figure 3.9: Growth of Registered Vehicles – Dehradun District

3.7.3 Road accidents

Dehradun as the capital of the Uttarakhand state offered better employment opportunities in this region that have attracted a large number of people to move into Dehradun city. With the improvement in economic conditions and disposable income, the number of vehicles owned by people has increased significantly. The rapid vehicular growth coupled with the inadequate capacity of the road and poor traffic management had caused several road accidents. It is seen in Table 3.5 that the data collected for the last five years shows that accidents have marginally reduced after improvements like widening, signaling, etc.

Table 3.5: Number and Type of Accidents in Dehradun

Year	Accidents	Fatalities	Injuries
2001	314	14	238
2002	356	157	269
2003	320	115	300
2004	323	161	382
2005	351	166	377
2006	358	167	276
2007	355	149	281
2008	357	205	349
2009	316	143	429
2010	334	170	260
2011	302	171	242
2012	325	136	273
2013	296	138	274
2014	314	146	285
2015	343	143	303
2016	295	139	220

Source: Traffic Police, Dehradun (http://uttarakhandtraffic.com/statistics)

3.7.4 Public Transport (Bus)

Uttarakhand Transport Corporation (UTC) operates inter-city Bus transport system in Dehradun. There are two intercity bus terminals, one at Inter State Bus Terminal (ISBT) and Mussoorie Bus Stop near Railway Station operating buses only between Dehradun-Mussoorie. There is one bus terminal for intra-city buses operated by private operators at Parade Ground.

Private Buses are the main cause of slow traffic movements as they do not have fix stops and authorized off-street parking facilities. All the intra-city routes are operated by private operators only. Table 3.6 represents the 16 intracity bus routes in Dehradun

Table 3.6: Intra City Routes Operated by Private Operators in Dehradun

Route No.	Routes	No. Of Buses
1	Dehradun-Doiwal	62
2	Rajpur - Clement town City Bus Route	34
3	DL Road - Defence Colony	23
4	Prem Nagar - Raipur Marg	33
5	Seemadwar – Nalapani	47
6	Sahastradhara – Dehradun ISBT	24
7	Prem Nagar – GularGhati	20
8	Dehradun - Pelio–Nayagaon	2
9	Banjarawala - Kargi – GularGhati	12
10	Parade Ground - Prem Nagar – Parval	19
11	Purkulgaon – Motharawala	12
12	Prem Nagar – ChowkiDaulas	2
13	MDDA – Dalanwala – DuttaMandir	14
14	Kaulagarh – Vidhansabha	6
15	Parade Ground – Thana Cantt. Via ISBT - Rispana	13
16	Dehradun - Raipur – Maldevata	14
	Total	**337**

Source: RTO office, Dehradun

As per the data provided by the RTO office, 337 buses are running on 16 intracity routes. Earlier around 416 buses running on 22 routes intra-city routes. These buses are operating at an average of 7 minutes with each bus making 3-4 trips per day. This frequency is fixed by RTO but these buses are operating in an unorganized manner.

Figure 3.10: Private Buses Parked around Parade Ground

Figure 3.11: Unplanned Bus Shelter

Facilities like a bus shelter and designated stop along the routes are usually missing. Due to the inadequacy of proper bus terminal and stops buses are parked around parade ground shown in Figure 3.10. Buses running on intracity routes don't have any planned bus stops(Figure 3.11) and they operate as per the convenience of passenger which create traffic problem for other traffic movements.

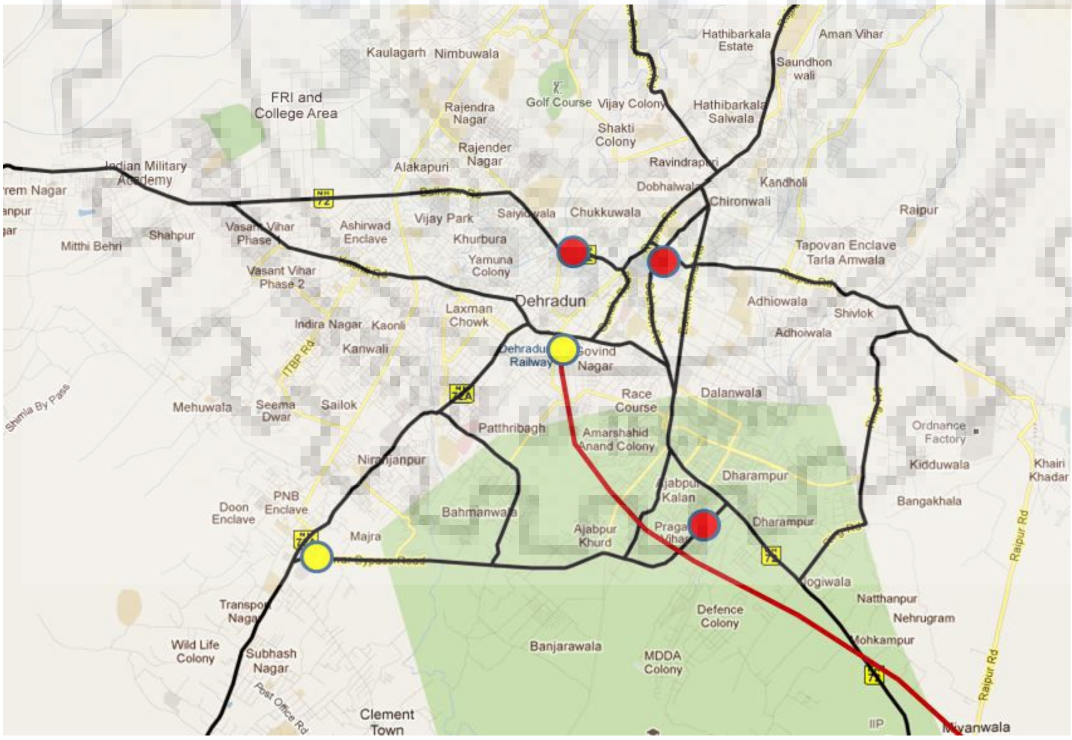
Bus shelters visible along some of the intracity routes are in dilapidated condition and the absence of lighting and sitting arrangement on these bus shelters further discouraged the use of public transport facilities.

3.7.5 Intermediate Public Transport (Autos)

Autos/Tempos are the most frequently used public transport in Dehradun. They account for approximately 24% of total trips in Dehradun. The unorganized operation of buses in the city further compelled people to rely on Autos/Tempos for day-to-day travel. Figure 3.12 shows the present auto stand in Dehradun city.

Figure 3.12: Auto Stand at Railway Station

There are two kinds of Intermediate Public Transport (IPT) are seen in Dehradun, one which provides door to door service and second which ply on designated routes known as Vikram. There are three Vikram stands in the city namely; i) Parade Ground, ii) Haridwar Bypass, iii) Chakrata Road (Connaught Place). Whereas, the autos don't have designated stands except for ISBT and Railway Station. (Shown in Figure 3.13)



Tempo Stand
Auto Stand

Figure 3.13: Auto & Tempo Stand Locations in Dehradun

Tempos (Vikram) are operating on fixed routes and carry more than 10 passengers per trip. Routes operated by Tempos (Vikram) in the city are given in Table 3.7 below:

Table 3.7: List of Routes operated by Vikram

S.No.	Routes Operated By Tempos
1	Raipur to Ashley hall
2	Darshanlal Chowk to IT Park
3	Rispana bridge to Ghanta ghar
4	Lachwala to Rispana bridge
5	KANAK theatre hall to ISBT
6	CISF to Connaught place
7	Prem Nagar to Connaught place
8	ISBT to Raipur
9	Gadi to Cannaught place
10	Prem Nagar to tehsil

The actual numbers of valid permits are given to limited Vikram only but the actual number of Vikram operating on various routes are much higher. All these Vikrams are plying illegally contributing to traffic congestion on roads. In the lack of public transport facility, people are forced to use these intermediate public transport (IPT) modes. Absence of dedicated stands for these IPT adds to the increasing traffic problem in the city. Major issues in the city transportation system are discussed in the following section.

3.8 Mobility Issues in Dehradun City

3.8.1 Modes of Transport

- Inadequate public transport facilities have led to the growth of private vehicles in the city (Figure 3.14).
- Mixed traffic along all roads reduces the speed of traffic and creates congestion. (Figure 3.15)
- The road lane capacity in the city is inadequate especially in the CBD area (Figure 3.16)

Figure 3.14: Lack of Public Transport

Figure 3.15: Mix Traffic Condition

Figure 3.16: Inadequate Lane Capacity on Chakrata Road Near Clock Tower

3.8.2. Road Network

- Absence of road hierarchy for traffic carrying corridors
- Improper utilization of the road network and lack of enforcement measures have deteriorated the situation.
- Encroachment of carriageway by hawkers and vendors further reduce the width of the carriageway (Figure 3.17).

Figure 3.17:Enchroachment of Carriageway by Hawkers near Lalpul

- Hindrances to pedestrian movement due to the absence of footpaths (Figure 3.18) and Ineffective traffic control and management measures.
- Lack of adequate parking space leading to haphazard on-street parking causing traffic congestion.

- Lack of Public Transport system in the city has forced people to use unorganized Intermediate Public Transport vehicles causing traffic congestion.
- Inadequate Road Infrastructure and Safety measures.
- Poor road condition & loading and unloading activities by goods vehicles in the central area.(Figure 3.19 & 3.20)

Figure 3.18: Pedestrian are Forced to Move on Carriageway

Figure 3.19: Loading/ Unloading activities in Central Area

Figure 3.20: Poor Road Condition

3.8.3. Intersections

Poor intersections design with high volume of traffic causing traffic congestion during the peak hours. The rotary at Clock Tower, Saharanpur Chowk, Prince Chowk and Junction near Bindalpur are most congested and problematic intersections in the city. Figure 3.21 shows the poor intersection design in Dehradun city.

Figure 3.21: Poor Intersection Design

3.8.4. Vehicular Parking Facilities

The parking space in the CBD area is missing. The vehicles are parked on-street along important principal roads and in the CBD area i.e. near Railway Station, Paltan Bazar, Clock Tower, Darshan Lal Chowk, Connaught Place, on Rajpur Road and other local streets, which create hurdles in the smooth flow of vehicular movement.Figure 3.22 present that on-street parking encroached the road space in Paltan market.

Figure 3.22: Absence of Parking Space

Absence of off street parking facilities and increase in numbers of vehicles has further aggravated the problem

3.8.5. Traffic Management System

- Inadequate traffic signals and non-functioning of signals installed at important junctions.(Figure 3.23)
- No separate phase for the pedestrian in the signal timings at all major intersections.
- Lack of traffic police on major intersections and junctions.
- Missing signage along all road, intersection, and junctions.
- Proper street lighting facilities are not available on the roads.

Figure 3.23: Non-Operative Signals at Aaraghar Chowk

3.8.6. Vehicular Pollution

High volumes of Tempos and Autos on roads are the main cause of the high level of air pollution in the city. Poor maintenance of vehicles particularly Vikrams plying on various routes leads to high emission of pollutants i.e.SPM, carbon, etc. Studies have been done by various technical institutes such as University of Petroleum and Energy Studies - Dehradun, Central Pollution Control Board to check the existing level of air and noise pollution in the city of Dehradun.

3.8.6.1 Air pollution

Dehradun was ranked the 31st most polluted city in the world by WHO as per Air Quality Data 2016, indicating that vehicular pollution deteriorating the ambient air quality of Dehradun at alarming rate (Kumar, V. 2015_a, Deoli, B. K. 2018) The study conducted by USPCB (Uttarakhand State Pollution Control Board) in 2017 found that the concentration of PM 10 (Particulate matter) was increased up to 330.42 µg/m3 in various locations (USPCB 2017). Table 3.8 shows the pollutant concentration at major locations in different years. This shows the parameters SO_2, PM crossed the maximum permissible limits of NAAQ (2009) in almost all the sampling location while the parameter NO2 was found under the limit in all the sampling location

Table 3.8: Ambient Air Quality in Dehradun

Locations	Clock Tower (ug/m3)			ISBT (ug/m3)			Rajpur Road (ug/m3)		
Year	P.M. 10	SO2	NO2	P.M. 10	SO2	NO2	P.M. 10	SO2	NO2
2011	185.43	23.20	24.69	138.32	23.33	24.72	140.64	23.10	24.66
2012	177.15	26.52	28.25	176.72	24.75	26.89	163.87	25.16	27.18
2013	138.69	24.18	27.37	168.12	24.73	26.95	128.92	23.60	26.10
2014	152.52	25.78	29.31	186.51	26.30	29.53	145.11	26.16	29.38
2015	159.54	26.48	29.92	237.75	27.45	30.43	155.35	26.33	29.53
2016	180.05	25.07	28.66	288.12	27.10	30.05	245.23	25.92	28.99
2017	190.40	24.97	28.50	302.34	26.66	29.68	223.71	25.84	28.85

Source: A report by Gati foundation, March 2018

3.8.6.2. Noise pollution

A survey was done by Uttaranchal Environment Protection and Pollution Control Board (UEPPCB) to check the noise levels at various locations in Dehradun city. The findings of the survey are given in Table 3.9.

Table 3.9: Noise Levels at Various Locations in Dehradun

Locations	Zone Noise Level dB (A) (Day Time)			
	2017	**2016**	**2015**	**2014**
Survey Chowk	74.6	73.0	72.9	72.1
Gandhi Park	54.7	50.1	55.4	56.0
Clock Tower	73.7	72.5	73.9	74.4
Doon Hospital	53.4	51.9	53.7	56.6
CMI Hospital Chowk	73.2	72.5	-	-
Race Course	55.3	53.9	52.1	58.5

Source: http://ueppcb.uk.gov.in/

The survey data shows that the noise levels at many locations are much higher than the standards given by CPCB. Therefore, there is a need to curb the noise levels produced by the movement of vehicles on the road which is the main source for this pollution. Action plan has to be developed to discourage the usage of personalized modes of vehicles like cars and two-wheelers which are the major components producing noise pollution. This can be achieved by encouraging the commuters to use ecologically sustainable public transport system in the form of Bus.

CHAPTER-4

ASSESSMENT OF EXISTING TRAFFIC AND TRANSPORT CHARACTERSTICS

4.1 Introduction

Assessment of traffic characteristics within an urban area is pre-requisite to understand and quantify the problems with respect to traffic movement, identifying the possible alternative solutions and the need for implementation in an efficient and economical manner. This appreciation and understanding are essential for identifying the present conditions and constraints and formulate suitable transport policies and strategies. So in order to appreciate the traffic and transport system characteristics, a number of primary field surveys have been carried out within the study area and are presented in the subsequent sections.

4.2 Data Collection

For undertaking the assessment of existing transport system data needs to be collected from secondary and primary sources. The secondary data has been collected from the various published report and from different government institution like MDDA, MCD, STU, RTO, Traffic police and pollution control boards. The primary data has been collected by field survey and questionnaire survey. The brief methodology adopted, location, nature, and extent of data collected under each of the above-mentioned surveys have been discussed below. The data collected have been analyzed to assess the existing traffic and travel pattern of intra and intercity traffic as well as the socio-economic characteristics of the study area.

4.3 Data Analysis

4.3.1 Analysis of Public Transport Operation In The City

For assessing the performance of public transport operation in Dehradun city, the methodology adopted is service level benchmarking for urban transport given by MOUD, Government of India and suggested by JnNURM.To analyze the operation of public transport in the study area, data has been collected against 6 parameters enlisted below in Table 4.0.

Table 4.0: Public Transport Facilities Parameters

Parameters.	**Data to be collected**
Presence of organized public transport system in urban area	• Total buses in the city • Total buses under the ownership of STU/SPV
Extent of supply availability of public transport	• Available No of buses in a city per day • Total Population of the city
Service coverage of public transport in the city	• Total road length (kms) of the corridors on which public transport systems operateTot • Area of the urban limits of the city
Average waiting time for public transport users (mins)	• Total Bus stops within the city • Route wise headway (in minutes) estimation for buses
Level of comfort in public transport	• Key routes of public transport in the city • Seats available in a bus (standard and mini) on each identified route • Passenger count on bus at key identified routes
% of fleet as per urban bus specification	• Total number of buses as per urban bus specifications in the city

The Public transport (PT) system is principally only bus based system in Dehradun city. PT system is characterized by fixed origin and destination; fixed routes and schedules; fixed stoppage time and fixed fares. Therefore it doesn't include IPT, RTV auto rickshaw, 3W, 2W, tempos, shared taxis and other vehicles providing point to point service. A primary survey was conducted for bus service facilities inventory in different locations of Dehradun city There are ten major routes for intercity public transport operation in Dehradun city.

Route wise headway (in minutes) for buses was collected by bus stop headway estimation survey(Annexurre-I) and bus occupancy survey(Annexure-II) is done to calculate the seat availability in bus and passenger count on the bus at key identified

routes. Passenger data has been calculated for the different routes and headway data has been calculated for 6 different routes. The 6 identified routes are

Route1:	ISBT to Daakpathar
Route 2:	Parade Ground to Jolligrant Hospital
Route 3:	Parade Ground to Gularghati
Route 4:	Parade Ground to Sahasdhara
Route 5:	Clementown to Raipur Road
Route 6:	Prem Nagar to I.S.B.T.

Data taken at different stops are

- Arrival time of Bus,
- Passenger Alighted,
- Passenger Boarded,
- Passenger Count
- Seat Availability
- Passenger standing etc.

Figure 4.0   indicate the primary survey compilation of bus headway estimation and bus occupancy survey.

Route:PARADE GROUND TO JOLLIGRANT HOSPITAL

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	PARADE GROUND	OP	11.1	11.19	11.25
2	TEHSIL CHOWK	OP	11.3	11.35	11.44
3	PRINCE CHOWK	OP	11.5	11.53	11.55
4	DHARAMPUR CHOWI	OP	12.01	12.15	12.2
5	RISPANA BRIDGE	OP	12.27	12.29	12.41
6	JOGIWALA	OP	12.47	12.54	12.54
7	MOOKHANPUR	OP	1	1.04	1.08
8	MIYAWALA	OP	1.1	1.17	1.23
9	HARRAWALA	OP	1.28	1.35	1.43
10	LAKSHMISIDDH	OP	1.45	1.5	1.5
11	KERAWALA	OP	1.54	2	2.1
12	LACCHEWALA	OP	2.14	2.15	2.3
13	DOIWALA	OP	2.35	2.39	2.5
14	DHANIAWALA	OP	2.54	3.01	3.01
15	JOLLYGRANT HOSPIT.	OP	3.1	3.15	3.25

AVERAGE HEADWAY OF ROUTE =6.13 MINUTES

Route:CLEMENTOWN TO RAIPUR ROAD

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	CLEMENTOOWN	OP	10.4	10.45	10.55
2	CLEMENTOWN T	OP	10.59	11.04	11.4
3	CHANDRABAANI	OP	11.07	11.14	11.2
4	I.S.B.T.	OP	11.25	11.26	11.26
5	MAAZRA	OP	11.28	11.35	11.42
6	SABJIMANDI	OP	11.45	11.53	11.54
7	LAALPUL	OP	12.05	12.14	12.14
8	PATELNAGAR	OP	12.22	12.3	12.35
9	SAHARANPURCH	OP	12.44	12.5	12.52
10	RAILWAYY STATI	OP	12.55	12.55	12.55
11	PRINCE CHOWK	OP	12.58	12.58	12.58
12	GHANTAGHAR	OP	1.05	1.12	1.13
13	**ASHLEY HALL**	OP	1.2	1.27	1.35
14	DILARAM BAZAR	OP	1.55	2	2.1
15	R.T.O	OP	2.15	2.18	2.18
16	JHANKANKAAN1	OP	2.3	2.38	2.4
17	KISANCHUNGI	OP	2.46	2.51	2.55
18	KATHBANGLA	OP	2.58	3.02	3.1
19	RAJPUR ROAD	OP	3.15	3.25	3.34

AVERAGE HEADWAY OF ROUTE = 4.69 MINUTES

Route:PREM NAGAR TO I.S.B.T.

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	PREMNAGAR	P	4.53	5	5
2	PANDITWADI	P	5.2	5.21	5.24
3	F.R.I	P	5.37	5.4	5.44
4	BALLUPUR	P	5.52	6	6.05
5	BALLIWALA	P	6.3	6.34	6.43
6	I.S.B.T.	OP	7.06	7.2	7.22

AVERAGE HEADWAY OF ROUTE =5 MINUTES

Route: ISBT to Daakpathar

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	ISBT	OP	11.1	11.19	11.25
2	BALLUPUR	OP	1130	11.35	11.44
3	PREMNAGAR	OP	11.5	11.53	11.55
4	SIDDHUWALA	OP	12.01	12.15	12.2
5	JHAZARA	OP	12.27	12.29	12.41
6	DHULKOT	OP	12.47	12.54	12.54
7	SELAQUI	OP	1	1.04	1.08
8	RAMPUR	OP	1.1	1.17	1.23
9	SEHASSPUR	OP	1.28	1.35	1.43
10	LANGAROAD	OP	1.45	1.5	1.5
11	JASSOWALA	OP	1.54	2	2.1
12	KHARBAT	OP	2.14	2.15	2.3
13	VIKASNAGAR	OP	2.35	2.39	2.5
14	DAAKPATHAR	OP	2.54	3.01	3.01

AVERAGE HEADWAY OF ROUTE = 5.14 MINUTES

Route:PARADE GROUND TO SAHASDHARA

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	PARADE GROUND	OP	10.4	10.57	11.11
2	SURVEY CHOWK	OP	11.13	11.33	11.4
3	NALAPANI CHWK	OP	11.5	11.59	12.05
4	RISHINAGAR	OP	12.07	12.2	12.21
5	MAYURVIHAR	OP	12.25	12.31	12.5
6	GURURAMRAI	OP	12.56	12.58	1.09
7	I.T.PARK	OP	1.16	1.3	1.42
8	GUJARADA	OP	1.46	1.17	1.23
9	KULAN	OP	2.19	2.3	2.41
10	NAGAL	OP	2.43	2.55	2.58
11	SAHASTRADHARA	OP	3.01	3.21	3.33

AVERAGE HEADWAY OF ROUTE = 11.32 MINUTES

Route:PARADE GROUND TO GULARGHATI

Stop no	Name of Stop	Peak/Off	BUS-1	BUS-2	BUS-3
1	PARADE GROUND	OP	2	2.32	3.08
2	KANAK CHOWK	OP	3.15	3.43	4.1
3	SURVEY CHOWK	P	4.15	4.33	4.35
4	SAHARDHARA CROSSING	P	4.5	5.15	5.45
5	RAIPUR	P	5.57	6.33	6.45
6	GULARGHATI	OP	6.53	7.1	7.28

AVERAGE HEADWAY OF ROUTE =23 MINUTES

Figure 4.0: Primary Survey Compilation of Bus Headway Estimation

The key indicators to calculate the adequate public transport facilities with level of service (LOS) are given in Table 4.1

Table 4.1: Indicators with Level of Service for Public Transport Facilities

LOS	1. Presence of Organized Public Transport System in Urban Area (%)	2. Extent of Supply Availability of Public Transport	3. Service Coverage of Public Transport in the city	4. Average waiting time for Public Transport users (mins)	5. Level of Comfort in Public Transport	6. % of Fleet as per Urban Bus Specification
1	>= 60	>= 0.6	>= 1	<=4	<= 1.5	75 - 100
2	40- 60	0.4 - 0.6	0.7- 1	4 – 6	1.5 – 2.0	50 - 75
3	20 - 40	0.2 - 0.4	0.3 - 0.7	6 – 10	2.0 – 2.5	25 - 50
4	< 20	< 0.2	< 0.3	> 10	>2.5	<= 25

Source : SLB,MoUD,2010

The overall LOS for the parameter "Public Transport facilities" citywide is identified by adding the LOS of all indicators calculated byTable 4.1, is described in Table 4.2.

Table 4.2: Overall LOS of Public Transport Facilities City Wide

Overall LOS	Calculated LOS	Comments
1	< 12	The City has a good public transport system which is wide spread and easily available to the citizens. The system provided is comfortable.
2	12 - 16	The City has public transport system which may need considerable improvements in terms of supply of buses/ coaches and coverage as many parts of the city are not served by it. The frequency of the services available may need improvements. The system provided is comfortable.
3	17 - 20	The City has a public transport system which may need considerable improvements in terms of supply of buses / coaches and coverage as most parts of the city are not served by it. The frequency of the services available needs improvements. The system provided is not comfortable as there is considerable over loading.
4	21-24	The city has very poor or nil organized public transport system.

Source : SLB,MoUD,2010

After collecting the data the SLB is quantifying for public transport by 6 parameters.

1. **Presence of Organized Public Transport System in Urban Area**

The parameter has been calculated with the help of two factors

Total No. of buses (A)	Total no of buses under the ownership of STU/SPV or under concession agreement (B)	%=B/A*100	LOS1
3899	337	8.64%	4

The value of LOS1 as per above-mentioned indicator Table 4.1 is 4.

2. **Extent of Supply/ Availability of Public Transport**

This parameter has been calculated with the help of two factors

No. of busses available in city in a day (A)	Total population of the city(B)/1000	Ratio A/B	LOS2
337	578000/1000	0.583	2

The value of LOS2 as per above-mentioned indicator Table 4.1 is 2.

3. **Service Coverage of Public Transport in the City**

Here parameter has been calculated with the help of two factors

Total length in road Kms of the corridors on which public transport systems ply in the city.(A)	Area of urban limit of the city in km^2(B)	Ratio (A/B)	LOS 3
217.7	359	0.606	3

The value of LOS3 as per above-mentioned indicator Table 4.1 is 3.

4. **Average Waiting Time for Public Transport Users**

The average head way is calculated by bus stop headway count survey at 6 different bus routes.

Average headway = 5.14+6.13+23+11.32+4.69+5)/6=9.2

Average headway = 9.2 minutes LOS4 =3

The value of LOS4 as per above-mentioned indicator Table 4.1 is 3.

5. **Level of Comfort in Public Transport**

Passenger count in the bus (A)	Seat available in the bus (B)	Ratio(A/B)	LOS5
24.563	28	0.87	1

The value of LOS5 as per above-mentioned indicator Table 4.1 is 1.

6. **Percentage Fleet as per Urban Bus Specification**

Total no. of buses in the city (A))	The number of buses as per urban bus Specification (B)	Percentage=(B/A)*100	LOS 6
337	73	19.57	4

The value of LOS6 from the indicator Table 4.1 is 4.

Overall Level of Service

Calculated LOS = LOS1+ LOS2+ LOS3+ LOS4+ LOS5+ LOS6
= 4+2+3+3+1+4=17

The value of the overall Level of service is 17 which lies in the range of 17-20 in Table 4.2. Hence the overall level of service for Dehradun city is at level 3**.**

4.3.1.1 Summary of Findings

- The presence of public transport system in Dehradun city is 8.64% which comes below the range of 20%, thus marking the LOS (level of service) 4. This implies that there is a lack of good quality of organized public transport in Dehradun city.
- The extent of supply/availability of public transport ratio in Dehradun is .583 per 1000 people which comes under LOS 2. It implies that the number of buses required for the public is less than the demand. So there is an immediate need to increase the number of buses in the city.
- Calculated Average waiting time for public transport users was 9.21 minutes that makes this parameter to level of service 3. This is one of factors for commuter while choosing the mode of transportation.

- The level of comfort in public transport in Dehradun city is calculated as LOS1, however there are some stops like Clock tower, Balliwala chowk where the passenger count in buses increased intensely and some routes where seat are vacant. Level of comfort is calculated in terms of seat availability however the quality of buses in terms of suspensions, comfortable seats, cleaniness etc. need to be improved.
- The standard bus fleet is only 19.57% and marked it as the level of services (LOS) 4 to this parameter.
- The overall level of service of public transport operation in Dehradun city is calculated 17 which marked in LOS 3. It means there is a considerable improvement is needed in terms of frequency of buses their service coverage with world class quality buses.

4.3.2 Result of the User Opinion Survey

The user survey was performed at various locations in Dehradun city with an objective to understand socio-economic characteristics of commuters like 2 wheeler, 4 wheeler, cyclist, bus users and pedestrians towards various parameters. In this questionnaire survey, the various socio-economic characterstics of commuters and their perception towards various parameters of strategies have been incorporated in three categories (refer Annexure-III)

(i) Personal information

(ii) Daily travel activities of commuters

(iii) User opinion on mobility system in the city

4.3.2.1 Personal information:

In this section, the information about name, gender, sex, occupation, income details, transport expenditure and type of vehicles owned was asked to understand the most common profile of commuter that helped to segment commuters based on their socio-economic characteristics.

a) Gender

The conducted survey included response from 300 numbers of respondents. As per received responses, there were about 213 male respondents that represent approx. 71% of the total respondents.Table:4.3 describe the sample size distribution on the mode used.

b) Composition of commuter based on the mode used

As per surveyed participants, commuters using 2-wheeler (33%) and Vikarm (37%) represented the highest share. It was followed by bus users (22%), car users (7%) and auto users (1%). (Refer Figure: 4.1)

Table 4.3: Sample Size Distribution Based on Mode Used

Mode	Number of commuters
2w	100
Car	22.5
Vikram	110
Bus	65
Auto	2.5
Total	**300**

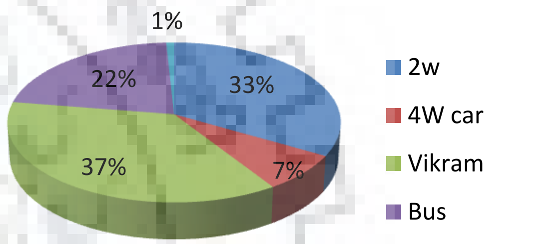


Figure: 4.1- Mode Wise Sample Distribution

c) Monthly household income:

Table 4.4 shows that people having lower income are using buses and as the income increases the commuter shift to private transport to travel.

Table 4.4: Distributions of Commuters by Monthly Household Income (%)

Modes	Income (INR)				
	<10,000	10,000-20,000	20,000-50,000	50,000-1 lakh	>1 lakh
2W	24.1	41.4	34.5	0	0.0
Bus	31.6	47.4	21.1	0	0.0
Car	10.0	32.5	40.0	17.5	0.0
Vikram	20.7	44.8	34.5	0.0	0.0
Auto	10.5	42.1	36.8	10.5	0.0
Minibus	28.6	42.9	28.6	0.0	0.0

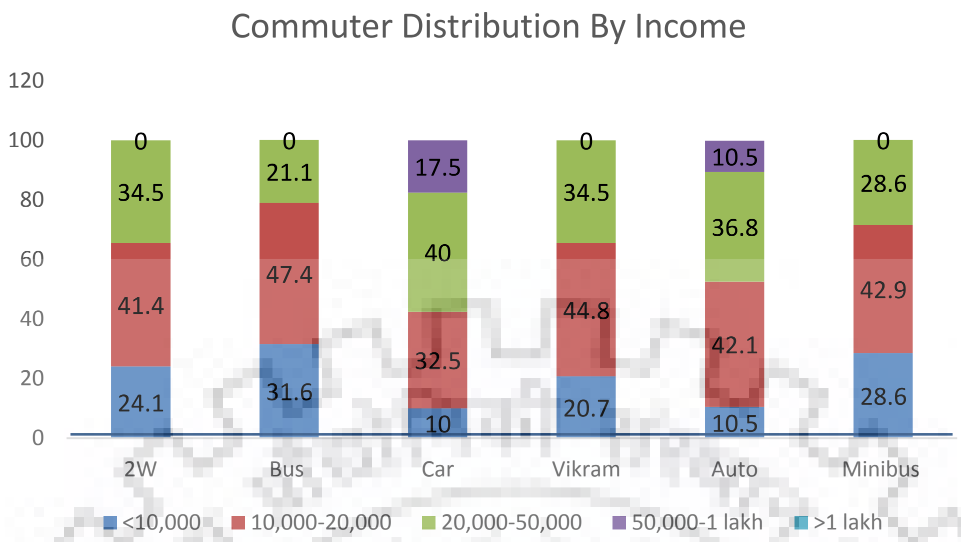


Figure 4.2: Commuter Distribution by Income

Of the surveyed respondents, commuters using 2-wheelers spread across a wide range of income level. The commuters having income range 10,000-20,000 constitute the major share of 2-wheeler users. Commuters having lower income level (<10,000) preferred bus as the key transportation mode whereas higher income level (40,000-50,000) preferred car as the key transportation mode. Vikarm, Auto and Minibus are the most preferred transportation mode of commuter with Income Range 10,000-20, 000.Figure:4.2 represent the commuter distribution by income.

4.3.2.2 Daily Travel Need and Activities of Commuters

It is very important to understand the daily travel activities of commuters since it would help to design the most appropriate transport solution. All the survey participants were asked about travel purpose, travel time, trip length, travel cost, perception on existing infrastructure, willingness to pay and influencing factors impacting the decision to choose transportation mode.

a) Purpose to travel

Table 4.5 shows the purpose wise usage of different mode. It depicts that commuters preferred auto and vikram as the key transportation modes to reach to their workplace and shopping and other purposes in the absence of a good transport system. Buses are

mostly used by students residing in the surrounding areas of the city for education and by peoples for intercity travel. People preferred cars as key transportation mode to travel to work, business and recreation purpose.

Table 4.5: Purpose Wise Trip Distributions

Modes	Trip purpose						
	Work place	Education	Shopping	Recreation	Medical	Business	Others
2W	17.2	6.9	31.0	10.3	3.4	17.2	13.8
Bus	10.5	31.6	21.1	21.1	5.3	10.5	0
Car	20	7.5	15.0	20.0	5	17.5	15
Vikram	44.8	6.9	24.1	10.3	3.4	6.9	3.4
Auto	52.6	5.3	15.8	5.3	0	0	21.1
Minibus	15.3	28.6	14.3	0	0	14.3	28.6

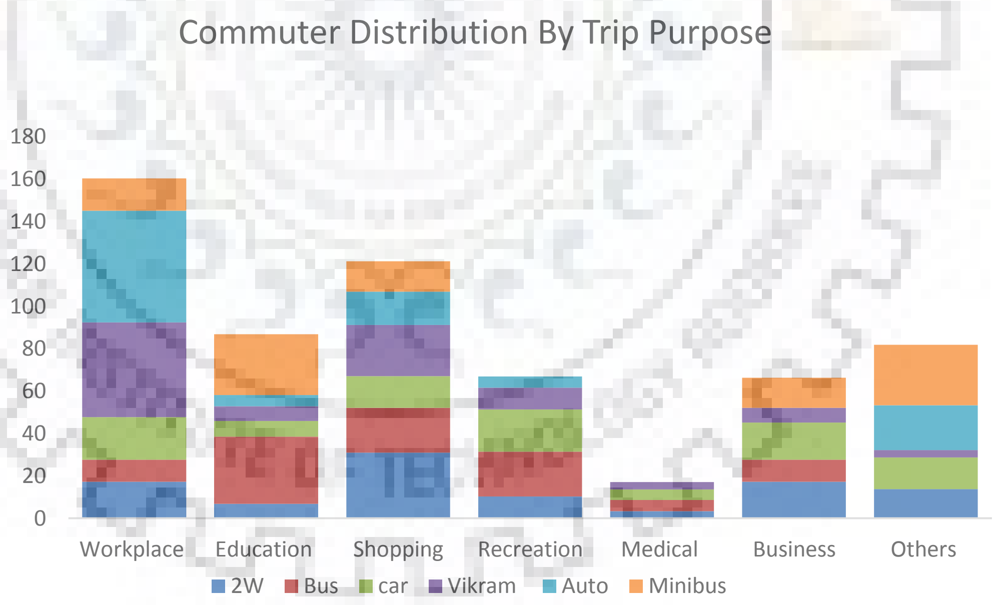


Figure 4.3: Commuter Distribution by Trip Purpose

Of the surveyed respondents, most of the commuters are using various transportation modes to get to the workplace, shopping and education. It is followed by commuters that are traveling for other purposes such as recreation, business, medical, etc. Figure: 4.3 show the purpose-wise commuter distribution.

b) Total travel time

Table: 4.6 envisaged that majority of commuters are using various transportation modes for the travel time ranging from 10 to 30 minutes. Travel time spent by peoples in different modes shows that 2-wheelers are used mainly for short distance trips with travel time less than 20 minutes. In the absence of public transport system, vikram are catering the needs of the people residing in the periphery of the towns. Average time spent in vikram ranges between 20-30 minutes. Buses are used by the people for intercity travel only. Mini buses are used by the peoples residing in the areas not covered by vikram. Figure: 4.4 below shows that 43% of the user spent more than 20 minutes in the mini buses to reach their destination.

Table 4.6: Percentage Distributions of Trips by Travel Time

Modes	Travel time (min)					
	<10	10 -20	20- 30	30-45	45-60	>60
2W	31.0	37.9	27.6	3.4	0.0	0.0
Bus	31.6	42.1	36.8	15.8	5.3	0.0
Car	10.0	27.5	30.0	15.0	10.0	7.5
Vikram	20.7	24.1	51.7	10.3	6.9	0.0
Auto	10.5	36.8	26.3	26.3	0.0	0.0
Minibus	28.6	28.6	42.9	0.0	0.0	0.0

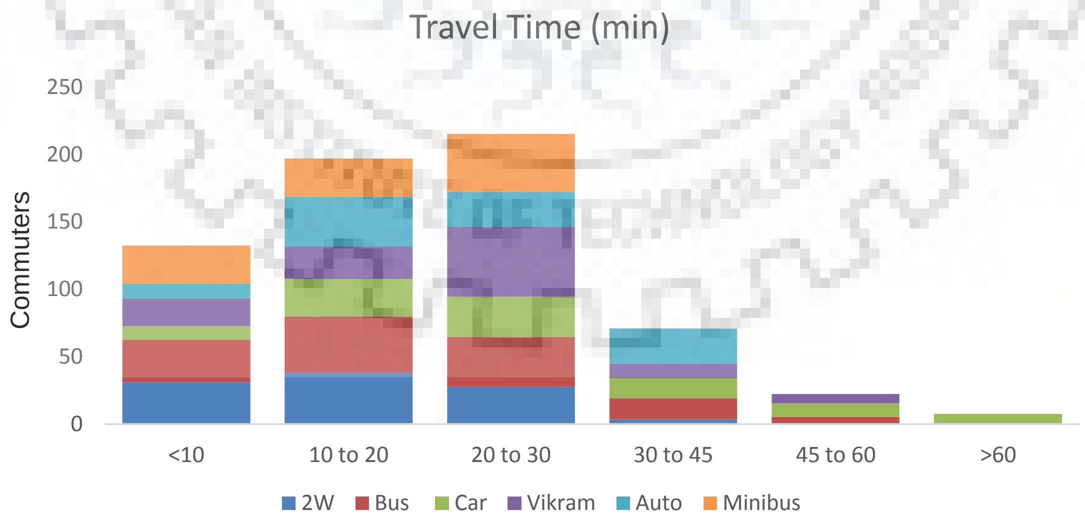


Figure 4.4: Commuter Distribution of Trips by Travel Time

c) **Total trip length (Kms)**

Table: 4.7 shows mode wise trip length. It dictates that for the smaller trip lengths (0 to 5 kms), commuters preferred vikram as the key transportation mode. As the trip length increases (beyond 5 km), commuters prefer to use buses and cars as key transportation modes. Figure:4.5 shows the mode wise trip length in Dehradun city.

Table 4.7:Trip Length by Transportation Mode

Trip Length (Kms)	2 W	Car	Bus	Vikram	Auto/Tempo
0-2	29.41	----	17.65	52.94	----
2-5	27.45	5.88	25.49	37.26	3.92
5-10	28.95	15.79	31.58	21.05	2.63
>10	21.43	21.43	35.71	21.43	----

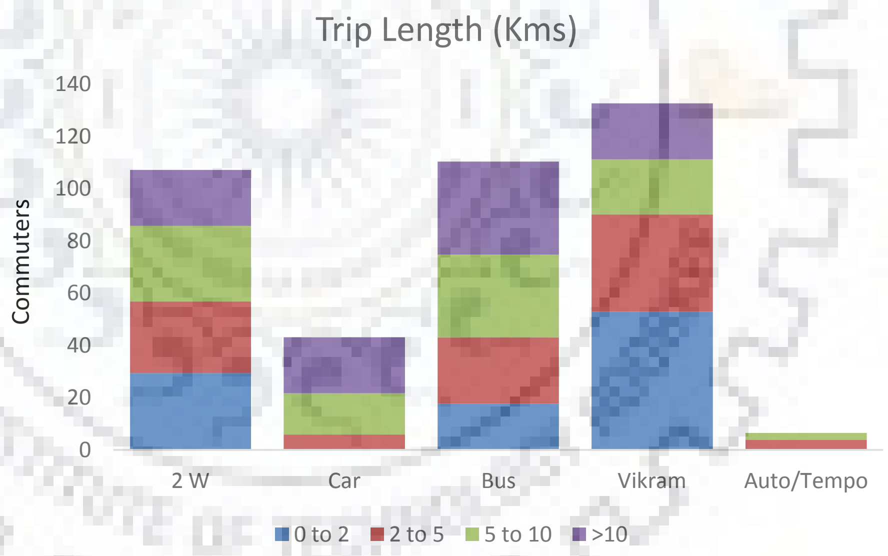


Figure 4.5: Mode Wise Trip Length

d) **Travel cost**

According to the Table 4.8, Cost spent on trip plays a very important role in mode selection. Students are using Mini Buses because they have to spend less to travel more. Peoples using private modes like two-wheeler and cars are spending more money daily on their trips. 45% of car users are spending more that Rs 50 on their daily trips. 85% of mini bus users spend between Rs 5 to Rs 10 daily to reach their destination. Autos are used by the people coming from the other cities to town for various purposes. Auto driver are charging very high from the users. 31% of users have to spend more than Rs 50 for their trip. Two wheeler users are spending between 5 to 50 rupees daily on their trips because two-wheelers are used by the people for intra-city as well as inter-city trips. Following Table 4.8 shows the money spent by the user in different modes.Figure:4.6 depict the distribution of trips by travel cost.

Table 4.8 : Percentage Distributions of Trips by Travel Cost

Modes	Percentage Distribution of Trips by Travel Cost (INR)						
	<5	5 to10	10 to 20	20 to 30	30 to 40	40 to 50	> 50
2W	10.3	27.6	37.9	13.8	6.9	0	3.4
Bus	5.3	36.8	52.6	5.3	0	0	0
Car	0	0	22.5	12.5	10	10	45
Vikram	6.9	44.8	31	13.8	3.4	0	0
Auto	0	0	5.3	26.3	15.8	21.1	31.6
Minibus	14.3	85.7	0	0	0	0	0

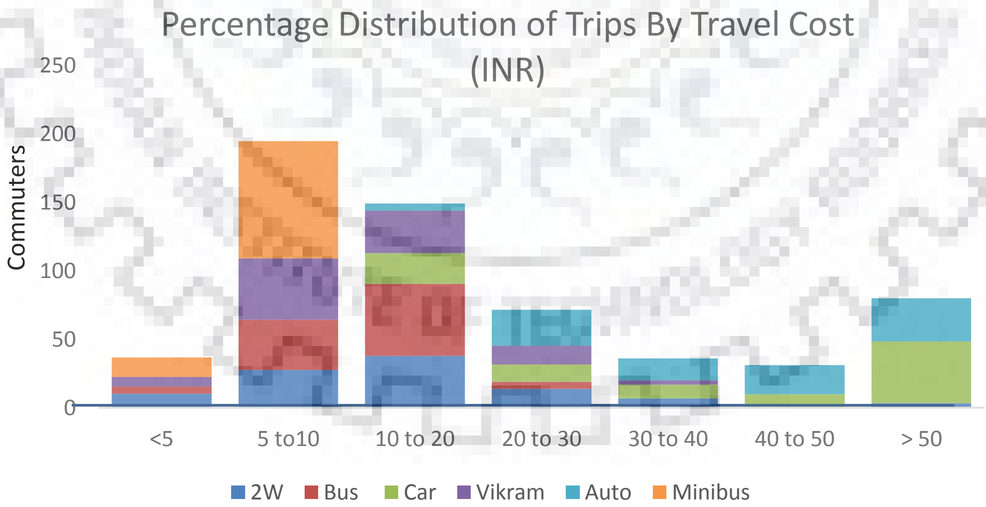


Figure 4.6: Percentage Distribution of Trips by Travel Cost

e) **User Perception on Existing Infrastructure**.

Users of different modes were asked how easy it was to drive/ride and the responses were analyzed and shown in Table 4.9. Considering the lack of public transportation, commuters are facing difficulty in using public transportation modes like buses and vikram.

Table 4.9: Level of Comfort and Usage of Different Mode

Modes	Very Easy	Easy	Ok	Difficult	Very difficult
2W	13.8	44.8	10.3	31.0	0.0
Bus	5.3	26.3	10.5	57.9	0.0
Car	20.0	57.5	15.0	7.5	0.0
Vikram	3.4	55.2	6.9	34.5	0.0
Auto	10.5	63.2	15.8	10.5	0.0
Minibus	28.6	42.9	14.3	14.3	0.0

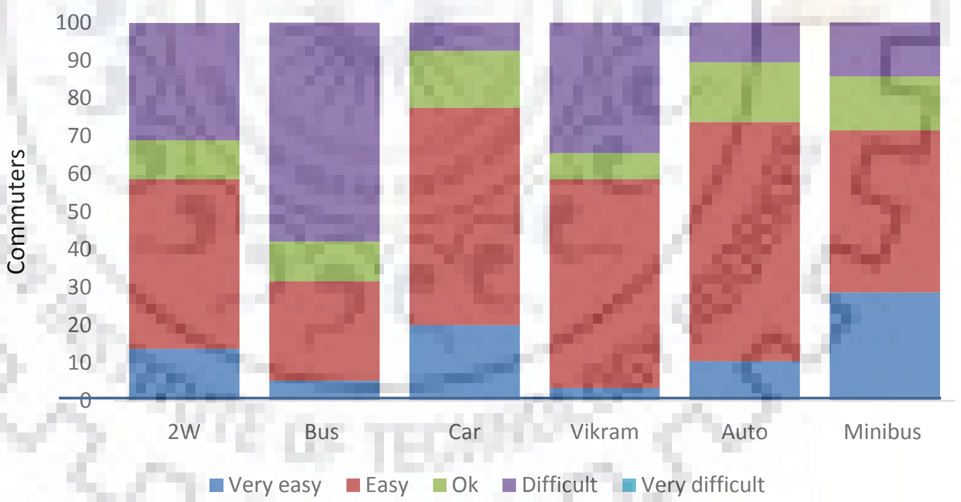


Figure 4.7: Level of Comfort and Usage of Different Mode

Figure 4.7 shows that about 58% of bus users are not comfortable in riding the bus and around 35% of user found difficulties in traveling by Vikram. Most of the peoples are comfortable in traveling by personal modes

f) Willingness to Pay for PT

Table 4.10 and Figure: 4.8 represent mode wise distribution of commuters and willingness to pay for a good public transport system. Of the surveyed respondents, commuters are willing to spend Rs. 10-20 for good public transportation modes. Majority of surveyed commuters, which are using 2-wheelers, Vikram, Bus, Auto and Minibus, willing to spend in the range of Rs. 10-15. Commuters traveling by car are willing to spend more. i.e. Rs. 30 or more. Although all commuters willing to spend a reasonable amount of money for a good public transportation system but vikram and buses plying on city roads are not reliable, comfortable and also lack in route coverage.

Table 4.10: Mode wise Distribution of Commuters and Willingness to Pay

Modes	Amount in Rs.				
	<10 Rs.	Rs 10 -15	Rs 15-20	Rs 20-30	>30
2W	17.2	41.4	27.6	10.3	3.4
Bus	21.1	68.4	10.5	0.0	0.0
Car	5.0	12.5	37.5	37.5	7.5
Vikram	27.6	62.1	10.3	0.0	0.0
Auto	10.5	31.6	42.1	15.8	0.0
Minibus	28.6	57.1	14.3	0.0	0.0

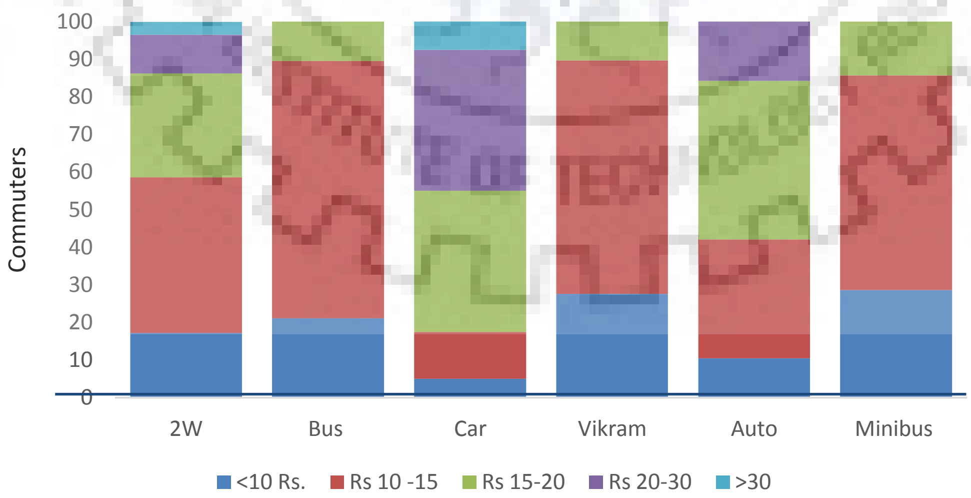


Figure 4.8: Mode Wise Distribution of Commuters and Willingness to Pay

J) Influencing factors while choosing a mode

All the survey participants were asked to provide scores against various critical factors that can influence the commuters to choose different transportation modes. Majority of the commuters indicated fare, availability, and frequency of services as the most critical decision-making criteria followed by special coverage, comfort and time.

Table 4.11: Factors Influencing Selection of Transportation Mode

Factors	Very important	Moderately important	Not important
Fare	75.2	24.8	0.0
Travel time	57.1	42.9	0.0
Riding comfort	60.5	39.1	0.4
Frequency of service	65.5	34.0	0.4
Availability of transport	66.4	33.6	0.0
Special coverage of mode	61.8	37.0	1.3

Survey participants were also asked about their opinion about the existing modes like autos, vikrams, bus and mini buses, their availability, and frequency. More than 50% of the users are satisfied with the availability of autos and vikrams but are not satisfied with the service of minibuses and buses plying in the city.

4.3.2.3 User opinion matrix

User opinion survey is very important to understand the importance and successfulness of the project in the city. In this section, users are asked to rate the strategies and their influencing factor on five points (1-5) rating scale, where 1 is the least important and 5 is extremely important as given below.

Scale	Least Important 1	Less Important 2	Average 3	More Important 4	Extremely Important 5

The survey participants rated each parameter against each strategy to assess the priority of each parameter in the social context. The Table-4.12 envisages the identified influencing parameters against each strategy and its rating result calculated by the formula mentioned in Equation (4.1)

$$\text{Rating average} = \frac{(W_1X_1+W_2X_2+W_3X_3\ .\ .\ .W_nX_n)}{X_t} \qquad \text{……….…….Eq (4.1)}$$

Where

n = Number of respondents

X_i = Number of responses for i^{th} parameter,

W_i = Weightage /Rating of i^{th} parameter

X_t = Total number of responses

The survey shows the social aspect of the stakeholders. According to the survey, Figure 4.10 indicates that pollution (air & noise) and congestion are the main issues in the city. To reduce the pollution in the city, public transport enhancement, transport management, non-motorized transport system, and alternative fuel and technology are most socially acceptable.

Table 4.12: Influencing Parameters against Each Strategy

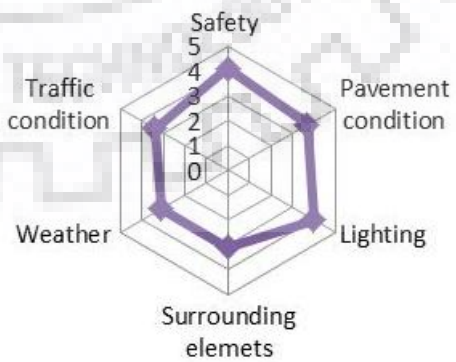
Strategy	Parameters	Rating Result	Result Chart
Pedestrian / Bicycle Track	Safety	4.1	
	Pavement condition	3.7	
	Lighting	4	
	Surrounding elements	3.1	
	Weather	3.1	
	Traffic condition	3.4	

Figure 4.9: Graphical Rating Representation of Influence on Parameters of Pedestrian/ Bicycle Track

Reduce adverse impact of transportation in the city	Reduced VMT	2.4
	Improve and encourage PT	2.7
	Visual surrounding	2
	Reduce congestion	2.8
	Reduce noise	2.7
	Reduce pollution	2.9

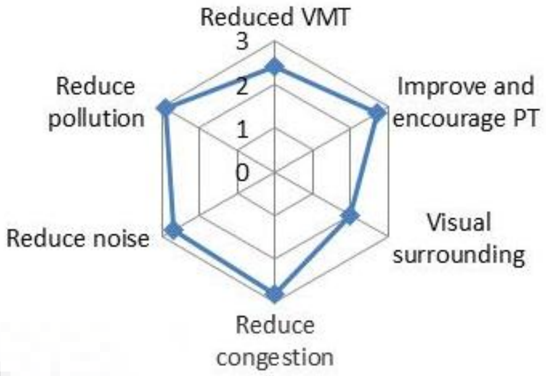


Figure 4.10: Graphical Rating Representation of Influence on Parameters to Reduce the Adverse Impact of Transportation in the City

Improve Safety (Reduce Accident)	Road condition& Road geometry	4
	Weather	3.1
	Street lighting	3.8
	Traffic condition	3.6
	Access control.	3.6
	Proper Signage's &ITS	3.6
	Speed reduction	3.9
	Safety protection	3.5

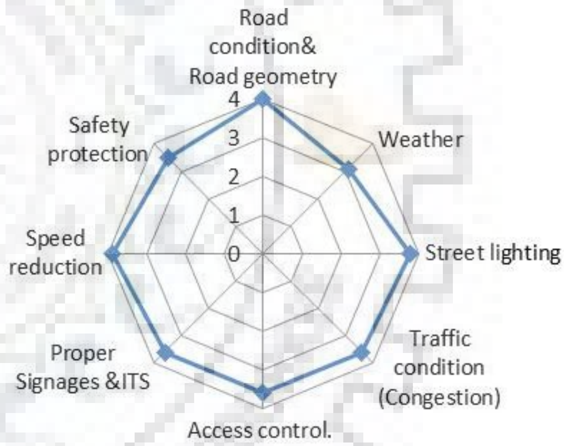


Figure 4.11: Graphical Rating Representation of Influence on Parameters to Improve Safety

Improve Public Transport system in the city	World class facility of PT	3.6
	Dedicated bus lanes	3.8
	Frequency of bus	*3.9*
	Cleanliness and comfort	*4.4*
	Safety and security	*4.5*
	Prioritization to bus at intersection	*4.1*
	Affordable transportation	*4.5*

	Accessible to all (children, elder, disable etc.)	*4.4*
	Integration of transport (Interchange terminals)	*3.8*
	Mix land use scheme	*3*
	Transit oriented development	*3*
	ATIS	2.9

Figure 4.12: Graphical Rating Representation of Measures to Improve Public Transport System

*ATS (Automated transport information system)

Measure to reduces private vehicles in the city	Increase parking fees	*3.6*
	Limited parking space in CBD	*3.8*
	Parking relocation	*3.4*
	Increase in taxes for private vehicles	*3.3*
	Cess on petrol	*5.4*
	Restrict motor vehicles in CBD.	*3.6*
	Subsidy for shared / public transport.	*3.8*
	Road congestion charging	*3.5*
	Integration of transportation	*3..6*

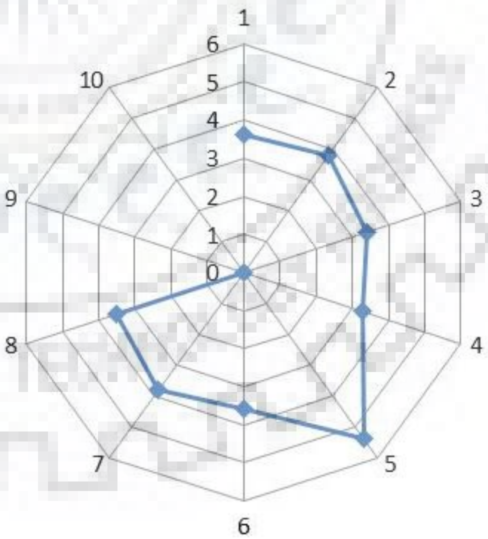


Figure 4.13: Graphical Rating Representation of Measure to reduces private vehicles in the city

Measures to improve pedestrian movement in the city		
	Pedestrian network	4.6
	Signage's and information to way finding	4.3
	Comfort and safety	4.5
	Shading trees and design.	4.1
	Street scape (street furniture and landscape)	5.4
	Barrier free design (accessible for disables)	3.6
	Pedestrian oriented land use planning (Reduction the distance between facilities.)	3.8
	Road congestion charging	3.5
	Integration of transportation	3.6

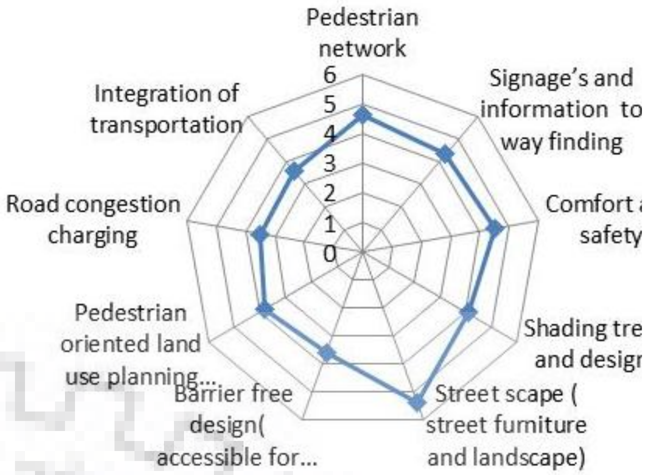


Figure 4.14: Graphical Rating Representation of Measures to Improve Pedestrian Movement in the City

Improve Non-Motorized transport movement in the city		
	Dedicated bicycle/NMT network	3.8
	Full service station	3.9
	Parking facilities open and covered (near transit also)	4.2
	Introduced innovative design to bicycle (electric bicycle) with music	4
	Subsidy or loan for bicycle	3.2
	Integrate with transit(cycle/transit integration)	3
	Traffic calming and vehicle restriction.	4.3

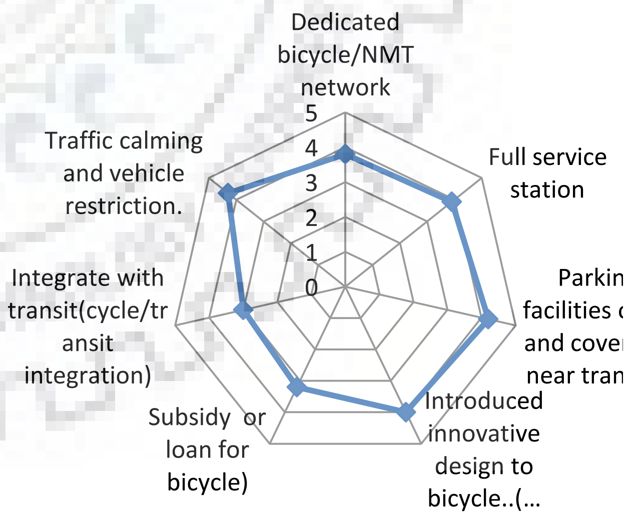


Figure 4.15: Graphical Rating Representation of Measures To Improve Non-Motorized Transport Movement In The

Measures to reduce air pollution in the city	Improvement in public transport	*4.5*
	Non-motorized transport planning	*4.2*
	Transportation system management	*4.5*
	Transit oriented development	*4*
	Measures to discourages use of private vehicle	*3.4*
	Cess and levy on fuel to use	*3.8*
	Alternate type of fuel	*3.8*
	Alternate type of engines in vehicles.	*4.5*
	Traffic calming and vehicle restriction.	*4.2*

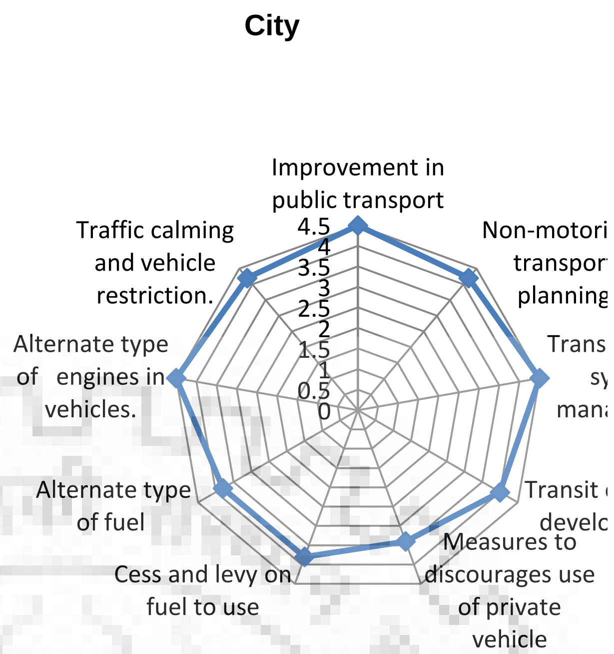


Figure 4.16: Graphical Rating Representation of Measures To Reduce Air Pollution In The City

Reduce Noise Pollution in The City	Vegetation along road	*4.2*
	Noise barrier	*4.4*
	Restriction of vehicles	*3.9*
	Vehicle design and maintenance	*4.7*
	Encourage public transport	*4.1*
	Limiting traffic speed	*4.3*
	Improve road condition	*4.7*

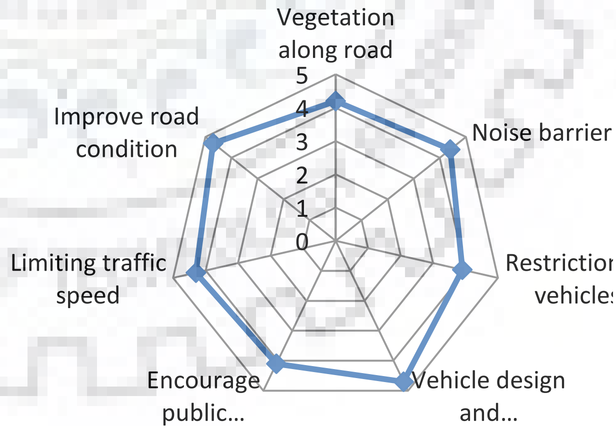


Figure 4.17: Graphical Rating Representation of Measures To Reduce Noise Pollution In the City

4.4. Result and Discussion

In user opinion survey analysis, the priority of each parameter against each strategic alternative was identified and quantified in the 5-point rating scale. It helped to identify user's social characteristics and behavior to prioritize various strategic alternatives for a sustainable transport solution. It would also help to manage the future transport problems in Dehradun city that may appear due to an increase in travel demand. From the survey it is evident that buses are mostly used by the students and due to inadequate public transport 3Wheelers and Car are the key transport modes for work and shopping purpose. Around 31% of the users have to spend more than Rs 50 for their trips and willing to pay a reasonable amount of money for good public transport system. Hence a reliable, comfortable and improved public transport with increased route coverage has to be introduced in the study area.

According to survey, from Figure 4.10 it is very clear that pollution (air and noise) and congestion are the main issues in the city. Figure 4.16 dictate that to reduce the air pollution in the city, public transport enhancement, transport management are most socially acceptable sustainable solution for Dehradun city followed by non-motorized transport system and alternative fuel and technology Whereas according to Figure 4.12 safety, cleanliness, comfort and affordability of PT are the main concern to users followed by priorities intersection for buses, increased bus frequency and dedicated bus lanes; to enhance the public transport operation. Non-motorized transport system can be successful by dedicated planned bikeways and bike design improvement and by providing proper parking lots near transit to encourage public transport as mentioned Figure 4.15. The Figure 4.9 envisages that user becomes more sensitive towards environment, comfort, and safety when walking on pathways. As per Figure 4.14, proper pathway network with streetscape and adequate signages are primary concern to improve the pedestrian movement, and while moving on the road, road condition and vehicle speed are major responsible factors to improve the safety as shown in Figure 4.11. As per Figure: 4.13, fiscal measures like cess on fuel and parking charges should also are applied to discourage the use of private vehicles. The Figure 4.17 elucidate that to reduce noise pollution in the city, there is a need to improve road condition and vehicle design first then after noise barrier works fast. Nevertheless, now the public becomes more sensitive and aware towards sustainability.

4.5 Summary

Due to the heterogeneity of the transport system and different technology background, society needs more indigenous and integrated plan for sustainable urban mobility. This study optimizes the urban mobility parameters. All possible sustainable urban transport scenario/strategies are not acceptable by each group of society because of their different culture and background that will ultimately effect on the success of plan and strategy. So for sustainable urban mobility, all plan, project, and strategies should be socially acceptable. These studies elucidate the user acceptance towards each parameter. According to that, a framework of short, medium and long term strategies and guidelines can be prepared as per their rating assessment.

CHAPTER 5

EVALUATION OF SUSTAINABLE TRANSPORT STRATEGIES

5.1 Introduction

It is crucial to evaluate all possible alternatives for developing urban transport to create value for all stakeholders in a sustainable manner. Based on the literature review and initial user survey, six alternatives were selected to identify the most sustainable transport solution for the Dehradun city. Each alternative strategy was evaluated against main decision criteria and sub-criteria by using multi-criteria decision approach named “Analytical Hierarchy Process” (AHP).

5.2 Analytics Hierarchy Process (AHP)

AHP is a technique that is used for decision making in complex situations where multi-criteria are considered for the evaluation and priortization of various alternatives. It is the most appropriate tecnique for the assessment of various alternative strategies for the sustainable transport solutions as it takes into account of tangible and intangible aspects of decision problem. The capability to transform empirical data into numerical values is key differentiating factor that separates AHP from other comparing techniques. In this technique, the decision problem is decomposed into hierarchal structure of different criteria so that it can be easily analyzed and compared independently. This hierarchal structure help to assess the various alternatives by making pair-wise comparisons for each of the chosen criteria. Figure 5.0(a) represents the hierarchial structure of AHP concept.

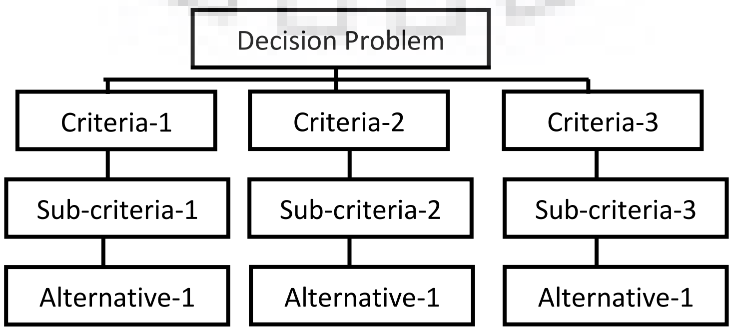


Figure 5.0 (a): Hierarchial Structure of AHP

After completion of all the comparisons, the relative weights between each of the criteria are evaluated to calculate the probability of each alternative. The significance of probability indicates the likelihood of that alternative to meet desired objectives.

A set of pairwise comparison matrices (size $n \times n$) is constructed for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement. There are n(n-1)/2 judgments required to develop the set of matrices in level 3. Reciprocals are automatically assigned in each pair-wise comparison.

Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows: $CI = (\lambda_{max} – n) / (n-1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in mentioned below in Table 5.0 . The CR is acceptable if it does not exceed 0.10.

Table 5.0 : Random Consistency

Size of materix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.42	1.45	1.49

Normalized values are calculated for each criteria/alternative and decision is made based on normalized values.

5.3 Alternatives, Criteria and Sub-Criteria

Based on the initial user survey and literature review, following six key alternative strategies were identified for the design of most sustainable transport solution for the Dehradun city.

- Improving public transport (PT)
- Enhancement of non motorized transport (NMT)
- Pedestrian facility (PF)
- Transit oriented development (TOD)
- Reduction of car usage (CU)
- Alternative fuel and technology (AFT)

5.3.1 Core Criteria

Each alternative strategy needs to be evaluated on tripple bottom line. i.e Economic, Social and Environmental parameters to create value in a most sustinable manner. The sustainability of transport solution is measured by its system effectiveness and efficiency along with environmental and climate impacts of the system. For the identification of most sustainable transport solutions for Dehradun city, all the economic, social and enviromental aspects of each alternative strategy were studied and evaluated with the help of experts and users. Along with these three dimesions, it is also important to understand the risks associated with sustainability of transport solutions as it addresses risks associated with project delays, cost-overruns and other operational risks in project execution. Risk to sustainabily will be judged on proposals, risk to operation, its implementation and construction, etc. The framework of risks to sustainability is adopted from Asian Development Bank 2010 report for appraisal of sustainability framework for transport.

All the alternative strategies were evaluated against each core decision criteria. i.e. economical, social, environmental and risk to sustainability. Table 5.1 represents the description of core criteria: Economic effectiveness, social sustainability,and envirnmental sustainabilty,risk to sustainability.

Table 5.1: Core Criteria

Economic effectiveness

- Economic effectiveness refers to both the significance of the expected economic impacts over the life cycle of a project or program, and the efficiency with which economic resources are used to deliver them.

Social Sustainability

- Poverty and social sustainability describes extent to which project impacts will accrue to the poor, and those vulnerable and discriminated against, and will be used to strengthen social cohesion and safety, and the degree of stakeholder participation

Environment sustainability

- Environmental Sustainability describes the net contribution to reducing transport emissions and pollution, conserving the natural and built environment, minimizing wasteful use of natural resources, and increasing the resilience to climate effects.

Risk to sustainability

- Risk to sustainability measures the risk that expected impacts may not be realized or maintained because of weak institutions, lack of financing, or simply uncertainty in the forecasts.

All the alternative strategies were tested on core sustainable transportation criteria (Economical, Social and Environmental) by conducting survey.

5.3.2 Identification of Sub Criteria

In order to identify the sub-criteria under each core criteria, 55 design criteria have been identified from various past research on sustainable transport.Although all these criteria meet the 3 dimensions of sustainability however not to same extent for each dimension of sustainability. Subsequently a survey was conducted with relevant stakeholders(academia, scholars, urban & transport planners and designers) from different industries with an objective to identify key sub-criteria and their relative importance to all three core sustainable criteria. The respondents of this survey were 60 experts. The questionnaire(Annexure-IV) survey was conducted with the objective to obtain the judgments on the relative importance of the criteria.The sample distribution of all respondant are shown in Figure 5.0. All the respondents were asked to provide percentage weight to economic, social and environmental criteria along with ranking of the 55 sub-criteria on a scale of 1-5 (1 being strongly disagreed and 5 being strongly agreed).

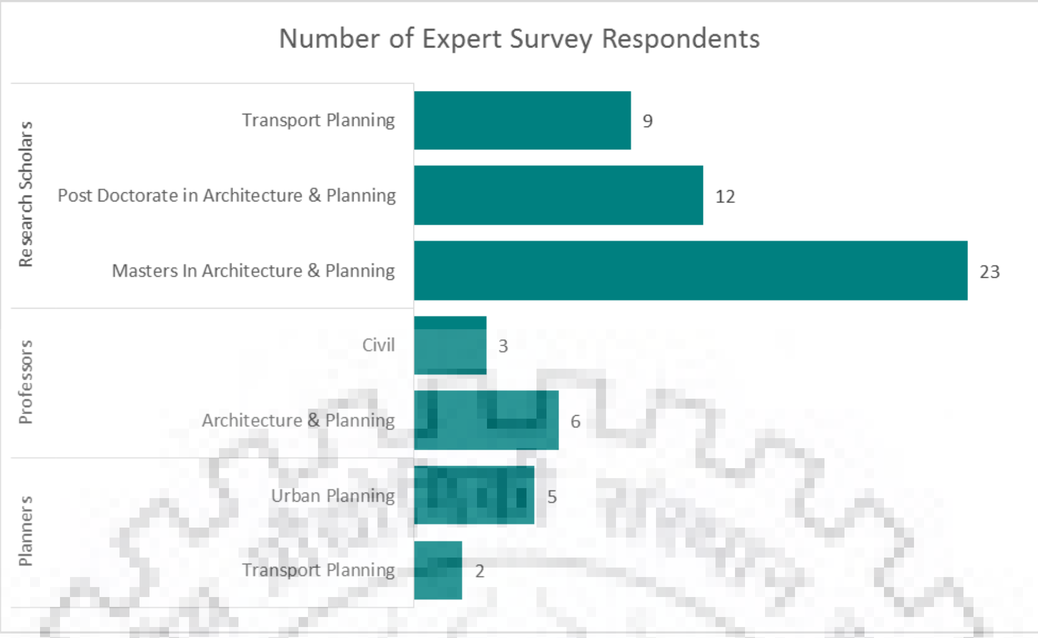


Figure 5.0: Sample Distribution of Stakeholders

The weighted mean score (W.M.S) was calculated for each design sub-criteria by using sub-criteria rank scores and percentage ratings for sustainable criteria by Equation 5.1(Annexure-V). The WMS of all design sub-criteria is shown in Table 5.2 mentioned below.

W.M.S = (RiEc x % Ec + RiEn x % En + RiSo x % So)/ (RiEc + RiEn +RiSo)……..Eq.(5.1)

where

Ri represents stakeholder survey respondent

RiEc represents score provided by survey respondent for economical criteria

RiEn represents score provided by survey respondent for environmental criteria

RiSo represents score provided by survey respondent for social criteria

Ec represents economical factor weightage

En represents environmental factor weightage

So represents social factor weightage

All the sub-criteria were then ranked by calculated weighted mean scores to identify the importance of each sub-criteria for the design of sustainable transport solution in Dehradun City.

Table 5.2: Weighted Mean Scores Obtained from Expert Survey

Sustainable Design Sub-Criteria	Mean Average
Provision of basic public facilities (school, health care, and sport facility)	3.83
Diversity in Transportation Modes (Walking/Cycling/Ride sharing /Public Transportation etc.)	3.77
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	3.72
Mobility management (a network that allows working of mobile phones) to address problems and increase transport system efficiency	3.67
Per capita fossil fuel consumption, and emissions of CO_2 and other climate change emissions	3.67
Portion of travel to school and other local destinations by walking and cycling	3.67
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	3.66
Access to work	3.65
Access to transit	3.65
GPS System	3.63
User satisfaction for the current transport system	3.62
Alternate use of fuel	3.62
% of travel by various efficient travel modes	3.61
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	3.59
Commute time	3.59
Land use planning for more acessible multi-modal communities	3.58
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area	3.57
Security against crimes	3.54
Provision of Trees and Planters	3.53
Resource efficiency - Non-renewable resource consumption in the	3.52

production and use of vehicles and transport facilties	
Dedicated Bus lane and stations (BRTS)	3.51
Land use impacts - Per capita land devoted to transportation facilities	3.50
Per capita emissions of air pollutants (CO, VOC, Nox, particulates, etc.)	3.49
Noise Pollution - Portion of the population exposed to high levels of traffic noise	3.48
Efficient Pricing and Prioritization (Roads/Parking/Insurance/Fuel etc)	3.48
Convenience efficiency and safety of public transport users	3.47
Quality of transport services for commercial users	3.47
Per capita motor-vehicle mileage in urban area	3.46
Water pollution - per capita vehicle fluid losses	3.45
Vehicle speed	3.43
Road safety, capacity, traffic signal and street lighting	3.43
Availability of street furniture	3.43
Air Pollution - frequency of air pollution standard violations	3.42
Per capita expenditures on roads, parking and traffic facilities	3.42
Per capita traffic congestion delay	3.41
Habitat protection	3.41
Habitat fragmentation	3.37
Per capita fatalities and injuries	3.35
Availability of appropriate electronic communication facility (Internet service)	3.33
Cultural preservation	3.33
Quantity and quality of delivery services	3.31
User rating	3.31
Community involvement in decision making	3.29
Inclusive planning to include disadvantaged and vulnerable groups	3.29
Per capita crash costs (costs associated with accidents)	3.29
Convenience efficiency and safety of drivers	3.29
Driver education and behaviour	3.27
Convenience efficiency and safety of pedestrains	3.25
Priority signal system for the public transportation	3.24
Affordability - Portion of budget spent on transport by lower income households	3.22

Affordability - Portion of household budget devoted to transport	3.14
Freight Efficiency - Speed and affordability of freight and commercial transport	3.12
Quality of transport facilities and services for disabled, elderly or children	3.11
Individual cost expenditure on transport	3.06
Appearance of Pedestrian Routes	3.00

As survey respondents also ranked each sub-criteria on a scale of 1-5 against each core design criteria. i.e. economic, social and environmental.These scores were used to identify sub-criteria, important to each sustainable core design criteria and showed in Table 5.3, 5.4 and 5.5. All the sub-criteria were ranked and categorized into core sustainable design criteria on the basis of calculated weighted mean score as mentioned in previous Table 5.1

Table 5.3: Economical Sub-Criteria Ranked by Weighted Mean Scores

S.No.	Economical Sub-Criteria	Mean Average
Ec1	% of travel by various efficient travel modes	3.61
Ec2	Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	3.59
Ec3	Land use planning for more accessible multi-modal communities	3.58
Ec4	Establishment of local business activities (retail, shop, bank, etc.) in the vicinity of residential area	3.57
Ec5	Land use impacts - Per capita land devoted to transportation facilities	3.50
Ec6	Efficient pricing and prioritization (Roads/Parking/Insurance/Fuel etc)	3.48
Ec7	Quality of transport services for commercial users	3.47
Ec8	Per capita motor-vehicle mileage in urban area	3.46
Ec9	Per capita expenditures on roads, parking and traffic facilities	3.42
Ec10	Per capita crash costs (costs associated with accidents)	3.29
Ec11	Affordability - portion of budget spent on transport by lower income households	3.22
Ec12	Affordability - portion of household budget devoted to transport	3.14
Ec13	Freight efficiency - Speed and affordability of freight and commercial transport	3.12
Ec14	Individual cost expenditure on transport	3.06

Table 5.4: Social Sub-Criteria Ranked by Weighted Mean Scores

S.No.	Social Sub-Criteria	Mean Average
S1	Provision of basic public facilities (school, health care and sports facility)	3.83
S2	Diversity in transportation modes (Walking/Cycling/Ride-sharing/Public Transportation etc.)	3.77
S3	Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	3.72
S4	Mobility management (the network that allows the working of mobile phones) to address problems and increase transport system efficiency	3.67
S5	Portion of travel to school and other local destinations by walking and cycling	3.67
S6	Intelligence Transport System (ITS) technology (such as tracking exact time of arrival or departure of public transport vehicles)	3.66
S7	Access to work	3.65
S8	Access to transit	3.65
S9	GPS system	3.63
S10	User satisfaction for the current transport system	3.62
S11	Commute time	3.59
S12	Security against crimes	3.54
S13	Dedicated bus lane and stations (BRTS)	3.51
S14	Convenience efficiency and safety of public transport users	3.47
S15	Road safety, capacity, traffic signal and street lighting	3.43
S16	Availability of street furniture	3.43
S17	Per capita traffic congestion delay	3.41
S18	Per capita fatalities and injuries	3.35
S19	Availability of appropriate electronic communication facility (Internet service)	3.33
S20	Cultural preservation	3.33
S21	Quantity and quality of delivery services	3.31
S22	User rating	3.31

S23	Community involvement in decision making	3.29
S24	Inclusive planning to include disadvantaged and vulnerable groups	3.29
S25	Convenience efficiency and safety of drivers	3.29
S26	Driver education and behaviour	3.27
S27	Convenience efficiency and safety of pedestrians	3.25
S28	Priority signal system for public transportation	3.24
S29	Quality of transport facilities and services for disabled, elderly or children	3.11
S30	Appearance of pedestrian routes	3.00

Table 5.5: Environmental Sub-Criteria Ranked by Weighted Mean Scores

S.No.	**Environmental Sub-Criteria**	**Mean Average**
En1	Per capita fossil fuel consumption, and emissions of CO_2 and other climate change emissions	3.67
En2	Alternate use of fuel	3.62
En3	Provision of trees and planters	3.53
En4	Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilities	3.52
En5	Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.)	3.49
En6	Noise pollution - portion of population exposed to high levels of traffic noise	3.48
En7	Water pollution - per capita vehicle fluid losses	3.45
En8	Vehicle Speed	3.43
En9	Air pollution - Frequency of air pollution standard violations	3.42
En10	Habitat protection	3.41
En11	Habitat fragmentation	3.37

Further, correlation analysis were performed to understand the relationship among various sub-criteria for each sustainable core criteria. All key sub-criteria for each sustainable factors were identified and co-merged on the basis of their correlation coeficients. (Annexure VI)

5.3.2.1 Correlation Analysis of Economical Design Sub-Criteria

While performing correlation analysis for various sub-criteria for economical design criteria, it was obseved that sub-criteria number En11, En12, En13, and En14 had strong correlation as per matrix Table 5.6 shown below;

Table 5.6 : Correlation matrix of Economic Design Sub –Criteria

	Ec11	Ec12	Ec13	Ec14
Ec11	1	0.639	0.580	0.561
Ec12	0.639	1	0.681	0.803
Ec13	0.580	0.681	1	0.630
Ec14	0.561	0.803	0.630	1

As these sub-criteria were related to the affordability of transport system so these were replaced by single sub-criteria "Affordability of transport systems for businesses".

Other sub-criteria Ec8, Ec9, and Ec10 had strong correlation as per matrix Table 5.7 shown below. As these sub-criteria associated with the expenditures for the benefits for taxpayers so these can be replaced by single sub-criteria "Transport incentives for taxpayers"

Table 5.7 : Correlation matrix of Economic Design Sub -Criteria

	Ec8	Ec9	Ec10
Ec8	1	0.658	0.687
Ec9	0.658	1	0.748
Ec10	0.687	0.748	1

Other sub-criteria Ec1 and Ec6 were associated with the mobility and efficiency of transport modes so these sub-criteria were combined together and replaced by single sub-criteria "People's mobility and accessibility to efficient transportation modes".

Few other sub-criteria Ec2, Ec3, Ec4, and Ec5 have also presented the similar factors associated with the efficient land use planning so these were replaced by single sub-criteria “Land use planning or integrated transport systems planning for the economic development of the region”

5.3.2.2. Correlation analysis of Social Design Sub-Criteria

While performing correlation analysis for various sub-criteria for social design criteria, it was observed that sub-criteria number S12, S14, S25, S26 and S27 had strong correlation as per matrix Table 5.8 shown below:

Table 5.8 : Correlation Matrix of Social Design Sub –Criteria

	S12	S14	S25	S26	S27
S12	1	0.754	0.814	0.667	0.738
S14	0.754	1	0.878	0.677	0.855
S25	0.814	0.878	1	0.743	0.819
S26	0.667	0.677	0.743	1	0.638
S27	0.738	0.855	0.819	0.638	1

As these sub-criteria were associated with the safety and security of commuters so these were replaced by single sub-crtiteria “Safety and Security of transport users”.

Sub-criteria S24 and S29 had a correlation as per matrix Table 5.9 shown below. As these criteria were associated with the inclusion of disadvantaged group people so these sub-criteria were relplaced by single sub-criteria “Inclusive planning to include disadvantaged and vulnerable groups”.

Table 5.9 : Correlation matrix of Social Design Sub -Criteria

	S24	S29
S24	1	0.599
S29	0.599	1

Other sub-criteria S1 and S23 were associated with the basic accessibilities and inclusion of community folks in the overall decision-making process so these sub-criteria were merged together and replaced by single sub-criteria “Provision of basic accessibilities (healthcare/education) and community involvement in decision making”.

Sub-criteria S5, S6, S7, S8, S9, S10, S11, S17, S19, and S28 were all related to the use of technological solutions to improve convenience efficiency of transport users. So, these were also merged together and replaced by single sub-criteria "Convenience efficiency for transport users by utilizing new technologies. i.e. ITS".

Few other sub-criteria S2, S3, S4, S13, S15, S21, S22, and S30 also fall under various modes of transportation so these were bundled together and replaced by single sub-criteria "Availability of a diverse range of transportation modes (Walking/Cycling/Ridesharing/Public Transportation, etc.)".

5.3.2.3 Correlation analysis of Environmental Design Sub-Criteria

While performing correlation analysis for various sub-criteria for environmental design criteria, it was observed that sub-criteria number En5, En6, En7, and En9 were all related to environment protection with respect to air, water and noise and highly correlated as per matrix Table 5.10 shown below;

Table 5.10: Correlation Matrix of Environmental Design Sub -Criteria

	En5	En6	En7	En9
En5	1	0.838	0.763	0.824
En6	0.838	1	0.884	0.866
En7	0.763	0.884	1	0.887
En9	0.824	0.866	0.887	1

As En5, En6, En7, and En9 were highly correlated so these sub-criteria were merged together and replaced by single sub-criteria "Environment protection and control on account of transportation including air, water and land pollution".

Other sub-criteria that were observed with strong correlation were En2, En3, and En8 as per matrix shown in Table 5.11.

Table 5.11 : Correlation Matrix of Environmental Design Sub –Criteria

	En2	En3	En8
En2	1	0.741	0.649
En3	0.741	1	0.637
En8	0.649	0.637	1

As these sub-criteria were associated with identifying alternative ways of energy to improve environment and vehicle emissions. So these were replaced by single sub-criteria "Use of alternative sources of energy to design sustainable transport systems".

Two more sub-criteria for environmental core design criteria were highly correlated as per matrix Table 5.12 shown below;

Table 5.12 : Correlation matrix of Environmental Design Sub -Criteria

	En10	*En11*
En10	1	0.778
En11	0.778	1

Both En10 and En11 sub-criteria were related to the preservation of natural habitats. so these were replaced by single sub-criteria "Preservation of natural habitat".

All the surveyed sub-criteria against each sustainable core design criteria were reviewed and revised into a more refined list of sub-criteria that represented all aspects of requirements of sustainable transport solutions. Risk of sustainability is another dimention add to this framework to evaluate the strategies.Table 5.13 gives an overview of all core criteria and sub criteria.The Figure 5.1 presents the conceptual hierarchical framework where each core dimensions constitute 5 sub criteria under them. And risk to sustainability has 3 sub criteria related to operation , implementation and cost return etc.

Table 5.13 : Overview of All Criteria and Subcriteria

Economical effectiveness	**Eco 1**	People's mobility and accessibility to efficient transportation modes
	Eco 2	Affordability of transport systems for businesses
	Eco 3	Quality of transport facilities and services
	Eco 4	Transport incentives for taxpayers
	Eco 5	Land use planning or Integrated transport systems planning for economic development of region

Social sustainability	**Soc 1**	Provision of basic accessibilities (healthcare / education) and community involvement in decision making
	Soc 2	Convenience efficiency for transport users by utilizing new technologies. i.e. ITS
	Soc 3	Availability of diverse range of transportation modes (Walking/Cycling/Ride sharing/Public Transportation etc.)
	Soc 4	Safety and security of transport users
	Soc 5	Inclusive planning to include disadvantaged and vulnerable groups

Environmental sustainability	**Env 1**	Reduction of per capita fossil fuel consumption, and emissions of CO_2 and other climate change emissions such as green house gases
	Env 2	Environment protection and control on account of transportation including air, water and land pollution
	Env 3	Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilities
	Env 4	Use of alternative sources of energy to design sustainable transport systems
	Env 5	Preservation of natural habitat

Risk to sustainability	**Risk 1**	Risks associated with the design & evaluation of sustainable transport systems
	Risk 2	Risks associated with the implementation of sustainable solutions for the urban transport
	Risk 3	Risks associated with the transport operational services

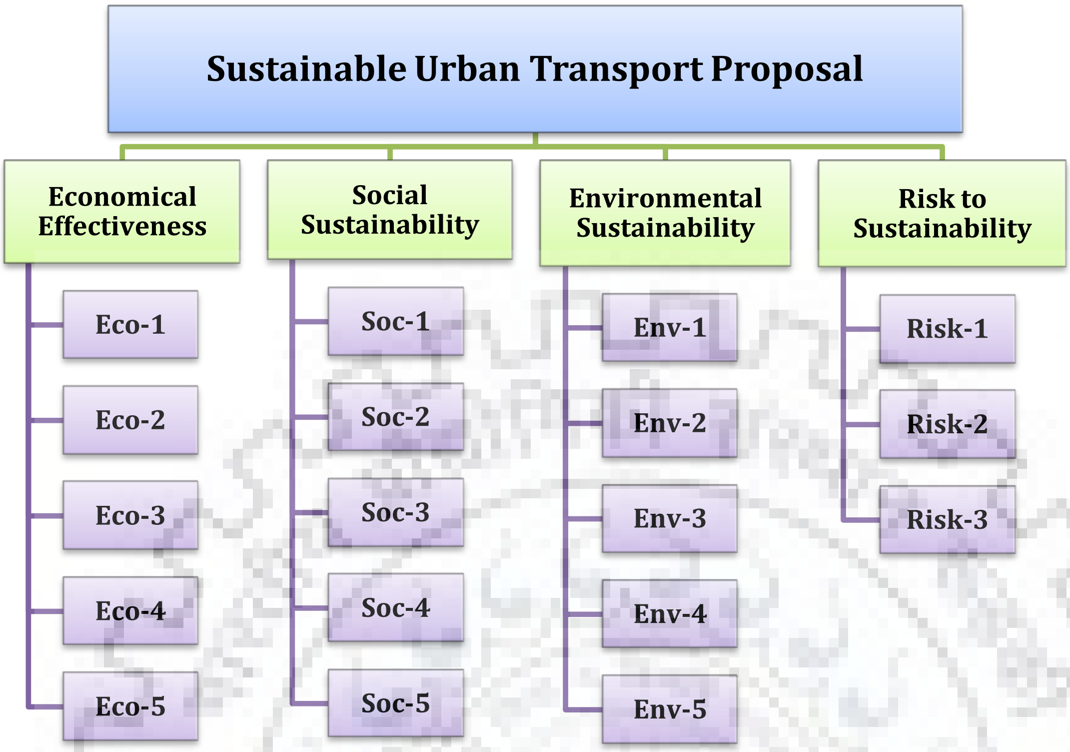


Figure 5.1: Conceptual Framework for Evaluation of Strategies

5.4 Evaluation of Alternative Strategy

For the evaluation of identified alternative strategies, a Multi-criteria decision analysis method, Analytical Hierarchy Process (AHP) methodology was employed to quantify the benefits of each alternative in consideration of sustainable practices. Figure 5.2 describe the process of evaluation.

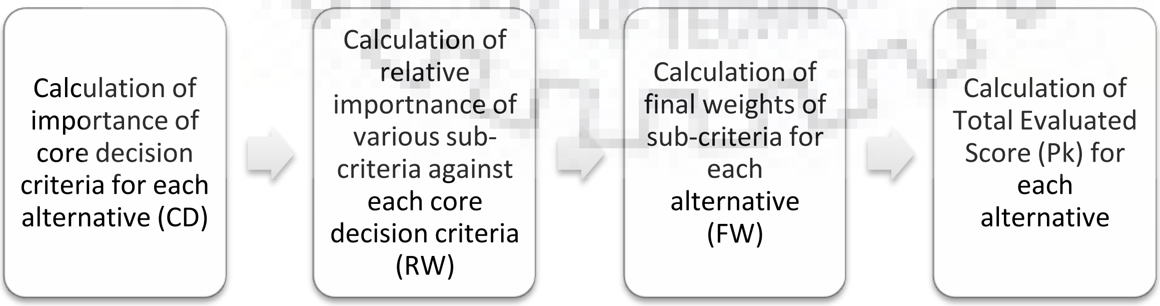


Figure 5.2: Process of Evaluation of Alternative Strategies

The Total Evaluated Score (Pk) for each alternative was calculated using the formula as shown in Equation (5.2).

$$P_k = \sum_j W_j \, x \, S_{kj} \qquad \text{..............................Eq. (5.2)}$$

Where,

P_k = Urban transport proposal;

W_j = Final Weight of criterion j in level 3;

S_{kj} = Score of proposal k on criterion j (j= 18 criteria)

5.4.1 Data Collection

In order to obtain the necessary criteria weight to this application, the sets of surveys were conducted to elicit distributional judgments from relevant groups of experts. This group includes transport specialists, Transport Planners, Transport-related Academic scholars, architects, environmentalist, Urban planner, Property dealers, etc. with minimum of 10 years of experience in their fields except research scholars .Total 23 respondents participated in this survey. The structured questionnaire(Annexure VII) was framed and the experts were individually interviewed for judgments. The questionnaire contained two parts; First part has personal information of respondents. It includes their name , Field of specialization, education, experience and awareness towards sustainability. The second part consists of pairwise comparison of relative importance question on core criteria and sub-criteria. As per Table 5.13 each core criteria has 5 sub-criteria so as per method (n (n-1)/2), 10 pairwise comparisons are made in each core criteria and for each alternate strategy. First the expert has to rate core criteria with respect to alternate strategy (means up to which extent this criteria is responsible for alternate strategy) and then rate sub criteria with respect to respective core criteria on nine- point scale as mentioned in Table 5.15. During the process, each expert is asked to make a judgment on the relative importance of core criteria and sub criteria on 9 point scale .Before commencement of the judgment on sub-criteria, it was ensured that the experts have got the concept of pairwise judgments, as described in questionnaire Annexure-VII. At each level of hierarchy the pairwise comparison of relative importance of criteria has been done and presented in the matrix with corresponding CR value that should be <0.10. Figure 5.5 presents the structure of SUTSF (Sustainable urban transport solution framework) model following the AHP procedure for alternate strategies. The base case of the evaluation process of alternative strategy – Enhancing Public Transport (PT) is explained in the following steps;

Process Step 1: Calculation of importance of core decision criteria for each alternative (CD)

Process Step 2: Calculation of relative importance of various sub-criteria against each core decision criteria (RW)

Process Step 3: Calculation of final weights of sub-criteria for each alternative (FW)

Process Step 4: Calculation of Total Evaluated Score (Pk) for each alternative

5.4.2 Calculation of Importance of Core Decision Criteria for Each Alternative (CD)

Based on the expert survey, each alternative strategy was evaluated against four core decision criteria (Economical, Social, Environmental and Risks to Sustainability) and Eigenvector values are calculated to quantify the importance of these core decision criteria by excel based software. Table 5.14 shows the pairwise comparison matrix of core criteria with respect to the alternate strategy-enhancing public transport. This revealed that alternate strategy is responsible for environment sustainability most than social and economic and risk respectively.

Table 5.14 Pairwise Comparison Matrix of Core Decision Criteria With Respect to Strategy

	Economical	Social	Environmental	Risk to sustainability	Eigen vector
Economical	1	0.979	0.911	1.277	0.257
Social	1.022	1	0.931	1.305	0.262
Environmental	1.098	1.074	1	1.408	0.281
Risk to sustainability	0.783	0.766	0.713	1	0.200
				CR	0.0

5.4.3 Calculation of Relative Importance of Various Sub-Criteria against Each Core Decision Criteria (RW)

The Second section of the questionnaire survey was conducted with experts to identify the importance of various sub-criteria against each core decision criteria for six alternative strategies. All the survey respondents evaluated various sub-criteria based on the scale of 0-9 (as shown below in Table-5.15)

Based on the average score of various sub-criteria, the relative importance of the pairwise comparison matrix of sub-criteria was developed to calculate Eigenvector values CR value for each sub-criterion against core decision criteria for six alternative strategies. Table 5.16, 5.17, 5.18, 5.19 are representing pairwise comparison matrix of sub-criteria with respect to economic sustainability, social sustainability, environmental sustainability, and risk to sustainability respectively with acceptable level of CR i.e. <0.10.

Table 5.15: Pair-Wise Comparison Scale for AHP Preference

Importance	Definition	Explanation
1	Equal importance	The two criteria are being compared are of equal importance to choosing sustainable urban transport.
3	Moderate importance	Experience and judgments slightly favor one criterion over another.
5	Strong importance	Experience and judgments strongly favor one criterion over another
7	Very strong importance	Criterion is favored strongly over another
9	Overwhelmingly more important	The evidence favoring one criterion over another is the highest possible order of affirmation.
2,4,6,8	Intermediate values to represent the shades of judgment between the five basic assessment above	There may be times when experience and judgment may not render one criteria comparable to another in accordance with the five scale above instead a middle value between two scales may be more appropriate.

Source: Saaty, 1980

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Table 5.16: Pairwise comparison matrix of sub-criteria with respect to Economic Effectiveness

	Eco 1	Eco 2	Eco 3	Eco 4	Eco 5	Eigenvector
Eco 1	1	0.833	1.019	0.639	0.907	0.227
Eco 2	1.200	1	1.222	0.767	1.089	0.190
Eco 3	0.982	0.818	1	0.627	0.891	0.232
Eco 4	1.565	1.304	1.594	1	1.420	0.145
Eco 5	1.102	0.918	1.122	0.704	1	0.206
					CR	0.0

Note: Eco1- People mobility and accessibility to efficient transport mode, Eco 2- Affordability of transport system for business, Eco 3- Quality of transport facilities and services, Eco 4- Transport incentives for tax payers, Eco 5- Integrated transport system planning,

Table 5.17: Pairwise comparison matrix of sub-criteria with respect to Social Sustainability

	Soc 1	Soc 2	Soc 3	Soc 4	Soc 5	Eigenvector
Soc 1	1	0.750	0.905	0.879	0.776	0.232
Soc 2	1.333	1	1.207	1.172	1.035	0.174
Soc 3	1.105	0.829	1	0.971	0.857	0.209
Soc 4	1.137	0.853	1.029	1	0.882	0.204
Soc 5	1.288	0.967	1.167	1.133	1	0.180
					CR	0.0

Note: Soc 1- Provision of basic accessibilities and community involvement, Soc 2- Convenience efficiency for transport users by utilising new technology, Soc 3- Availability of a diverse range of transportation modes, Soc 4- Safety and security of transport users,

Soc 5- Inclusive planning to include disadvantaged and vulnerable groups.

Table 5.18: Pairwise comparison matrix of sub-criteria with respect to Environmental Sustainability

	Env 1	Env 2	Env 3	Env 4	Env 5	Eigenvector
Env 1	1	1.160	0.960	0.990	0.980	0.197
Env 2	0.86	1	0.828	0.853	0.845	0.23
Env 3	1.04	1.21	1	1.031	1.021	0.189
Env 4	1.01	1.17	0.97	1	0.990	0.195
Env 5	1.02	1.18	0.98	1.01	1	0.192
					CR	0.0

Note: Env 1- Reduction of GHG emission, Env 2- Environment protection, Env 3- Resource Efficiency, Env 4- Use of alternative source of energy, Env 5- Preservation of natural habitat

Table 5.19: Pairwise comparison matrix of sub-criteria with respect to Risks to Sustainability

	Risk 1	Risk 2	Risk 3	Eigenvector
Risk 1	1	1.103	0.846	0.340
Risk 2	0.91	1	0.767	0.374
Risk 3	1.18	1.30	1	0.286
			CR	0.0

Note: Risk 1 - Risk Associated with design and evaluation, Risk 2 - Risk associated with implementation of project, Risk 3 - Risk associated with transport operational services.

5.4.4: Calculation of Final Weights of Sub-Criteria For Each Alternative (Fw)

The final weights of sub-criteria were calculated by the following equation

Final Weight **(FW)** = Relative Weights **(RW)** x Core Criteria **(CD)** x Score Point **(S)**

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The score point (S) was calculated by weighted average of end user responses against each sub-criterion are mentioned in Table 5.20. A Stakeholder survey is carried out among 100 stakeholders out of which 92 responses are valid response here users are asked to rate each sub criteria on 1,3,5,7,9 rating scale where 1 is the least important criteria for core criteria of proposed alternative and average score point is calculate by Equation (4.1). Table 5.21 represents the result of final weight calculation. Where final weight is derived by multiplying the weight of core criteria, relative criteria, and score point.

Table 5.20: Average Score Point Result with Respect of Criteria

Sub-Criteria		1	3	5	7	9	Number of Users	Score Point (S)
People mobility and accessibility to efficient transport mode	ECO-1	0	0	12	56	24	92	7.3
Affordability of transport system for business	ECO-2	0	12	24	44	12	92	6.2
Quality of transport facilities and services	ECO-3	0	0	24	40	28	92	7.1
Transport incentives for tax payers	ECO-4	12	12	28	32	0	92	4.5
Integrated transport system planning,	ECO-5	4	8	24	44	12	92	6.1
Provision of basic accessibilities and community involvement	SOC-1	0	0	20	24	48	92	7.6
Convenience efficiency for transport users by utilising new technology	SOC-2	0	8	24	48	12	92	6.4
Availability of diverse range of transportation modes	SOC-3	0	0	12	56	24	92	7.3
Safety and security of transport users,	SOC-4	8	0	20	20	44	92	7.0
Inclusive planning to include disadvantaged and vulnerable groups	SOC-5	0	20	28	36	8	92	5.7
Reduction of GHG emission	ENV-1	0	8	20	20	36	92	6.4
Environment protection	ENV-2	8	0	20	16	48	92	7.1
Resource Efficiency	ENV-3	8	8	12	32	32	92	6.6
Use of alternative source of energy	ENV-4	0	24	12	28	28	92	6.3
Preservation of natural habitat	ENV-5	0	8	4	60	20	92	7.0
Design and Evaluation Risk	RISK-1	28	44	8	0	0	92	2.2
Implementation Risk	RISK-2	44	12	40	0	0	92	3.0
Operational sustainability Risk	RISK-3	52	24	16	0	0	92	2.2

The final weight of the strategy has been calculated by Equation (5.3)

Final Weights (FW) = RW x CD X S…………………………… …Eq.(5.3

Table 5.21 Final Weight Calculation

Enhancing Public Transport						
	CD		RW	W	S	FW
Economical effectiveness	0.2568	Eco 1	0.2274	0.0584	7.2	0.4205
		Eco 2	0.1902	0.0488	6.0	0.2931
		Eco3	0.2316	0.0595	7.3	0.4360
		Eco4	0.1450	0.0372	4.6	0.1713
		Eco 5	0.2059	0.0529	6.5	0.3453
Social sustainability	0.2616	Soc-1	0.2321	0.0607	7.7	0.4693
		Soc-2	0.1744	0.0456	5.8	0.2646
		Soc-3	0.2098	0.0549	7.0	0.3842
		Soc-4	0.2039	0.0533	6.8	0.3627
		Soc-5	0.1798	0.0470	6.0	0.2822
Environmental sustainability	0.2813	Env-1	0.1965	0.0553	6.7	0.3681
		Env-2	0.2280	0.0641	7.7	0.4951
		Env-3	0.1887	0.0531	6.4	0.3397
		Env-4	0.1945	0.0547	6.6	0.3611
		Env-5	0.1924	0.0541	6.5	0.3534
Risk to sustainability	0.2002	Risk-1	0.3402	0.0681	2.6	0.1771
		Risk-2	0.3737	0.0748	2.9	0.2140
		Risk-3	0.2862	0.0573	2.2	0.1261

5.4.5: Calculation of Total Evaluated Score (Pk) for Each Alternative

1. For Alternative Strategy – Enhancing Public Transport

   The total evaluated score (Pk) for each alternative was calculated by summation of final weights of all sub-criteria for core decision criteria

Table 5.22: Total Evaluated Score for Alternative Strategy :Enhancing Public Transport

Enhancing Public Transport							
	CD		RW	W	S	FW	Pki
Economical effectiveness	0.2568	Eco 1	0.2274	0.0584	7.2	0.4205	1.6660
		Eco 2	0.1902	0.0488	6.0	0.2931	
		Eco3	0.2316	0.0595	7.3	0.4360	
		Eco4	0.1450	0.0372	4.6	0.1713	
		Eco 5	0.2059	0.0529	6.5	0.3453	
Social sustainability	0.2616	Soc-1	0.2321	0.0607	7.7	0.4693	1.7631
		Soc-2	0.1744	0.0456	5.8	0.2646	
		Soc-3	0.2098	0.0549	7.0	0.3842	
		Soc-4	0.2039	0.0533	6.8	0.3627	
		Soc-5	0.1798	0.0470	6.0	0.2822	
Environmental sustainability	0.2813	Env-1	0.1965	0.0553	6.7	0.3681	1.9175
		Env-2	0.2280	0.0641	7.7	0.4951	
		Env-3	0.1887	0.0531	6.4	0.3397	
		Env-4	0.1945	0.0547	6.6	0.3611	
		Env-5	0.1924	0.0541	6.5	0.3534	
Risk to sustainability	0.2002	Risk-1	0.3402	0.0681	2.6	0.1771	0.5171
		Risk-2	0.3737	0.0748	2.9	0.2140	
		Risk-3	0.2862	0.0573	2.2	0.1261	
Total Evaluated Score (Pk) For Enhancing Public Transport Strategy							5.8637

Similarly, other alternative strategies were evaluated, and their total evaluated scores were calculated by repeating process steps 1 to 4. (refer Annexure-VIII).Total evaluated score of all identified strategy are presented in Table 5.23,5.24,5.25.5.26 &5.27

Table 5.23: Total Evaluated Score for Alternative Strategy: Non-Motorised Transport

Non-Motorised Transport							
	CD		RW	W	S	FW	Pki
Economical Effectiveness	0.3099	Eco 1	0.2253	0.0698	5.7	0.3980	1.5834
		Eco 2	0.1835	0.0569	4.7	0.2650	
		Eco3	0.1912	0.0593	4.9	0.2880	
		Eco4	0.2037	0.0631	5.2	0.3283	
		Eco 5	0.1963	0.0608	5.0	0.3042	
Social Sustainability	0.3249	Soc-1	0.2149	0.0698	6.1	0.4231	1.8621
		Soc-2	0.1602	0.0520	4.5	0.2358	
		Soc-3	0.2232	0.0725	6.3	0.4590	
		Soc-4	0.1974	0.0641	5.6	0.3592	
		Soc-5	0.2043	0.0664	5.8	0.3850	
Environmental Sustainability	0.2029	Env-1	0.2211	0.0449	7.7	0.3454	1.4206
		Env-2	0.2193	0.0445	7.6	0.3382	
		Env-3	0.1790	0.0363	6.3	0.2274	
		Env-4	0.1903	0.0386	6.6	0.2548	
		Env-5	0.1903	0.0386	6.6	0.2548	
Risk to Sustainability	0.1624	Risk-1	0.2922	0.0475	2.1	0.1011	0.3640
		Risk-2	0.4019	0.0653	2.5	0.1606	
		Risk-3	0.3059	0.0497	2.1	0.1023	
Total Evaluated Score (Pk) For Non-Motorized Transport Strategy							5.2301

Table 5.24 Total Evaluated Score for Alternative Strategy : Alternative Fuel and Technology

Alternative Fuel and Technology							
	CD		RW	W	S	FW	Pki
Economical Effectiveness	0.2759	Eco 1	0.2311	0.0638	5.7	0.3609	1.3730
		Eco 2	0.2012	0.0555	4.9	0.2720	
		Eco3	0.1985	0.0548	4.9	0.2662	
		Eco4	0.1523	0.0420	3.7	0.1567	
		Eco 5	0.2169	0.0598	5.3	0.3172	
Social Sustainability	0.2484	Soc-1	0.4097	0.1018	3.9	0.3928	0.9894
		Soc-2	0.1778	0.0442	4.4	0.1943	
		Soc-3	0.1005	0.0250	4.1	0.1031	
		Soc-4	0.1560	0.0388	3.9	0.1496	
		Soc-5	0.1560	0.0388	3.9	0.1496	
Environmental Sustainability	0.3079	Env-1	0.2327	0.0716	7.7	0.5538	1.9876
		Env-2	0.2072	0.0638	6.5	0.4166	
		Env-3	0.1945	0.0599	6.1	0.3671	
		Env-4	0.1755	0.0540	5.5	0.2988	
		Env-5	0.1901	0.0585	6.0	0.3512	
Risk to Sustainability	0.1678	Risk-1	0.3077	0.0516	1.8	0.0929	0.3293
		Risk-2	0.3632	0.0609	2.1	0.1298	
		Risk-3	0.3291	0.0552	1.9	0.1066	
Total Evaluated Score (Pk) For Alternative Fuel & Technology Strategy							4.6792

Table 5.25: Total Evaluated Score for Alternative Strategy: Reduction in Car Usage

Reduction In Car Usage							
	CD		RW	W	S	FW	Pki
Economical Effectiveness	0.2563	Eco 1	0.2186	0.0560	5.3	0.2986	1.2639
		Eco 2	0.1861	0.0477	4.5	0.2161	
		Eco3	0.1939	0.0497	4.7	0.2351	
		Eco4	0.1722	0.0441	4.2	0.1854	
		Eco 5	0.2291	0.0587	5.6	0.3288	
Social Sustainability	0.2872	Soc-1	0.1921	0.0552	4.7	0.2610	1.4486
		Soc-2	0.1511	0.0434	3.7	0.1619	
		Soc-3	0.2102	0.0604	5.2	0.3139	
		Soc-4	0.2369	0.0680	5.9	0.3987	
		Soc-5	0.2097	0.0602	5.2	0.3132	
Environmental Sustainability	0.2785	Env-1	0.2283	0.0636	7.1	0.4533	1.7346
		Env-2	0.1710	0.0476	5.3	0.2538	
		Env-3	0.2048	0.0570	6.4	0.3650	
		Env-4	0.1939	0.0540	6.1	0.3272	
		Env-5	0.1901	0.0529	6.3	0.3351	
Risk to Sustainability	0.178	Risk-1	0.3731	0.0664	2.9	0.1946	0.4690
		Risk-2	0.3134	0.0558	2.5	0.1372	
		Risk-3	0.3134	0.0558	2.5	0.1372	
Total Evaluated Score (Pk) For Reduction in Car Usage Strategy							4.9162

Table 5.26: Total Evaluated Score for Alternative Strategy: Transit Oriented Development

Transit Oriented Development							
	CD		RW	W	S	FW	Pki
Economical Effectiveness	0.2824	Eco 1	0.2279	0.0644	6.8	0.4376	1.7262
		Eco 2	0.2012	0.0568	6.0	0.3409	
		Eco3	0.2204	0.0622	7.1	0.4394	
		Eco4	0.1539	0.0435	4.2	0.1825	
		Eco 5	0.1966	0.0555	5.9	0.3257	
Social Sustainability	0.3178	Soc-1	0.2031	0.0645	6.8	0.4389	2.1672
		Soc-2	0.1639	0.0521	5.5	0.2844	
		Soc-3	0.1874	0.0596	6.3	0.3728	
		Soc-4	0.1969	0.0626	6.6	0.4130	
		Soc-5	0.2486	0.0790	8.3	0.6581	
Environmental Sustainability	0.2682	Env-1	0.2189	0.0587	6.2	0.3640	1.5842
		Env-2	0.2310	0.0620	6.0	0.3717	
		Env-3	0.2055	0.0551	6.4	0.3527	
		Env-4	0.1691	0.0454	5.3	0.2386	
		Env-5	0.1756	0.0471	5.5	0.2571	
Risk to Sustainability	0.1316	Risk-1	0.3737	0.0492	2.2	0.1082	0.2652
		Risk-2	0.3296	0.0434	2.0	0.0868	
		Risk-3	0.2967	0.0390	1.8	0.0703	
Total Evaluated Score (Pk) For Transit Oriented Development Strategy							5.7428

Table 5.27: Total Evaluated Score for Alternative Strategy: Pedestrian Facility Improvement

Pedestrian Facility Improvement							
	CD		RW	W	S	FW	**Pki**
Economical Effectiveness	0.2883	Eco 1	0.2011	0.0580	6.4	0.3711	**1.6220**
		Eco 2	0.1726	0.0498	5.7	0.2816	
		Eco3	0.2270	0.0654	5.5	0.3573	
		Eco4	0.2054	0.0592	4.9	0.2878	
		Eco 5	0.1939	0.0559	5.8	0.3242	
Social Sustainability	0.2601	Soc-1	0.2152	0.0560	5.5	0.3095	**1.3321**
		Soc-2	0.2278	0.0593	3.7	0.2169	
		Soc-3	0.1426	0.0371	5.1	0.1877	
		Soc-4	0.1968	0.0512	5.6	0.2867	
		Soc-5	0.2174	0.0565	5.9	0.3314	
Environmental Sustainability	0.2483	Env-1	0.2008	0.0499	6.4	0.3191	**1.6194**
		Env-2	0.1950	0.0484	6.6	0.3196	
		Env-3	0.2179	0.0541	6.8	0.3679	
		Env-4	0.2069	0.0514	6.7	0.3457	
		Env-5	0.1793	0.0445	6.0	0.2671	
Risk to Sustainability	0.2033	Risk-1	0.3576	0.0727	3.2	0.2326	**0.6228**
		Risk-2	0.3505	0.0713	3.3	0.2323	
		Risk-3	0.2919	0.0593	2.7	0.1579	
Total Evaluated Score (Pk) For Pedestrian Facility Improvement							**5.1963**

5.5 Result and Discussion

With the help of “Analytical Hierarchy Process” (AHP) approach, all identified six alternative strategies were evaluated against defined core decision criteria of sustainability. Based on their total evaluated scores, these six alternatives were ranked as follows in Table 5.28 and Figure 5.3.

Table 5.28: Total Evaluated Score of Identified Strategies

Alternatives	Economical Effectiveness	Social Sustainability	Environmental Sustainability	Risks to Sustainability	Total Score
Enhancing Public Transport (PT)	1.66	1.76	1.92	0.52	5.85
Transit Oriented Development (TOD)	1.72	2.17	1.58	0.27	5.74
Non- Motorised Transport (NMT)	1.58	1.86	1.42	0.36	5.22
Pedestrian Facility Improvement (PF)	1.62	1.33	1.62	0.62	5.19
Reduction in Car Usage (CU)	1.26	1.45	1.73	0.47	4.91
Alternative Fuel and Technology (AFT)	1.37	0.99	1.99	0.33	4.68

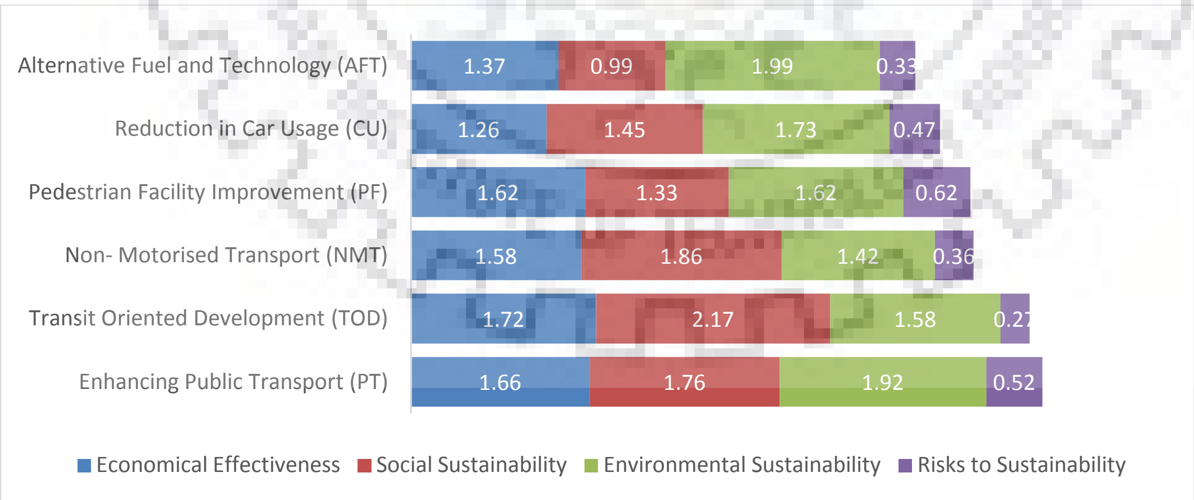


Figure 5.3: Shares of 4 Core Criteria on Identified Strategies

The relative relevance and impacts of each sustainable dimension (i.e. economic, social, environmental, and risks) on various alternatives are utilized for the prioritization and evaluation of most effective alternative strategy for the development of sustainable transport solutions in Dehradun City. The result of this analysis is summarized as below:

5.5.1 Significance of Economic effectiveness

For the economic dimension of sustainable transport solution, it is critical to improve the quality and reliability of transportation mode by reducing overall transportation costs associated with goods and people. This would help not only with the improvement of people's mobility but also help in economic development of the region. Higher the economic effectiveness score of alternative strategy, the higher is affordability of quality and reliability of economic transport solutions. Table 5.29 presents the score of economic effectiveness of each strategy

Table 5.29: Evaluated Score of Economic Effectiveness of all Strategies

Alternatives	Economical Effectiveness	Comments
Transit Oriented Development (TOD)	1.72	Transit oriented development (TOD) is most economic effective strategy as it impacts on affordability of transportation and integrated land use planning development with effective public transport. As high density transit-oriented development with integrated land use planning will reduce the trip length and trip time. Hence it impacts on accessibility of transit which increases the ridership of economical effective transit.
Enhancing Public Transport (PT)	1.66	
Pedestrian Facility Improvement (PF)	1.62	
Non- Motorised Transport (NMT)	1.58	
Alternative Fuel and Technology (AFT)	1.37	
Reduction in Car Usage (CU)	1.26	

5.5.2 Significance of Social Sustainability

For the social dimension of sustainable transport solution, it is critical to improve the safety and security of transport users. It is also important to provide equal transport opportunities for all vulnerable groups of society, including disable people, women and poor people. Higher the social sustainability score of alternative strategy, the higher is users' confidence on safety, security and convenience of transport solution. Table 5.30 presents the score of social sustainability of each strategy.

Table 5.30: Evaluated Score of Social Sustainability of all Strategies

Alternatives	Social Sustainability	Comments
Transit Oriented Development (TOD)	2.17	Transit oriented development strategy is most socially acceptable & sustainable strategy. This result depict that users/commuters are more in favor of transit that is in their close proximity and easily accessible so that they can reduce the trip length and time. AFT strategy is least socially sustainable as this strategy will not directly impact on user's safety, security & convenience and not provide any benefits for disadvantaged and vulnerable group.
Non- Motorised Transport (NMT)	1.86	
Enhancing Public Transport (PT)	1.76	
Reduction in Car Usage (CU)	1.45	
Pedestrian Facility Improvement (PF)	1.33	
Alternative Fuel and Technology (AFT)	0.99	

5.5.3 Significance of Environmental Sustainability

For the environmental dimension of sustainable transport solution, it is critical to improve the resilience of the transport solution by reducing climate impacts through reduction of greenhouse gas and other transport-related emissions and pollution. Higher the environmental sustainability score of alternative strategy, the higher is the chance of reducing emissions and air, water and noise pollution. Table 5.31 presents the score of environmental sustainability of each strategy

Table 5.31: Evaluated Score of Environmental Sustainability of all Strategies

Alternatives	Environmental Sustainability	Comments
Alternative Fuel and Technology (AFT)	1.99	Tremendous environmental impact on climate by reducing emissions by using alternative fuel and clean technological solutions. Reducing number of vehicles by enhancing public transport will also help in reducing gas emissions
Enhancing Public Transport (PT)	1.92	
Reduction in Car Usage (CU)	1.73	
Pedestrian Facility Improvement (PF)	1.62	
Transit Oriented Development (TOD)	1.58	
Non- Motorised Transport (NMT)	1.42	

5.5.4 Significance of Risks to Sustainability Score

For the risks to sustainability dimension of sustainable transport solution, it is critical to understand all the risks associated with design, cost overruns, implementation and operations. Higher the value of risks to sustainability, lower is the chance of occurrence of events i.e. lower residual risks. Similarly, for the moderate and lower values of risks to sustainability, the chance of occurrence of events will be moderate and significant respectively. Table 5.32 describes the criteria to measure the risk of sustainability. And Table 5.33 presents the score of Risk to sustainability of each strategy

Table 5.32: Criteria to Measure the Risk to sustainability

Score	Risks to Sustainability	Measure
High Value	Low	Risks are low as there is a minor chance of occurrence that may impact costs or benefits more than 20% or cause delay of > 1year
Medium Value	Medium	Risks are moderate as there is a moderate chance of occurrence that may impact 10%-20% costs or benefits or cause delay of 3-12 months
Low Value	High	Risks are high as there is significant chance of occurrence that may costs of benefits less than 10% or cause delay of less than 3 months

Table 5.33: Evaluated Score of Risk to Sustainability of All Strategies

Alternatives	Risks to Sustainability	Comments
Pedestrian Facility Improvement (PF)	0.62	Improvement in pedestrian and public transport facilities scored high in risks to sustainability that indicates that there is minor chance of occurrence of events associated with design, cost overruns, implementation and operations that may impact costs or benefits over 20% or cause delay of over one year.
Enhancing Public Transport (PT)	0.52	
Reduction in Car Usage (CU)	0.47	
Non- Motorised Transport (NMT)	0.36	
Alternative Fuel and Technology (AFT)	0.33	
Transit Oriented Development (TOD)	0.27	

5.5.5 Total Sustainability Score

Based on the total evaluated score (Table 5.34) of six alternative strategies, enhancement of public transport is identified as most sustainable the key strategy to design and implement in Dehradun City as it scored high for all dimensions of sustainable transport solutions. i.e. economic, social, environmental and risks to sustainability.

Table 5.34 : Total Score of all Strategies

Alternatives	Total Score	Comments
Enhancing Public Transport (PT)	5.85	Based on the total evaluated score of six alternative strategies, enhancement of public transport is identified as most sustainable key strategy to design and implement in Dehradun City as it has scored high and remain in top three in all sustainable dimensions of economic, social, environmental and risks.
Transit Oriented Development (TOD)	5.74	
Non- Motorised Transport (NMT)	5.22	
Pedestrian Facility Improvement (PF)	5.19	
Reduction in Car Usage (CU)	4.91	
Alternative Fuel and Technology (AFT)	4.68	

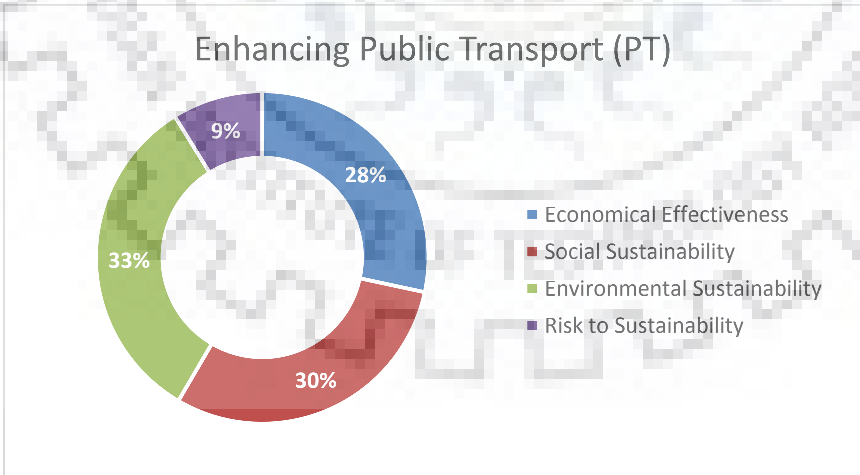


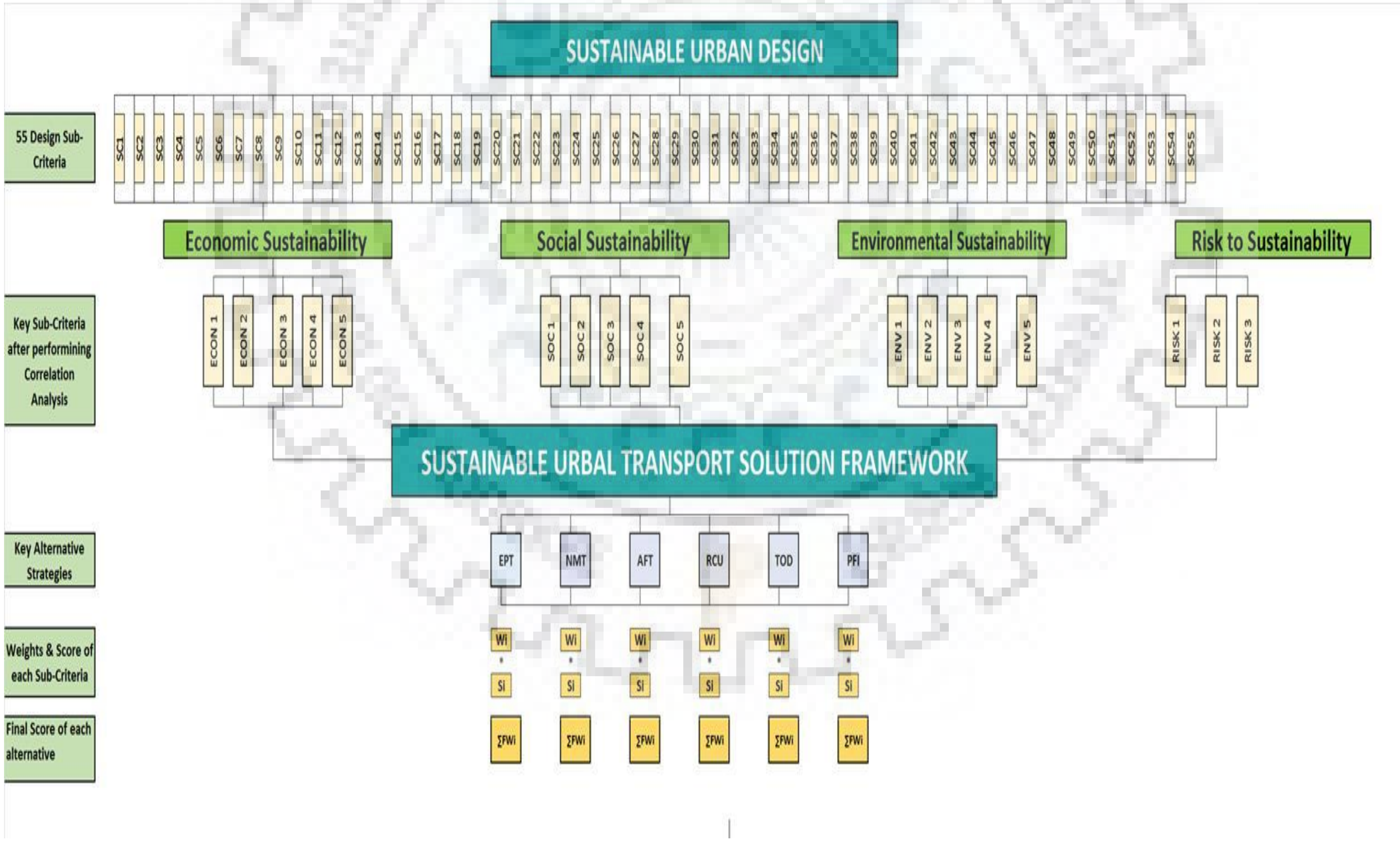
Figure 5.4: Percentage shares of 4 Sustainable Dimensions of Optimized Strategy

According the results Figure 5.4 revealed the percentage share of 4 sustainable dimensions of optimized strategy. Where PT strategy Accounting 33% environment sustainable and 30 % socially sustainable followed by the 28% of economic effectiveness of the project.

5.6 Summary

This chapter discusses the development of the framework(Figure 5.5) for evaluation of sustainable transport strategy using an analytical hierarchy process tool. First, this chapter discusses the identification of sub criteria under each sustainability dimension. Further, the evaluation of strategy in sustainability framework has been described in detail. The results reveal that the enhancement of public transport is the most sustainable proposal for the city with transit-oriented development.

Figure: 5.5 Structure of Sustainable Urban Transport Solution Framework (SUTSF)



CHAPTER-6
ESTIMATION OF CARBON EMISSION

6.1 Introduction

Human activities results in air pollution that negatively impact the health of millions of people and also lead to economic losses by damaging ecosystem and society. There is exponential rise in demand for power and industrial goods due to migration, tourist influx, and growth in mobility demands. The satisfaction of this need leads to deterioration of air quality in urban areas. In many places in India the monitored air quality are below the set standard. Transport sector significantly contributes to emission estimates of cities. Estimation of emission loads is an essential step for estimation of the share of various sources in the total emission load in a region. It also helps in understanding the potential of various strategies in reducing the emission loads in a region. However, there has been a gap in data availability for the estimation of emission loads in different Indian cities. This chapter presents the estimation of emissions from the road transport sector and also presents the estimation of vehicles under different categories of vehicles in Dehradun city. In order to minimize the emission further, some scenarios have been proposed and analyzed based on the surveys data to minimize the emissions.

6.2 Emission Estimation Methodology

In the present study, the methodology for estimation of emission has been worked out in the following steps.

1. Determine number of different categories of vehicles, plying on a selected corridor throughout the day. Say there are 4 categories of vehicles and their numbers are A, B, C, D

2. Determine total distance travelled by each category of vehicles by multiplying to the number of different modes of vehicle with average trip length (obtained through the survey) such as : [(A, B, C, D)]×Average_Trip_Length = Say (A_1,B_1, C_1, D_1);

$A_1/VKT_1 = A_2$, $B_1/VKT_2 = B_2$, $C_1/VKT_3 = C_2$, $D_1/VKT_4 = D_2$, Where, VKT_1, VKT_2, VKT_3, VKT_4, are the vehicle kilometer travelled by 4-different category of vehicles.

Step 2 and 3 are carried out as to adjust vehicles to account for total distance travelled by a vehicle in a day while a trip length by a commuter may correspond to a only a portion of whole VKT.

3. The fourth step involves distribution/apportionment of number of different categories of vehicles [e.g. A : 2W (2W- 2 stroke and 2W-4 stroke), B: 3W (3W-Auto and 3W-Vikram), C : cars (4W-Petrol and 4W-diesel), D: Bus (Bus-Standard, Bus-Mini) estimated in Step (1) to different years according to the % or age profile (vintage) and multiplied with respective emission factor (EF) and deterioration factor (DF) to obtain the emission of different components of Pollutant i.e. CO_2, CO, HC, NOx, and PM. The age profile (vintage) for different categories of vehicles and its distribution was obtained from fuel station surveys conducted along the sleeted corridor. Total vehicular emissions have been estimated by using the following Equation (6.1)

$$\mathrm{P(i,y)} = \sum_{j}^{8}\sum_{k}^{y} \mathrm{EF(i,j,k)} \times \mathrm{AGE(j,k)} \times DF\mathrm{(i,j,k)} \times \mathrm{N(j)} \times \mathrm{VKT(j)} \times 365 \times 10^{-6} \quad \text{Eq (6.1)}$$

Where :

i : Pollutant component (viz CO_2, CO, HC, NOx, PM)

j : Type of vehicle (i.e, 2W-2S, 2W-4S, 3W-A, 3W-V,4W-P, 4W-D, Bus-S, Bus-M)

k : Index for year

n : Number of type of vehicle

P(i,y) : Annual emissions of pollutant i in year y (t/year)

N(j) : Number of vehicles of a particular type j

VKT(j) : VKT is the Vehicle Kilometers Traveled per day by j type of vehicle(km).

EF(i,j,k): Emission factor (g/km) for pollutant i in the vehicle type j for year k

DF(i,j,k) : Deterioration factor for pollutant i in the vehicle type j for year k

AGE(j,k) : Fraction of vehicle type j in year k

6.3 Data Collection

According to the WHO study, Dehradun is ranked the 30th most polluted city (Gati Foundation,2010). The Dehradun city is selected for the study where the Chakrata Road (Figure 6.0) is chosen as a study area to estimate the carbon emission. The main criteria to choose the study corridor are; its mixed land use and potential (in terms of road space) and scope to implement the strategy.

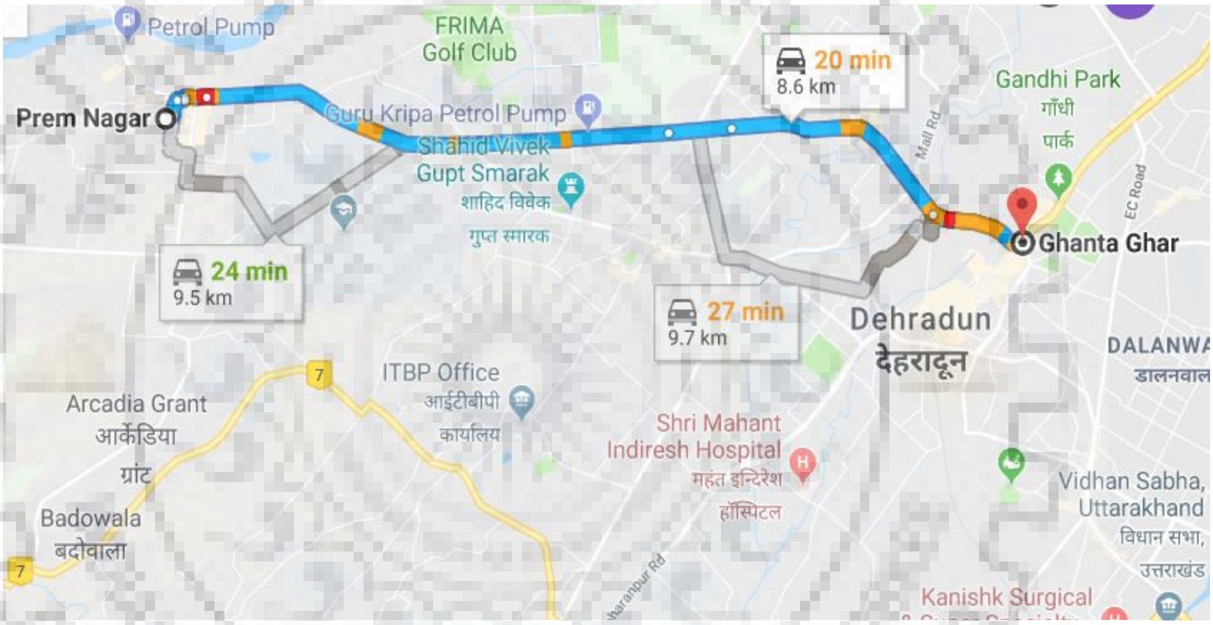


Figure 6.0 : Chakrata Road (Selected Corridor) for Estimation of Emission

6.3.1 Fuel Station Survey

Fuel stations surveys were carried out to understand the fleet of vehicles and determine the percentage of the age of vehicles and occupancy of vehicles. For that two petrol pumps are randomly selected on the selected corridor. These stations are located in mixed land-use. A questionnaire was asked to fill by vehicle owner/ driver, in which they are asked about the type of fuel used, year of manufacture and model, registration number, fuel efficiency (kilometer/liter), daily kilometer traveled by each type of the vehicles and occupancy of the vehicle. (Annexure-IX).

6.3.1.1 Age profile of vehicles

The survey reveals the percentage of different type of vehicles plying on the corridor. To determine the age distribution of vehicle, a statistical test was carried out and result is mentioned in Table 6.1.

Table-6.1, Age Profile of Different Category of Vehicles (Obtained from Fuel Station Survey)

Year	Two Wheelers (2W)		4 Wheelers (4W)		3 Wheelers (3W)		Bus	
	Two Strokes (2S)	Four Strokes (4S)	Petrol (P)	Diesel (D)	Auto (A)	Vikram (V)	Standard (S)	Mini (M)
1997	0.5	0.3						
1998	0.5	0.4						
1999	1.22	1.07						
2000	1.32	1.2						
2001	0.71	1.2						
2002	0.71	0.72	1.15	0.53				
2003	1.42	1	2.51	0.59				
2004	2.13	1.72	1.57	0.53				
2005	1.0	3.45	6.3	0.53				
2006	2.13	1.72	7.45	1.5				
2007	3.55	1.72	4.72	1.06	0.8	0.8	6.45	6.45
2008	4.64	8.62	6.54	4.35	0.8	0.8	5.57	5.57
2009	9.67	9.55	6.02	3.7	7.45	7.45	13.52	13.52
2010	9.55	3.45	7.09	10.58	25.4	25.4	19.22	19.22
2011	9.67	6.9	7.87	11.09	21.20	21.20	7.33	10.57
2012	9.55	10.98	7.24	15.42	11.01	11.01	6.856	7.83
2013	8.59	10.4	8.24	12.56	11.63	11.63	9.75	6.58
2014	6.7	7.05	7.21	9.66	6.5	6.5	9.75	6.56
2015	8.42	8.14	7.09	8.09	6.26	6.26	5.57	7.75
2016	9.67	10.34	9.24	9.67	5.23	5.23	8.37	8.37
2017	8.35	10.07	9.76	10.14	3.72	3.72	7.62	7.58
Total	100	100	100	100	100	100	100	100

Source : Primary Surve

6.3.1.2 Vehicle kilometer traveled (VKT)

The daily kilometer traveled by each type of vehicles was collected from fuel station survey. To Compute the emission from vehicles per day, average VKT in Dehradun city has been used. The standard buses ply continuously and cover maximum distances i.e 117 km/day followed by 77 km by minibusses. The three wheeler (3W) also cover a distance of 76 km /day. Cars travel on an average 52 km/day and two wheeler (2W) run 45 km per day.

6.3.1.3 Average occupancy of vehicles

Occupancy indicates the efficiency of usage of mode of vehicle. Based on the survey the average occupancy of each type of passenger vehicles on the selected Corridor has been calculated and mentioned in Table 6.2 and plotted in Figure 6.1.

Table 6.2: Average Occupancy by Mode

S.No.	Mode	Average Occupancy
1	2W	1.4
2	3W-Auto	3.5
3	3W-Vikram	6.72
4	Car	3.0
5	Bus-Mini	19.9
6	Bus-Standard	29.92

Source: *Field survey*

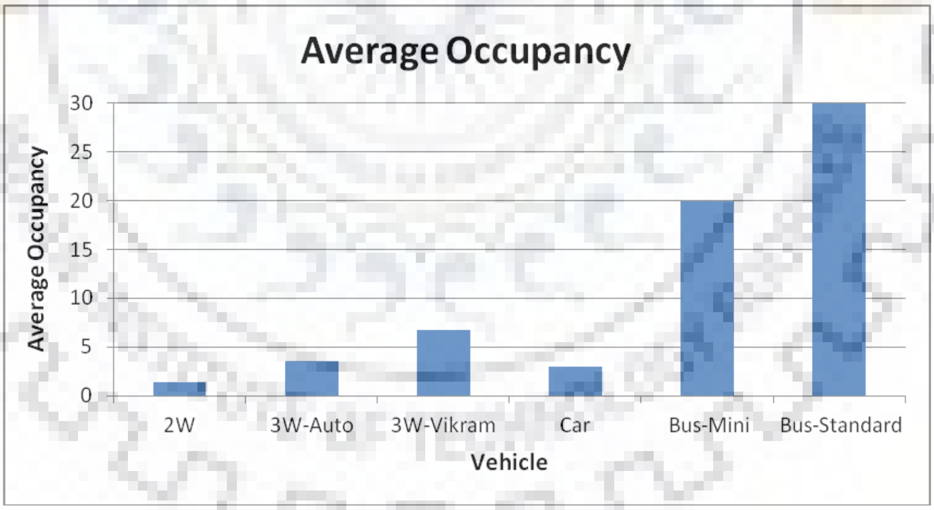


Figure 6.1 : Average Occupancy of Vehicles in Study

6.3.2 Road Corridor Length

Dehradun Chakrata road is selected to estimate the emissions. The length of road for which the emission to be calculated is 8.6 km, which is observed by field survey.

6.3.3 Traffic Count

The traffic Count on Chakrata road for 16 hrs in both directions has been taken from consistsary sources i.e. CMP (Comprehensive Mobility Plan) Dehradun, is presented in Table 6.3.

Table 6.3: Traffic Volume Count (16 hrs) on Chakrata Road

Time Period	Two Wheeler	Vikram	Auto	Car/ Van	Jeep/ Taxi	Bus		
						Mini Bus	Govt.	Private
Direction:	***Both Directions***							
07:00 - 08:00	1512	33	179	278	27	12	0	3
08:00 - 09:00	2702	107	241	352	63	35	8	43
09:00 - 10:00	3538	326	462	918	67	46	4	4
10:00 - 11:00	2362	209	397	707	76	43	9	4
11:00 - 12:00	1556	182	429	718	77	27	7	4
12:00 - 13:00	2338	212	338	708	41	23	4	0
13:00 - 14:00	2404	221	542	417	33	44	37	7
14:00 - 15:00	2523	134	395	1175	65	48	17	1
15:00 - 16:00	2275	131	483	532	53	34	17	3
16:00 - 17:00	2357	111	344	512	79	27	10	0
17:00 - 18:00	3114	228	469	1057	80	70	14	1
18:00 - 19:00	2583	166	447	1367	56	30	13	1
19:00 - 20.00	2593	197	386	1244	64	26	5	11
20:00 - 21:00	1114	88	279	625	62	4	0	0
21:00 - 22:00	589	14	41	306	31	6	0	0
22:00 - 23:00	412	12	21	181	5	0	0	0
Total	33972	2371	5453	11097	879	475	145	82

Source : CMP Dehradun(2012)

In the present study, following vehicles have been considered based on the survey data

1. Two Wheelers
   I. Two Wheelers-Two Strokes (2W-2S) : 70% of two wheelers have been Considerd as 2W-2S
   II. Two Wheelers-Four Strokes (2W-4S) : 30% of two wheelers have been Considerd as 2W-4S
2. Three Wheelers

I. Three Wheelers-Auto (3W-A) : 54.6% of three Wheelers have been Considerd as 3W-A

II. Three Wheelers-Vikram (3W-V) : 45.4% of three Wheelers have been Considerd as 3W-V

3. Four Wheelers: Summation of Car/Van and Jeep/ taxi is Considered as Four Wheelers 4W

I. Four Wheelers-Petrol (4W-P) or Petrol Car : 65% of four wheelers have been taken as 4W-P

II. Four Wheelers-Diesel (4W-D) or Diesel Car : 35% of four wheelers have been taken as 4W-D

4. Bus

I. Bus-Standard (Bus-S) : 37.9% of buses have been as Considered as Bus-S

II. Bus-Mini (Bus-M) : 62.1% of buses have been as Considered as Bus-M

Vehicle distribution in year 2011 is presented in Figure 6.2. From Figure 6.2, it can be seen that the maximum proportion of vehicles is 2W-4S followed by 2W-2S, 4W-D, 3W-A, 4W-P, 3W-V, Bus-S, and Bus-M.

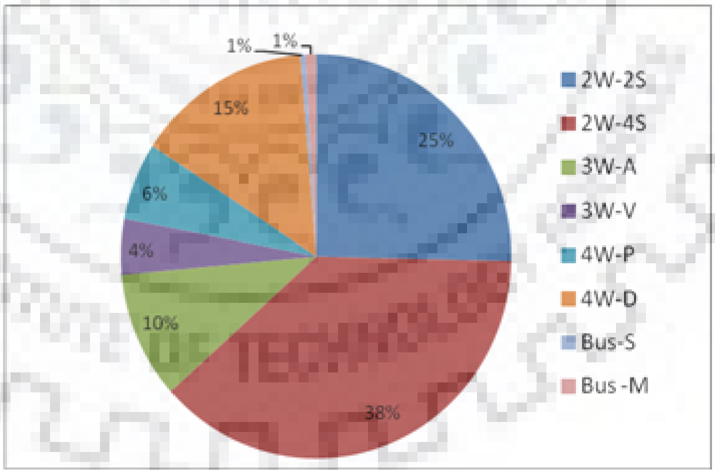


Figure 6.2 : Mode Distribution on Chakrata

Table 6.4 shows the distribution of traffic count (surveyed by DIMTS 2011) and Considering the growth rate of registered vehicle in the last 10 years(mentioned in Table 4.0), the traffic Count along the selected corridor has been projected for year 2017 and 2032. where vehicles are bifurcated according to fuel, technology and occupancy (as per fuel station survey mentioned in Table 6.3). Figure 6.3 shows the mode wise traffic projection in the future year. It depicts that all the modes of traffic will increse. Maximum increment of 118% will take palce in four wheelers followed by two wheelers , three wheelere and buses.

Table 6.4: Projected Traffic in Future Years

Vehicle	Year - 2011	Year - 2017	Year - 2032	Increased traffic in year-2032 with respect to year - 2017
2W -2S	13588.8	20845.2192	38986.2672	87.03%
2W -4S	20383.2	31267.8288	58479.4008	87.03%
3W-A	5453.328	8234.52528	15187.51848	84.44%
3W-V	2370.672	3579.71472	6602.32152	84.44%
4W-P	3329.08848	6325.26811	13815.71719	118.42%
4W-D	7767.87312	14758.9589	32236.67345	118.42%
Bus-S	227.0268	297.859162	474.9400656	59.45%
Bus-M	474.9732	623.164838	993.6439344	59.45%

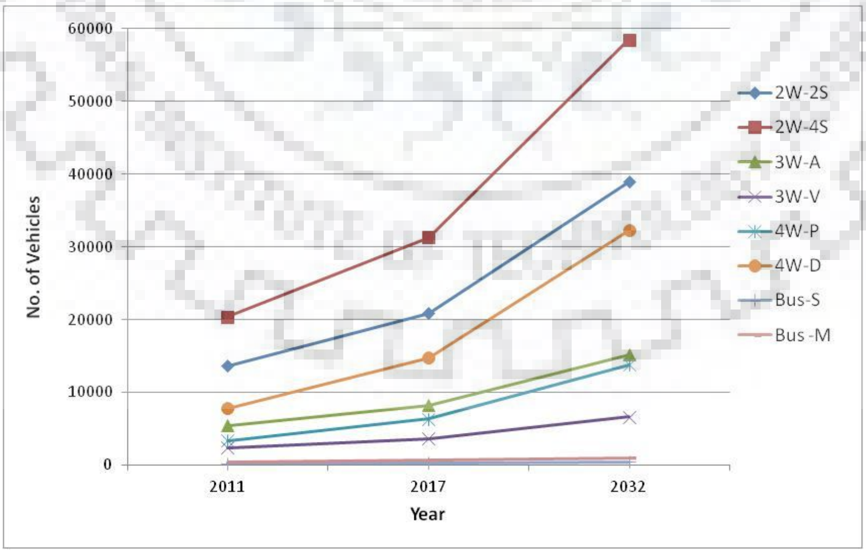


Figure 6.3 : Mode wise traffic projection in future

6.3.4 Emission Factor

Emission factor plays a vital role in estimating the emissions from particular mode of vehicles. In the current research, indigeneous emission factor developed by Automotive Research Association of India (ARAI, 2017) are used. Table 6.5 illustrates the emission factor of different categories of vehicles in India of different years. This is a compilation of extensive work carried out on developing emission factors for on-road vehicles of different categories which followed different vehicular emission norms (Pre-BS, BS-I, BS-II, BS-III) during different time frames. BS-IV norms are adopted from CPCB 2015.The emission rate of E-rickshaw is adopted from TERI. (2017). In present study, the tailpipe emission of PRT is considered to be zero (Hall and Lutsey, 2018).

Table 6.5 : Emission Factors for Different Categories of Vehicles in India

Type	Year	CO_2 (g/km)	CO (g/km)	HC (g/km)	NO_2 (g/km)	PM (g/km)
2W -2S	1996-2000	25.05	5.1	2.46	0.01	0.073
(>80CC)	2001-2005	33.31	2.76	2.16	0.03	0.025
	2006-2010	38.54	0.16	0.86	0.02	0.057
	≥2011	38.54	0.107	0.576	0.013	0.046
2W-4S	1996-2000	33.83	0.93	0.65	0.35	0.015
(>100CC)	2001-2005	33.83	0.93	0.65	0.35	0.015
	2006-2010	42.06	0.4	0.15	0.25	0.015
	≥2011	42.06	0.268	0.101	0.168	0.012
3W (2S)	1996-2000	54.5	3.15	6.04	0.3	0.11
(<200CC)	2001-2005	62.41	1.37	2.53	0.2	0.045
	2006-2010	71.5	1.15	1.63	0.16	0.043
	≥2011	71.5	0.771	1.092	0.107	0.034
3W (4S)	1996-2000	56.5	4.59	1.63	0.6	0.012
(<200CC)	2001-2005	56.5	4.59	1.63	0.6	0.012
	2006-2010	73.8	2.29	0.77	0.53	0.015
	≥2011	73.8	1.534	0.516	0.355	0.012
3W (D)	1996-2000	140.87	9.16	0.63	0.93	0.782
(<500CC)	2001-2005	173.85	2.09	0.16	0.69	0.347
	2006-2010	131.61	0.41	0.14	0.51	0.091

	≥2011	131.61	0.205	0.083	0.423	0.046
3 W(CNG)	OEM vehicles	57.71	0.69	2.06	0.19	0.118
(<200CC)	≥2001					
3W (Electric)	≥2015	21.9	0.0000003	0.0	0.048	0.045
4W-Petrol	1996-2000	106.96	4.53	0.66	0.75	0.008
(<1000CC)	2001-2005	126.37	1.3	0.24	0.2	0.004
	2006-2010	126.37	1.3	0.24	0.2	0.004
	2011-2015	126.37	0.84	0.12	0.09	0.002
	≥2016	126.37	0.361	0.06	0.048	0.002
4W- Diesel	1996-2000	129.09	0.87	0.22	0.45	0.145
(<1600CC)	2001-2005	156.76	0.72	0.14	0.84	0.19
	2006-2010	156.76	0.3	0.26	0.49	0.06
	2011-2015	148.76	0.06	0.08	0.28	0.015
	≥2016	148.76	0.047	0.048	0.14	0.008
Taxi	1996-2000	163.56	2.49	1.39	1.7	0.57
<3000>	2001-2005	189.48	1.38	1.39	0.65	0.56
	2006-2010	242.01	1.94	0.89	2.46	0.48
	2011-2015	242.01	1.94	0.89	2.46	0.48
	≥2016	255.98	0.25	0.19	0.67	0.096
Bus (Diesel)	1996-2000	920.77	4.48	1.46	15.25	1.213
(>6000CC)	2001-2005	668	3.97	0.39	11.5	0.795
	2006-2010	668	3.97	0.39	11.5	0.795
	2011-2015	602.01	3.92	0.16	6.53	0.3
	≥2016	602.01	2.838	0.112	4.571	0.051
Bus CNG	2001-2010	806.5	3.72	3.75	6.21	0.044
>6000CC	≥2010	806.5	3.72	3.75	4.347	0.035
Mini Bus	1996-2000	333.31	3	1.28	2.48	0.655
(<3000CC)	2001-2005	401.25	3.66	1.35	2.12	0.475
	2006-2010	401.25	3.66	1.35	2.12	0.475
	2011-2015	401.25	3.66	1.35	2.12	0.475
	≥2016	401.25	2.65	0.946	1.484	0.081

Sources :ARAI 2017,CPCB 2015,Teri 2017

6.4 Estimation of Emissions

Spreadsheet developed was carried out to estimate the emissions (CO_2, CO, HC, NO_x, and PM) during 2017 and 2032 due to different types of vehicles. The estimated emissions from different types of vehicles is given in Table 6.6. The total emission has been estimated to be nearly 359.18t in year 2017 to nearly 686.20t during year 2032, a two fold increase during this period. It is because of increment in number of vehicles. Similarly, CO_2 emission indicates 99.74% increment from 20698.30 t in 2017 to 41341.99 t in 2032. Vehicle wise emission for CO_2, CO, HC, No_2 and PM are shown in Figure 6.4, Figure 6.5, Figure 6.6, Figure 6.7, and Figure 6.8 respectively. Figure 6.4 depicts that 4W-P emits maximum CO_2-emission followed by 2W-2S, 4W-D, 2W-4S, 3W-A, 3W-V, Bus-M and Bus-S in both years 2017 and 2032. Figure 6.5 depicts that 2W-2S emits maximum CO-emission followed by 4W-P, 3W-A, 2W-4S, Bus-M, 4W-D, 3W-V, and Bus-S. It is clear from figure 6.6, 6.7 and 6.8 that source of maximum emission for HC, Nox and PM are 2W-2S, 2W-4S and 2W-2S respectively.

Table 6.6 : Emission in year 2017 and for 2032

Category of Vehicle	% of Commuters	Pollutant (t/year)					CO_2 (t/yr)
		CO	HC	No_x	PM	Total	
	Year 2017						
2W-2S	23.82	52.45	94.16	1.83	5.62	154.06	4331.73
2W-4S	10.21	18.38	8.54	10.25	0.64	37.82	2021.51
3W-A	13.45	23.31	33.03	3.24	0.96	60.54	1848.83
3W-V	11.18	3.09	1.15	5.07	0.69	10.00	1473.81
4W-P	20.94	44.59	7.55	6.10	0.13	58.37	5946.14
4W-D	11.28	3.10	2.86	7.82	0.68	14.47	3815.00
Bus-S	3.46	2.94	0.20	6.57	0.38	10.08	491.74
Bus-M	5.67	6.71	2.47	3.87	0.79	13.84	769.55
Total	**100**	**154.57**	**149.97**	**44.76**	**9.89**	**359.18**	**20698.30**
Year 2032							
2W-2S	22.96	98.09	176.11	3.43	10.50	288.13	8101.52
2W-4S	9.84	34.38	15.98	19.17	1.20	70.73	3780.79
3W-A	12.78	43.00	60.92	5.97	1.77	111.66	3409.92
3W-V	10.63	5.69	2.12	9.36	1.27	18.44	2718.25
4W-P	23.58	97.39	16.49	13.32	0.29	127.50	12987.61
4W-D	12.70	6.78	6.25	17.08	1.49	31.61	8332.76
Bus-S	2.84	4.68	0.32	10.48	0.60	16.08	784.08
Bus-M	4.66	10.70	3.93	6.17	1.26	22.06	1227.06
Total	**100**	**300.71**	**282.13**	**84.98**	**18.39**	**686.20**	**41341.99**

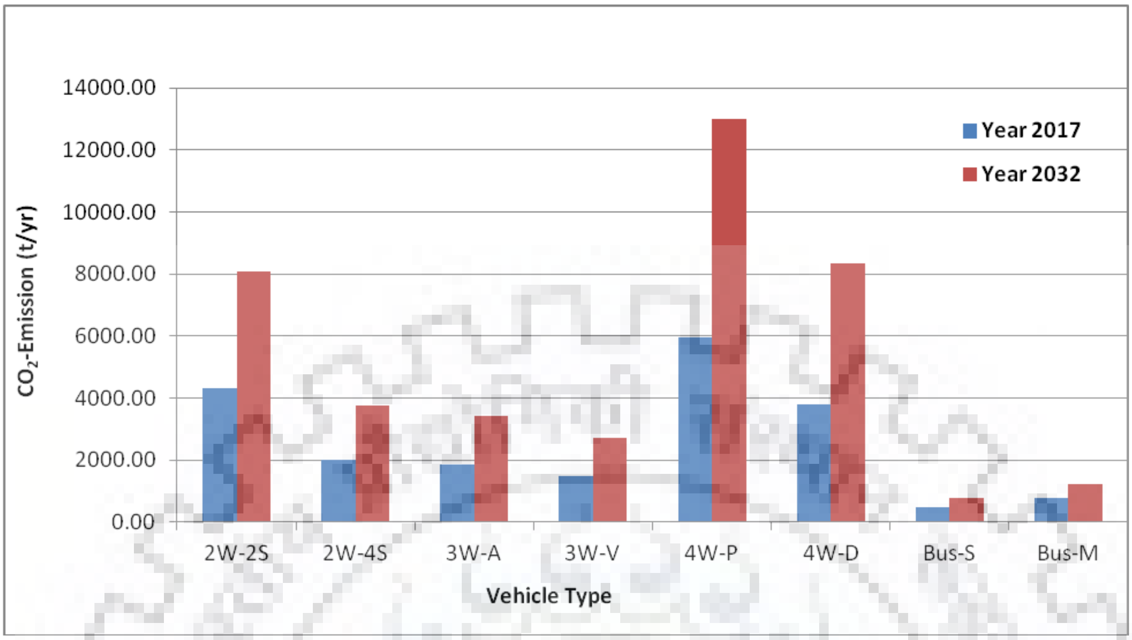


Figure 6.4: Vehicle wise CO_2 -Emission

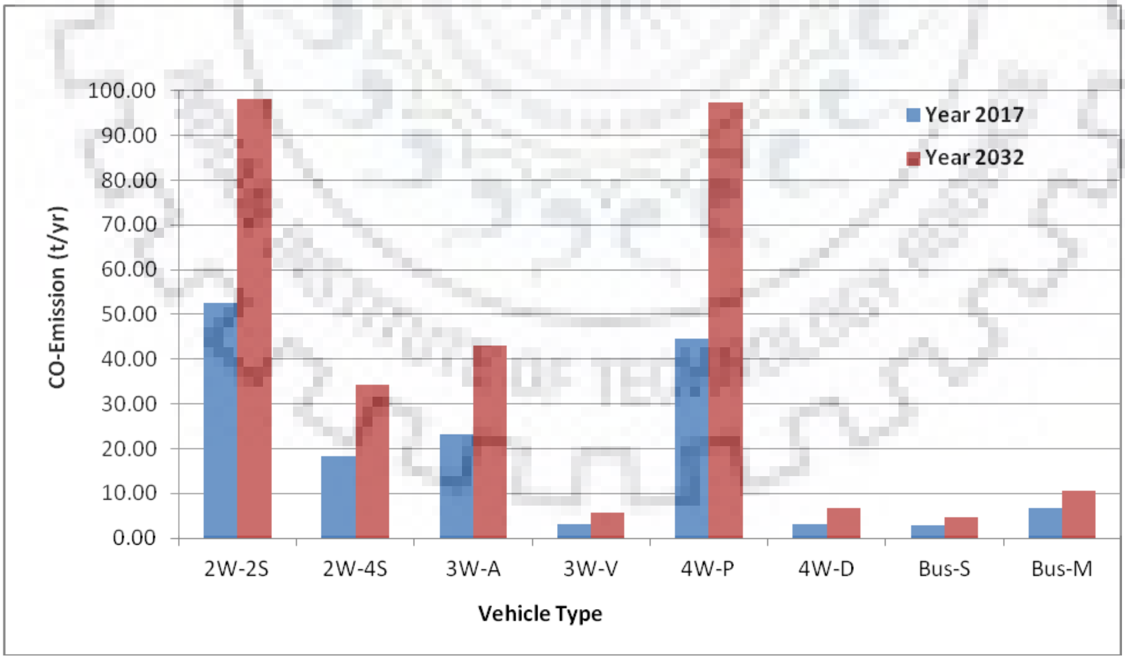


Figure 6.5: Vehicle wise CO-emission

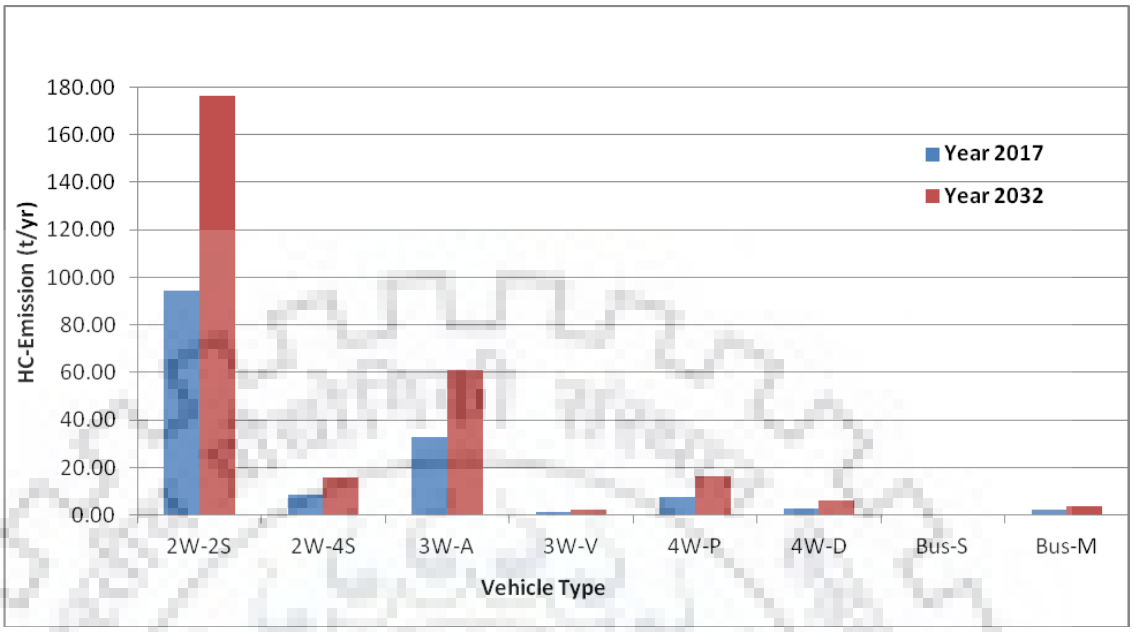


Figure 6.6 : Vehicle wise HC-Emission

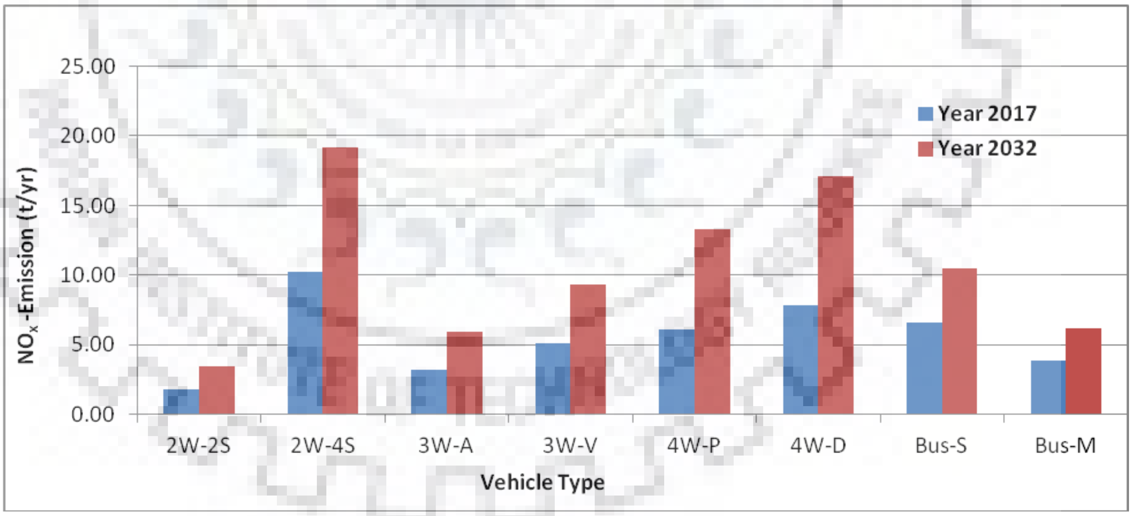


Figure 6.7 : Vehicle wise NOx-Emission

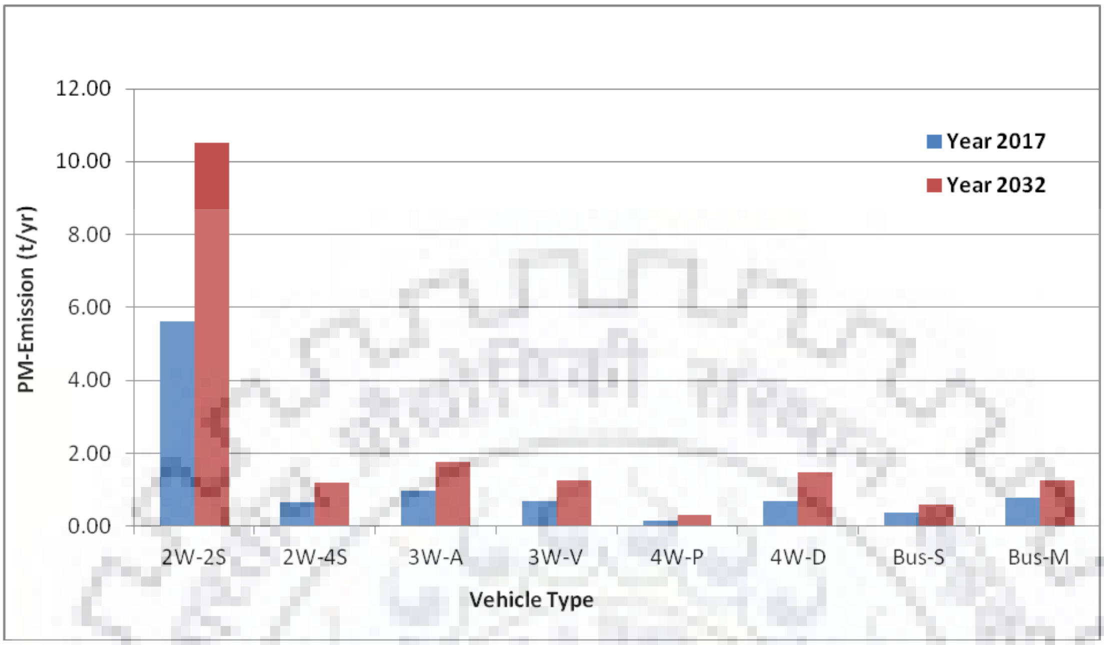
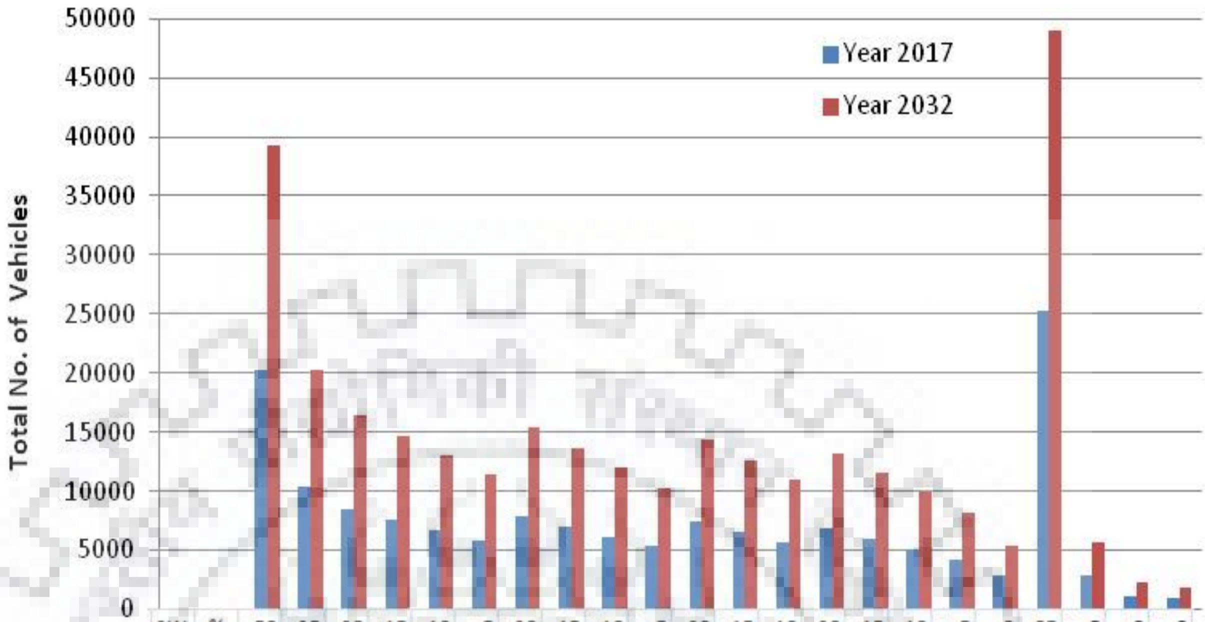


Figure 6.8 : Vehicle wise PM- Emission

6.5 **Sensitivity Analysis of Emissions**

Sensitivity analysis has been carried out to explain the changes in emission as a function of different % of Commuters traveled by different vehicles, fuel type and engine technology for cars and two-wheelers, three-wheelers, cars and buses. As per the growth factor calculation, Commuters % vehicle category wise is 34.03% 2W, 24.63%3W,32.22%4W,9.13% buses and 32.8%2W, 23.41%3W, 36.28%4W, 7.50% buses in year 2017 and year 2032 respectively, and coresponding total number of vehicles are 15190 and 29457 in year 2017 and 2032 respectively. Sensitivity analysis has been performed to study the total number of vehicle based on Commuters % traveled by different categories of vehicle. From Figure 6.9, it can be observed that if all Commuters will travel via bus then the total number of vehicles will be minimum as 947 and 1837 in year 2017 and 2032 respectively. On the other hand if commuters will prefer 2W then total number of vehicles will be maximum as 25246 and 48973 in year 2017 and 2032 respectively. This is quite obvious because the occupancy of the bus is more than 2W.



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuter (%)

Figure 6.9: Effect of Commuters, Travelled by Different Categories of Vehicle on total No. of Vehicles

6.5.1 **Effect of Commuters percentage, travelled by Different Categories of Vehicles on Emission**

In order to study the effect of commuters %, travelled by different categories of vehicles on emission, emission is determined at different sets of vehicle category wise Commuters % shown in Figure 6.10, 6.11, 6.12, 6.13 and 6.14 for the emission of CO_2, CO, HC, Nox and PM respectively. From the Figures 6.10, 6.11 and 6.12, it is clear that CO_2, CO and HC emission will be less if maximum commuters will travel via bus. From Figure 6.13, it is clear that Nox emission will be less if maximum commuters will travel via 2W. Figure 6.14 depicts that PM-emission is minimum if maximum commuters (60%) travel by buses. It is because buses have diesel engine whose combustion process is very efficient. All the carbon converted in to CO_2.

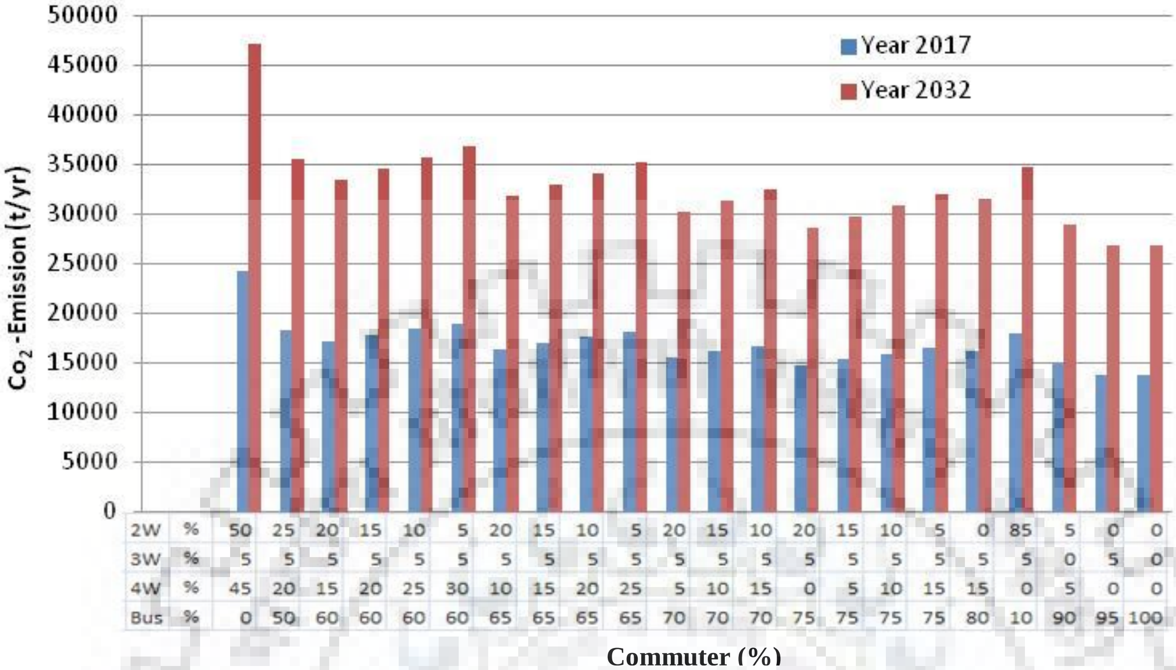


Figure 6.10: Effect of Commuters, Travelled by Different Categories of Vehicle on CO_2- Emission

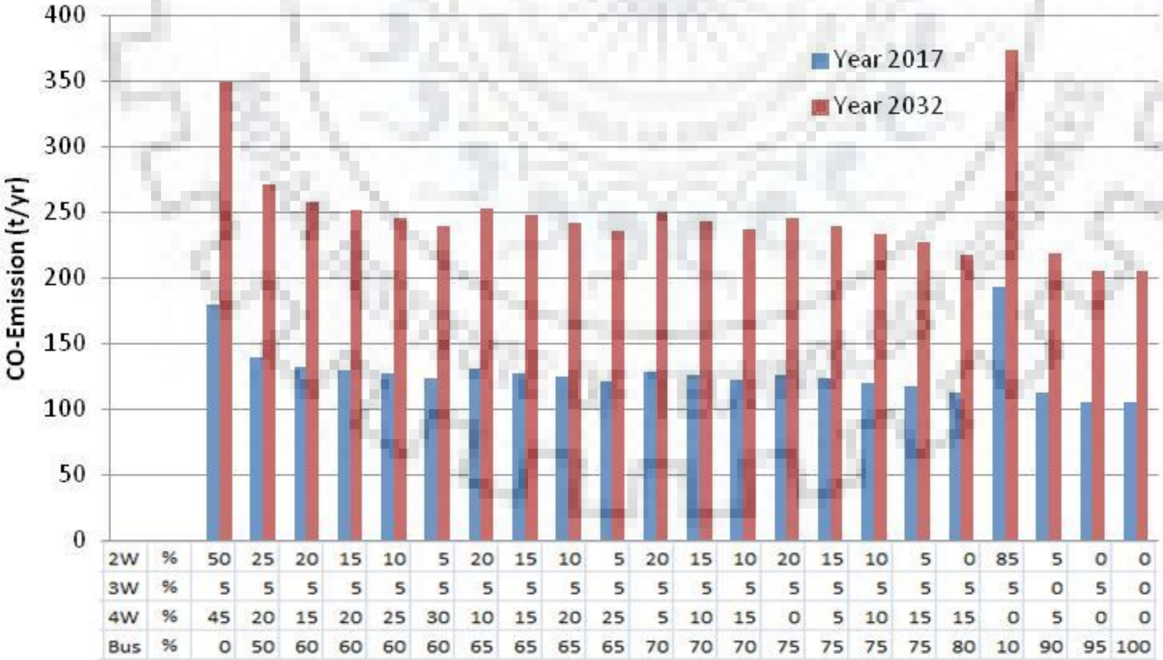
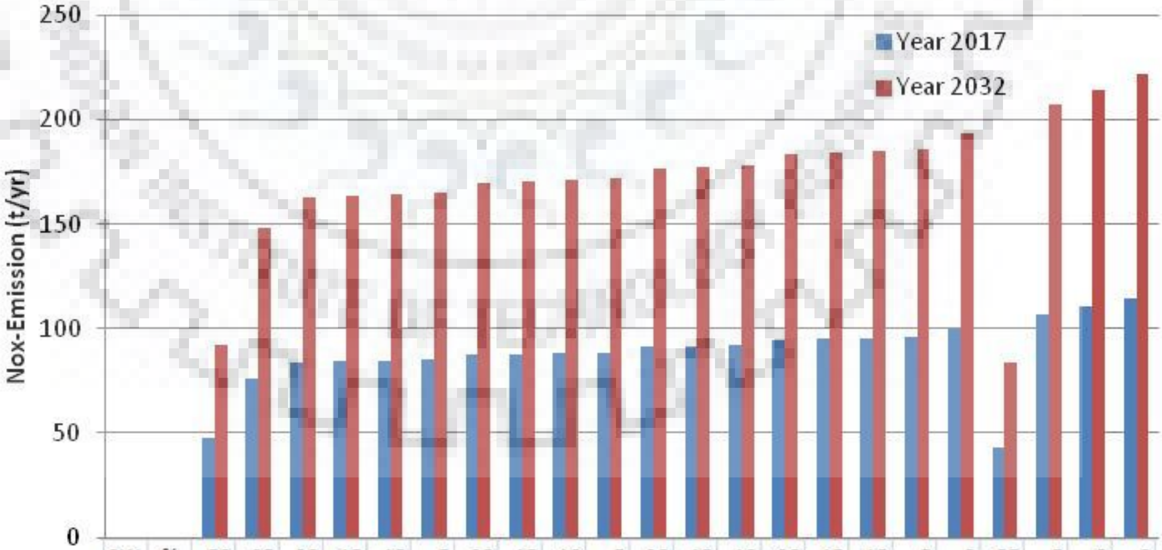


Figure 6.11: Effect of Commuters, Travelled by Different Categories of Vehicle on CO- Emission

2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Figure 6.12: Effect of Commuters, Travelled by Different Categories of Vehicle on HC- Emission



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuter (%)

Figure 6.13: Effect of Commuters, Travelled by Different Categories of Vehicle on NO_x- Emission

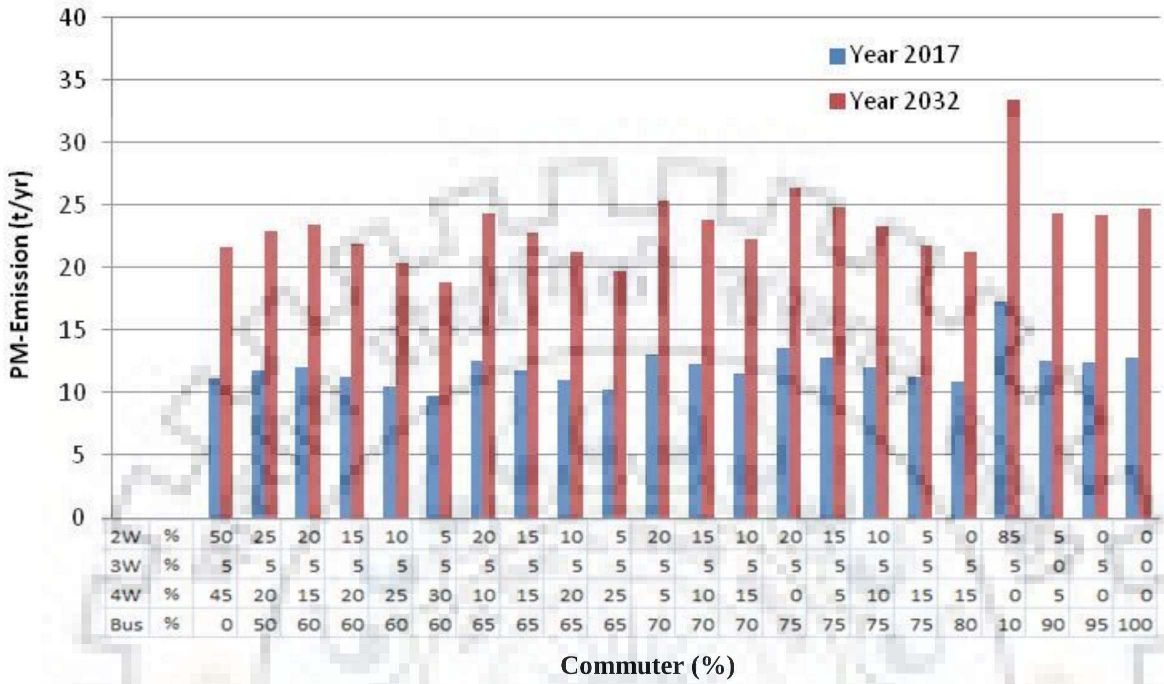


Figure 6.14: Effect of Commuters, Travelled by Different Categories of Vehicle on PM- Emission

6.5.2 **Effect of Engine Technology on Emission**

Effort has been made to determine impact of engine technology (in 2Ws) on emissions at commuters % vehicle category wise of 34.03%2W, 24.63%3W, 32.22%4W, 9.13% buses and 32.8%2W, 23.41%3W, 36.28%4W, 7.50% buses in year 2017 and year 2032 respectively shown in Table 6.7, It is observed that 2W-4S vehicles emits more CO_2 and No_x and less CO, HC and PM emission than 2W-2S vehicles. It is because the two-stroke engine is simpler mechanically than the four-stroke engine and it is unable to complete 100% combustion. On the other hand 4S-engine is very efficient for the combustion process.

Effect of 3Ws (Auto/Vikram) on emission has been studied and presented in Table 6.8. From the Table 6.8, it can be observed that as the proportion of Vikram increased, the emission also increases for NOx and decreases for CO_2, CO, HC and PM. Similarly, sensitivity analysis of emission by 4W (cars) based on petrol and diesel fuel has been conducted and mentioned in Table 6.9. As, the proportion of diesel driven 4W increases, the emission also increases for CO_2, Nox and PM, and decreases for CO and HC Since, Diesel engines work in leaner ranges of fuel, so the emissions of CO and HC are supposedly lesser than in petrol-engine. However,Diesel engine pollute more NOx and particulates emissions. The high rate of NOx comes from the high temperature in the chamber which favors the oxidation of N. Particulates (PM) comes from the diffusion flame that diesel engine uses. They are created as droplets of fuel do not have enough time to evaporate while travelling toward the front flame and then pass through it.

Table 6.7 : Effect of Technology of 2W (2S & 4S) on Emission

Commuters (100%						Emission (t/yr)				
2W	3W	4W	Bus	2W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	2S (%)	4S (%)					
						Year-2017				
34.03	24.63	32.22	9.13	70	30	20719.84	160.09	158.89	43.95	9.93
				60	40	20753.32	153.20	139.36	47.91	9.30
				50	50	20808.34	151.84	128.76	51.07	8.71
				40	60	20863.36	150.47	118.15	54.22	8.13
				30	70	20918.38	149.11	107.55	57.38	7.54
						Year-2032				
32.80	23.41	36.28	7.50	70	30	41381.71	310.90	298.59	83.49	18.46
				60	40	41444.89	298.16	262.29	90.88	17.29
				50	50	41547.79	295.60	242.46	96.78	16.19
				40	60	41650.69	293.05	222.63	102.68	15.09
				30	70	41753.59	290.50	202.80	108.58	13.99

Effect of standard and mini Bus on emissions also has been studied and presented in Table 6.10. From the Table 6.10, it can be observed that as the proportion of mini Bus (Bus-M) increases at a particular set of commuters % vehicle category wise, the emission increases for CO,HC and PM, and decreases for CO_2 and NOx. It is because of Bus-M has smaller capacity engine than Bus-S. Smaller capacity diesel engine will be inferior to large capacity diesel engine in order to make efficient combustion.

Table 6.8 : Effect of Three wheelers Auto and Vikram on Emission

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	3W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	A (%)	V (%)					
						Year-2017				
34.03	24.63	32.22	9.13	70	30	20719.84	160.09	158.89	43.95	9.93
				60	40	20705.85	156.50	153.10	44.47	9.90
				50	50	20691.87	152.91	147.30	45.00	9.88
				40	60	20677.88	149.32	141.50	45.52	9.85
				30	70	20663.90	145.73	135.71	46.05	9.83
						Year-2032				
32.80	23.41	36.28	7.50	70	30	41381.71	310.90	298.59	83.49	18.46
				60	40	41355.92	304.28	287.90	84.46	18.41
				50	50	41330.12	297.66	277.21	85.43	18.37
				40	60	41304.33	291.04	266.52	86.39	18.32
				30	70	41278.53	284.42	255.83	87.36	18.28

Table 6.9: Effect of Type of 4W Petrol and Diesel on Emission

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	4W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	P (%)	D(%)					
						Year-2017				
34.03	24.63	32.22	9.13	70	30	20610.70	157.55	150.14	44.11	9.80
				60	40	20785.90	151.58	149.79	45.40	9.98
				50	50	20961.11	145.61	149.45	46.70	10.15
				40	60	21136.32	139.63	149.11	48.00	10.33
				30	70	21311.53	133.66	148.76	49.29	10.50
						Year-2032				
32.80	23.41	36.28	7.50	70	30	41150.64	307.23	282.50	83.57	18.20
				60	40	41533.33	294.19	281.75	86.40	18.58
				50	50	41916.03	281.14	281.00	89.23	18.96
				40	60	42298.72	268.09	280.25	92.06	19.34
				30	70	42681.42	255.05	279.50	94.89	19.72

Table 6.10 : Effect of Standard and Mini Bus on Emission

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	Bus		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	L (%)	M (%)					
						Year-2017				
34.03	24.63	32.22	9.13	70	30	20717.00	153.58	148.86	48.32	9.80
				60	40	20711.17	153.89	149.20	47.21	9.83
				50	50	20705.35	154.19	149.55	46.10	9.86
				40	60	20699.52	154.50	149.89	44.99	9.88
				30	70	20693.70	154.81	150.24	43.88	9.91
						Year-2032				
32.80	23.41	36.28	7.50	70	30	41371.80	299.14	280.36	90.67	18.24
				60	40	41362.51	299.63	280.91	88.90	18.29
				50	50	41353.22	300.12	281.46	87.12	18.33
				40	60	41343.94	300.61	282.01	85.35	18.38
				30	70	41334.65	301.09	282.56	83.58	18.42

6.6 **Optimization**

Sensitivity analysis is performed in section 6.5 which shows that how emission depends on the number of different categories of vehicles. Planning of vehicles in a city is very important. Total number of vehicles should full fill the requirement of the transport on the other hand emitted emission from the vehicles should meet the air quality standard. Therefore the role of planner is to provide data on the number of different category of vehicles for a healthy transport. Emission can be minimized or optimized in order to determine the number of different categories of vehicle. Genetic algorithm is considered for the optimization.

6.6.1 **Genetic Algorithm**

Genetic algorithm (GA) is an optimization and random search technique. It works on natural selection and natural genetics' principle. It was developed with the primary intention of imitating the processes that exist in nature. Basic principles of genetic algorithms were published in 1962 (Holland) and the mathematical framework for their development was published in 1975 by the same author. In the field of optimization, these algorithms were used to optimize functions, process of images, solve trade man problem, identification systems and COntrol and so on. In the area of machine learning, GA was used to implement simple “If-Then” rules in an arbitrary environment (Cao and Wu, 1999). Figure 6.15 shows a typical pattern of a genetic algorithm (Chipperfield,et.al.,1994)

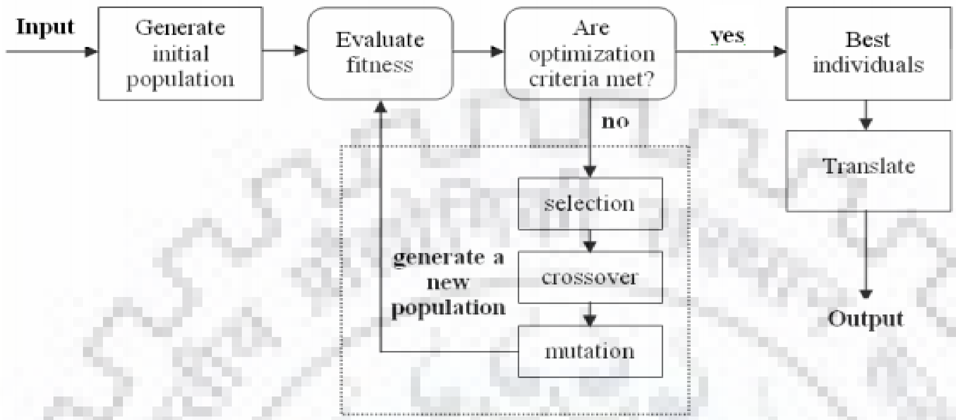


Figure 6.15. Standard procedure of Genetic Algorithm

Genetic algorithms are robust and adaptive methods, successfully used for solving optimization problems. They are powerful tools for the optimization of functions that can more easily locate the global optimum. The reason lies in the fact that GA seeks an optimal solution in the space of solutions, starting from groups of points, rather than a starting point. GA use only the objective function to search optimal solutions (derivatives or other additional information on the function are not necessary). The basic building block in the GA is a population of individuals, which is usually between 10 and 200. Each individual represents a possible solution of the problem.

The data processed by GA are represented by an array of strings (or chromosomes) with finite length, where each bit is called allele or gene. A value of the fitness function is attached to each individual, in order to evaluate its quality. A collection of strings is called population, and the population at a certain point of time is referred as generation. The generation of the initial population of strings is done in a random way.

The basic operators on the genes in the chromosome are crossover and mutation. Reproduction of some selected chromosomes is a process in which certain binary strings are transformed and passed to the next generation. Selection is usually implemented through the so called process roulette wheel. The crossover is the main operator, which generates new strings, eventually with better fitness values. After crossover, mutation is performed to ensure some randomness in the new chromosomes. In fact, even though crossover generally leads to better results, this does not bring new quality of information on the level of bits. As a source of different quality, the mutation of bits is usually performed. Mutations can lead to degenerative solutions (which probably will be soon eliminated by the process), or to a Completely new solution. These basic operators, as well as many other operators which can be applied depending on the problem, generate a new population, starting from the initial population and passing through an iterative process. This process creates a new population, which is estimated according to predefined criteria. The procedure repeats until the stopping criterion is satisfied. The Genetic algorithm has to provide a way to permanently improve, from generation to generation, the absolute fitness for each individual in the population and the average adaptability of the whole population. This is achieved by successive application of genetic operators of selection, crossing and mutation, thus getting better and better solutions to the problems under consideration (Cao and Wu, 1999). Since a genetic algorithm is a stochastic search method, it is difficult to specify some convergence criteria. Fitness of the whole population may remain unchanged through generations, while superior individuals appear. Because of that, the termination of the algorithm in the classical way (conditions satisfying) becomes problematic. Most often, in practice, genetic algorithm is stopped after a certain number of generations or after a certain time interval, after which the quality of the best individuals is tested. If the result is not acceptable, we can start again to search for new (better) solutions (Chipperfield et al.1994).

6.6.2 **Mathematical Modeling of Optimization Problem**

Emission optimization provides optimal or near-optimal solutions for actual vehicle-emission in transportation. The optimization procedure has two phases. First phase is mathematical modeling of the vehicle-emission where an objective multivariable function should be defined. In that phase, all constraints and bounds of the variables, by using equalities and (or) inequalities should be defined too. Second phase is searching for a global minimum of objective function, under all defined limitations.

The mathematical model of optimization consists of the objective function and constraints, as follows:

Emission is function of total number of commuters, commuter %, travelled by 2W, 3W, 4W and buses, vehicle detoriation factor, age of vehicle, and emission factors of respective vehicles. Functions to determine the CO_2-emission, CO-emission, HC-emission, No_X-emission, and PM-emission can be written as

CO_2-emission= f(C, C_{2W},C_{3W},C_{4W},C_{Bus},A_{2W},A_{3W},A_{4W},A_{Bus},CO_{2DF},CO_{2EF2W},CO_{2EF3W},CO_{2EF4W}, CO_{2EFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM})…………………………………………Eq. (6.2)

CO-emission = f(C, C_{2W},C_{3W},C_{4W},C_{Bus},A_{2W},A_{3W},A_{4W},A_{Bus},CO_{DF} ,CO_{EF2W},CO_{EF3W}, CO_{EF4W}, CO_{EFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM})…….. ……………………………Eq. (6.3)

HC-emission = f(C, C_{2W},C_{3W},C_{4W},C_{Bus},A_{2W},A_{3W},A_{4W},A_{Bus},HC_{DF}, HC_{EF2W},HC_{EF3W},HC_{EF4W},

HC_{EFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM}………………………………………..Eq.(6.4)

No_X -emission =f(C, C_{2w},C_{3w},C_{4w},C_{Bus},A_{2w},A_{3w},A_{4w},A_{Bus},No_{xDF},No_{xE2w},No_{xEF3W},No_{xEF4W},No_{xEFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM})………………………………. ………......Eq. (6.5)

PM-emission = f(C, C_{2W},C_{3W},C_{4W},C_{Bus},A_{2W},A_{3W},A_{4W},A_{Bus},PM_{DF},PM_{EF2W},PM_{EF3W},PM_{EF4W}, PM_{EFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM})……………………………………Eq. (6.6)

Where, C is total number of commuters (ridership). C_{2W}, C_{3W}, C_{4W} and C_{Bus} represent % of commuters, travelled by 2W, 3W, 4W and Bus respectively, A_{2W}, A_{3W}, A_{4W} and A_{Bus} represent age % of 2Ws,3Ws, 4Ws and Buses respectively in a typical year.

CO_{2DF}, CO_{DF}, HC_{DF}, No_{xDF}, PM_{DF} represent detoriation factor for 2W,3W, 4W and Buses respectively, CO_{2EF2W},CO_{2EF3W},CO_{2EF4W},CO_{2EFBus} represent CO_2-emission factor for 2W,3W, 4W and Buses respectively,CO_{EF2W},CO_{EF3W},CO_{EF4W},CO_{EFBus} represent CO-emission factor for 2W,3W,4W and Buses respectively, HC_{EF2W},HC_{EF3W},HC_{EF4W},HC_{EFBus} represent HC-emission factor for 2W,3W, 4W and Buses respectively, No_{xEF2w},No_{xEF3W},No_{xEF4W},No_{xEFBus}, HC_{EFBus} represent No_x-emission factor for 2W, 3W, 4W and Buses respectively, PM_{EF2W},PM_{EF3W},PM_{EF4W},PM_{EFBus} represent PM-emission factor for 2W,3W, 4W and Buses respectively.

Except C_{2W},C_{3W},C_{4W},C_{Bus}, f_{2w2s}, f_{2w4s},f_{3wA},f_{3wV}, f_{4wD} f_{4wP}, f_{BusS}, f_{BusM} all other variables are known. Therefore, these variables are known as designed variables for the optimization problem. Value of designed variables will be searched by minimizing the objective function under given upper and lower bonds of the designed variables and constraints.

Any of the functions (Eq. 6.2, 6.3, 6.4, 65 and 6.5) can be considered as objective function. In the present study, CO_2-emission is taken as objective function. Therefore, optimization problem can be defined as

Objective function

Minimize, CO_2-emission

Limits on designed variables which are:

$0 \le C_{2W} \le 100$ ………………………………………………… Eq. (6.7)

$0 \le C_{3W} \le 100$ …………………………………………………..Eq. (6.8)

$0 \le C_{4W} \le 100$ ………………………………………………… Eq. (6.9)

$0 \le C_{Bus} \le 100$ …………………………………………………..Eq. (6.10)

$0 \le f_{2w2s} \le 1$ ………………………………………………… Eq. (6.11)

$0 \le f_{2w4s} \le 1$ …………………………………………………Eq. (6.12)

Where f_{2w2s} and f_{2w4s} are proportion /fraction of 2S and 4S vehicles under 2W category

$0 \le f_{3wA} \le 1$ …………………………………………………..Eq. (6.13)

$0 \le f_{3wV} \le 1$ …………………………………………………...Eq. (6.14)

Where f_{3wA} and f_{3wV} are proportion of Auto and Vikram under 3W category

$0 \le f_{4wD} \le 1$ …………………………………………………..........Eq. (6.15)

$0 \le f_{4wP} \le 1$ …………………………………………………Eq. (6.16)

Where f_{4wP} and f_{4wD} are proportion of Petrol and Diesel Car under Car category

$0 \le f_{BusS} \le 1$ …………………………………………………...........Eq. (6.17)

$0 \le f_{BusM} \le 1$ …………………………………………………...........Eq. (6.18)

Where f_{BusS} and f_{BusM} are proportion of standard and medium Bus under Bus category

Constraints are:

$C_{2W} + C_{3W} + C_{4W} + C_{Bus} = 100$ …………………………………………..Eq. (6.19)

$f_{2w2s} + f_{2w4s} = 1$……………………………………………………………………..……..Eq. (6.20)

$f_{3wauto} + f_{3wvikram} = 1$………………………………………………………………………..Eq. (6.21)

$f_{4wD} + f_{4wP} = 1$………………………………………………………………………………Eq. (6.22)

$f_{BusS} + f_{Bus\ M} = 1$ ……………………………………………………..……..........Eq. (6.23)

$f(C, C_{2W}, C_{3W}, C_{4W}, C_{Bus}, A_{2W}, A_{3W}, A_{4W}, A_{Bus}, PM_{DF}, PM_{EF2W}, PM_{EF3W}, PM_{EF4W}, PM_{EFBus}, f_{2w2s}, f_{2w4s}, f_{3wA}, f_{3wV}, f_{4wP}, f_{4wD}, f_{BusS}, f_{BusM}) \leq x$ tones/year ……………………..……Eq. (6.24)

The second phase is solving of mathematical model to find a global minimum of the objective function. In this case, the objective function (CO_2-emission) is minimized by using GA toolbox in MATLAB. Following four MATLAB files have been written

1. main_opt_emission.m : It is a man file where inputs have been given and GA function is called
2. fitness_emission.m: It is a fitness function, used in GA function.
3. calculation_emission.m: It is user defined function used to calculate emission for different pollutants.
4. ineq_constraints.m: It is user defined function to evaluate constraints.

The GA parameters which have been changed during optimization are mentioned in Table 6.11.

Table6.11: GA Parameter

Sr. No.	Parameter Name	Value
1	Population size	50
2	Crossover probability	0.85
3	Migration fraction	0.02
4	Elite count	2
5	Tolerance of fitness function	1×10^{-15}
6	Tolerance of constraint function	1×10^{-15}
7	Number of generation	800

6.6.3 Discussion

Following four cases have been considered to predict number of different categories of vehicles and their proportions (designed variables).

Case-1: Determination of percentage of commuters travelled by different categories of vehicles with fixed proportion of vehicles. An optimization problem is formulated as:-

Objective function:

Minimization of CO_2 -Emission, given in Equation (6.2)

Equality constraint:

Sum of % of commuters, travelled by 2W, 3W, 4W and Bus respectively should be 100, given in Equation (6.19).

Proportions of vehicles under different categories are taken based on the survey data as

f_{2W2S} = 0.70, f_{2W2S} = 0.30

f_{3WA} = 0.55, f_{3WV} = 0.45

f_{4WP} = 0.65, f_{4WD} = 0. 35

f_{BusS} = 0.379, f_{BusM} = 0.621

Case-2: Determination of percentage of commuters travelled by different categories of vehicles and their proportions. An optimization problem is formulated as:-

Objective function:

Minimization of CO_2 -emission, given in Equation (6.2)

Equality constraints::

i) Sum of % of commuters, travelled by 2W, 3W, 4W and Bus respectively, should be 100, given in Equation (6.19).

ii) Sum of the proportion of 2S and 4S vehicles under 2W- category vehicles is unity, given in Equation (6.20)

iii) Sum of the proportion of auto and vikram under 3W- category vehicles is unity, given in Equation (6.21)

iii) Sum of the proportion of petrol and diesel cars under 4W- category vehicle is unity, given in Equation (6.22)

iv) Sum of the proportion of standard and mini buses under bus- category vehicle is unity, given in Equation (6.23)

Case-3: Determination of percentage of commuters travelled by different categories of vehicles and their proportions with PM-emission as a constraint

Objective function:

Minimization of CO_2 -emission, given in Equation (6.2)

Equality constraints:

i) Sum of % of commuters, travelled by 2W, 3W, 4W and Bus respectively, should be 100, given in Equation (6.19).

ii) Sum of the proportion of 2S and 4S vehicles under 2W- category vehicles is unity, given in Equation (6.20)

iii) Sum of the proportion of auto and vikram under 3W- category vehicles is unity, given in Equation (6.21)

iii) Sum of the proportion of petrol and diesel cars under 4W- category vehicle is unity, given in Equation (6.22)

iv) Sum of the proportion of standard and mini buses under bus- category vehicle is unity, given in Equation (6.23)

Inequality constraints

PM-emission imposes a severe human health risk. Due to the small size (PM2.5) quickly and adversely affects the respiratory tract and can result in lung cancer as well as other cardiopulmonary and cardiovascular diseases media. Major contributors to bad air quality in the city are particulate matter. Therefore, efforts should be made to keep PM-emission under a limit for a healthy transportation. In the present study, maximum limit on PM-emission is set 3.385 t/yr (50% of PM-emission of case-2) and 6.49 t/yr (50% of PM-emission of case-2) for the year 2017 and 2032 respectively in Equation (6.25)

i) PM-emission is less than or equal to x (3.385 t/yr for year 2017 and 6.49 t/yr for year 2032) given in Equation (6.27)

Case-4: Determination of percentage of commuters travelled by different categories of vehicles and their proportions with minimum number of commuters travelled by each category of vehicle

Objective function:

Minimization of CO_2 -emission, given in Equation (6.2)

Equality constraints:

i) Sum of % of commuters, travelled by 2W, 3W, 4W and Bus respectively, should be 100, given in Equation (6.19).

ii) Sum of the proportion of 2S and 4S vehicles under 2W- category vehicles is unity, given in Equation (6.20)

iii) Sum of the proportion of auto and vikram under 3W- category vehicles is unity, given in Equation (6.21)

iii) Sum of the proportion of petrol and diesel cars under 4W- category vehicle is unity, given in Equation (6.22)

iv) Sum of the proportion of standard and mini buses under bus- category vehicle is unity, given in Equation (6.23)

Generally, in a city, all categories of vehicles are used. In the present study, it is assumed that at least 10%, 5%, 5% and 10% of commuters are traveling by 2W, 3W, 4W and bus respectively. This lower cap on commuters can be implemented by modifying Eq. (6.7) to Eq (6.10) as

$10 \le C_{2W} \le 100$ …………………………………………………………………… Eq. (6.25)

$5 \le C_{3W} \le 100$ ……………………………………………………………………Eq. (6.26)

$5 \le C_{4W} \le 100$ ……………………………………………………………………Eq. (6.27)

$10 \le C_{Bus} \le 100$ ……………………………………………………………………Eq. (6.28)

When the optimization process was terminated, the minimal value of the objective function (equation (1)), has been found 13492.04t/yr, 13302.74t/yr, 20895.59t/yr and 14813.27t/yr for case-1, case-2, case-3 and case-4 respectively in the year 2017. Similarly, 26172.99t/yr, 25691.05 t/yr, 40743.16 t/yr and 28736.02t/yr for case-1, case-2, case-3 and case-4 respectively in the year 2032, corresponding number of different categories of vehicles and their proportions (design variables) are given in

Table 6.12. Then, population size, number of generations, and initial population have been changed, but the same or much closed results have been obtained in all cases. Emission for different pollutants is determined at the optimum value of design variables for the case-1, case-2 case-3 and case-4, given in Table 6.13, Table 6.14, Table 6.15 and Table 6.16 respectively

Table6.12: Optimum Solution for Design Variables

Design Variable	Case-1 % of Commuters and proportion	Case-2 % of Commuters and proportion	Case-3 % of Commuters and proportion	Case-4 % of Commuters and proportion
% of commuters, travelled by 2W (C_{2W})	0	0.43	0.21	10.42
Proportion of commuters, travelled by 2W-2S (f_{2W2S})	0.7	1.00	0.01	1.00
Proportion of commuters, travelled by of 2W-4S (f_{2W4S})	0.3	0	0.99	0.00
% of commuters, travelled by 3W(C_{3W})	100	93.23	48.88	9.75
Proportion of commuters, travelled by 3W-A (f_{3WA})	0.546.	0	0.00	0.00
Proportion of commuters, travelled by 3W-V (f_{3WV})	0.454	1.00	1.00	1.00
% of commuters, travelled by4W (C_{4W})	0	0.11	50.61	5.35
Proportion of commuters, travelled by 4W-P (f_{4WP})	0.65	1.00	1.00	1.00
Proportion of commuters, travelled by 4W-D (f_{4WD})	0.45	0	0.00	0.00
% of commuters, travelled by Bus (C_{Bus})	0	6.22	0.31	74.47
Proportion of commuters, travelled by Bus-S (f_{BusS})	0.379	0	0.85	0.00
Proportion of commuters, travelled by Bus-M (f_{BusM})	0.621	1.00	0.15	1.00

Table 6.13: Emission at Optimum Value of Design Variables for Case-1

Vehicle Type	% of Commuters	Pollutant (t/year)					CO_2 (t/year)
		CO	HC	Nox	PM	Total	
	Year 2017						
2W-2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2W-4S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3W-A	54.60	94.66	134.12	13.15	3.90	7753.26	7507.43
3W-V	45.40	12.53	4.67	20.60	2.80	6025.21	5984.61
4W-P	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4W-D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	107.20	138.79	33.75	6.69	13778.46	13492.04
Year 2032							
2W-2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2W-4S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3W-A	54.60	183.64	260.18	25.51	7.56	15040.42	14563.54
3W-V	45.40	24.31	9.05	39.96	5.43	11688.20	11609.45
4W-P	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4W-D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.00	207.95	269.23	65.47	12.98	26728.62	26172.99

Table 6.14: Emission at Optimum Value of Design Variables for Case-2

Vehicle Type	% of Commuters	Pollutant (t/year)					CO_2 (t/year)
		CO	HC	Nox	PM	Total	
	Year 2017						
2W-2S	0.43	0.96	1.71	0.03	0.10	81.69	78.88
2W-4S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3W-A	0.00	0.00	0.00	0.00	0.00	0.03	0.03
3W-V	93.23	25.74	9.58	42.30	5.74	12373.42	12290.05
4W-P	0.11	0.23	0.04	0.03	0.00	31.41	31.11
4W-D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-S	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Bus-M	6.22	7.37	2.71	4.25	0.87	860.13	844.94
Total	100.00	34.29	14.05	46.62	6.71	13346.70	13245.03
Year 2032							
2W-2S	0.76	3.24	5.82	0.11	0.35	277.41	267.89
2W-4S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3W-A	0.00	0.00	0.00	0.00	0.00	0.16	0.16
3W-V	93.30	49.96	18.61	82.11	11.15	24019.52	23857.69
4W-P	0.00	0.00	0.00	0.00	0.00	0.21	0.20
4W-D	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bus-S	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Bus-M	5.94	13.65	5.01	7.87	1.61	1593.23	1565.09
Total	100.00	66.86	29.45	90.10	13.10	25890.56	25691.05

Table 6.15: Emission at Optimum Value of Design Variables for Case-3

Vehicle Type	% of Commuters	Pollutant (t/year) CO	HC	Nox	PM	Total	CO_2 (t/year)
Year 2017							
2W-2S	0.00	0.00	0.01	0.00	0.00	0.30	0.29
2W-4S	0.21	0.37	0.17	0.21	0.01	41.69	40.93
3W-A	0.01	0.02	0.03	0.00	0.00	1.67	1.62
3W-V	48.87	13.49	5.02	22.17	3.01	6485.32	6441.62
4W-P	50.60	107.73	18.24	14.73	0.33	14507.76	14366.73
4W-D	0.00	0.00	0.00	0.00	0.00	1.30	1.29
Bus-S	0.26	0.22	0.01	0.50	0.03	37.81	37.05
Bus-M	0.04	0.05	0.02	0.03	0.01	6.18	6.07
Total	100.00	121.89	23.51	37.64	3.38	21082.02	20895.59
Year 2032							
2W-2S	0.00	0.01	0.02	0.00	0.00	0.73	0.70
2W-4S	0.01	0.05	0.02	0.03	0.00	5.26	5.16
3W-A	0.02	0.06	0.09	0.01	0.00	4.91	4.76
3W-V	48.27	25.85	9.63	42.48	5.77	12426.05	12342.33
4W-P	51.40	212.26	35.95	29.03	0.64	28583.82	28305.95
4W-D	0.01	0.00	0.00	0.01	0.00	4.56	4.54
Bus-S	0.10	0.17	0.01	0.37	0.02	28.26	27.69
Bus-M	0.20	0.45	0.17	0.26	0.05	52.97	52.03
Total	100.00	238.84	45.88	72.18	6.49	41106.55	40743.16

Table 6.16: Emission at Optimum Value of Design Variables for Case-4

Vehicle Type	% of Commuters	Pollutant (t/year) CO	HC	Nox	PM	Total	CO_2 (t/year)
	Year 2017						
2W-2S	10.42	22.94	41.19	0.80	2.46	1962.12	1894.74
2W-4S	0.00	0.00	0.00	0.00	0.00	0.03	0.03
3W-A	0.00	0.00	0.00	0.00	0.00	0.06	0.06
3W-V	9.75	2.69	1.00	4.43	0.60	1294.42	1285.70
4W-P	5.35	11.40	1.93	1.56	0.03	1535.17	1520.25
4W-D	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Bus-S	0.00	0.00	0.00	0.00	0.00	0.09	0.09
Bus-M	74.47	88.18	32.40	50.87	10.39	10294.21	10112.38
Total	100.00	125.21	76.52	57.66	13.48	15086.13	14813.27
Year 2032							
2W-2S	10.42	44.50	79.90	1.55	4.77	3806.29	3675.57
2W-4S	0.00	0.00	0.00	0.00	0.00	0.05	0.05
3W-A	0.00	0.00	0.00	0.00	0.00	0.12	0.12
3W-V	9.75	5.22	1.95	8.58	1.17	2511.03	2494.12
4W-P	5.35	22.11	3.75	3.02	0.07	2978.06	2949.10
4W-D	0.00	0.00	0.00	0.00	0.00	0.04	0.04
Bus-S	0.00	0.00	0.00	0.00	0.00	0.17	0.17
Bus-M	74.47	171.05	62.85	98.68	20.15	19969.58	19616.85
Total	100.00	242.90	148.44	111.85	26.15	29265.35	28736.02

From the table 6.12, it is clear that in the existing transportation, CO_2 emission can be reduced if all commuters travel by 3W. 3W-V are more effective than the 3W-A. It is because emission factor of 3W-V is less than other vehicles. If constraint is imposed on PM-emission then 48.88% commuters should travel by 3W-V and 50.6% commuters should travel by 4W-P and rest with other vehicles. It is because CO_2-emission and PM-emission have inverse relationship (i.e., the vehicles which emits higher CO_2, emits lower PM and vice versa. If all categories of vehicles are compulsory for the transportation, then maximum number of commuters (74.74%) will travel by Bus-M followed by 2W-2S (10.42%), 3W-V (9.75%) and 4W-P (5.35%). From the table 6.13, 6.14, 6.15 and 5.16 it can be observed that emission trend is same for the year 2017 and year 2032 in each case and emission of the year 2032 is higher than year 2017. It is because number of vehicles is higher in year 2032.

6.7 Emission Estimation and Scenario Analysis

Emission estimates for road transport sector for Dehradun city have been projected for the year 2032 using existing traffic count on study area (Table 6.4). Various factors such as population, vehicular growth and travel demand, fuel norms and technology, existing and planned public transport infrastructure, users comfort convenience and time etc. were taken into accunt for framimg the scenarios.In business as usual (BAU) scenario-there is no change in fuel and technolgy,vehicle growth and travel demand will incresed as prevailing pace.

In view of reducing emissions by improvement of public transport, we intervened some policies to enhance the public transport after reviewing the literature and discussion with concerned experts of this field and study area. 4-scenarios have been developed to calculate the emission reduction in the city. Table: 6.17 describe the scenarios.

Table 6.17: List of Scenarios

Scenario	Description	Remark
Base Scenario *Business as usual (BAU)*	In BAU the passenger demand hasn't been restricted by any assumptions or conditions and the growth is calculated based on the present trend.	
Scenario-1 *Enhancement of public transport*	In this scenario public transport system is assumed to be enhanced in terms of its mobility comfort, Convenience and frequency.	This scenario is influenced by NUTP 2014 for providing better mobility and sustainability by focus on people rather vehicle.

Scenario-2 *Introduction of CNG Buses*	In this scenario cleaner fuel CNG would be introduced for buses(where it is currently not present)	In 2001 Supreme Court has taken steps to introduce cleaner fuel (CNG) to reduce the adverse impact on environment by vehicle population.
Scenario-3 *Introduction of Electric Auto Rickshaw and CNG 3 Wheeler (Vikram)*	In this scenario CNG would be introduce as alternative fuel for 3W (Vikram) and 50% of Auto will be replaced by battery operated E-rickshaws	The National Electric Mobility Mission Plan 2020.GOI.provides electric vehicle (EV) as an alternative mobility option that can help to redress environmental adverse impact
Scenario-4 *Introduction of PRT (Personal Rapid Transit)*	PRT is an electric operated system which will be introduced at guided lanes from point to point destination.	Uttarakhand Government of India is interested to provide PRTS in this region.

6.7.1 Preference (Willingness to shift) Survey

The main aim of the survey is to check the feasibility of alternative that a decision maker chooses. A questionnaire is prepared to study the behavioral of commuters with respect to hypothetical scenarios (Annexure-X). In this questionnaire around 300 samples are being interviewed with commuters on and in influence area of selected corridor to study the behavioral of commuters with respect to a hypothetical scenario. commuters are asked to rate the willingness to shift from present mode to proposed mode where commuters are first informed about the proposed mode and scenario, its utilities and benefits and then asked if they will be willing to shift to propsed scenario. The percentage of mode wise shift to introduced scenario has beed discussed below;

a)Base scenario: Business as usual (BAU)

In BAU, existing transportation of 2017 has been considered. Figure 6.17(i) shows the modal split in base year .

b) Scenario-1: Enhancement of the public transport

From the survey it is evident that in scenario-1, all the bus users have shown interest to shift to enhanced public bus. However by improving comfort and convinience 7 % users of 2W and 10 % useres of 3W have also shown their interest to shift. Car users are not interested to travel by bus. Modal split is shown in Figure 6.17(ii)

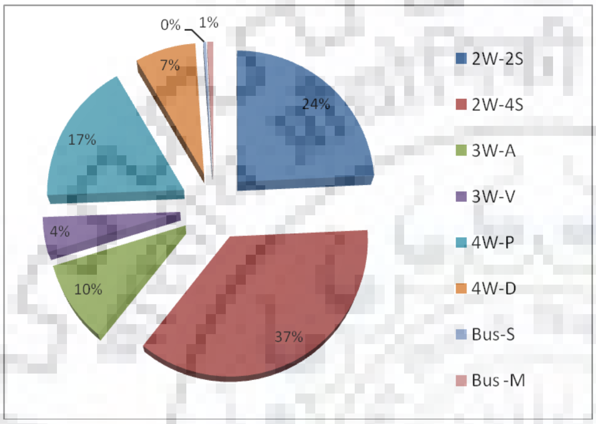


Figure 6.17 (i): Modal split in base

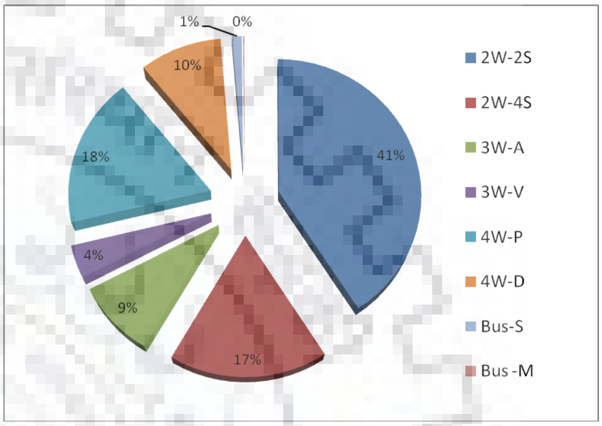


Figure 6.17 (ii) : Modal split in Sscenario-

c) Scenario-2 Introduction of CNG buses

In this scenario alternative fuel CNG based low floor buses with worldclass facility are introduced. The survey envisaged that , 100% bus users and 95% users of mini bus were willing to shift to CNG based buses. Users who run on shorter distance <3 km are not interested to shift from mini bus. As the cleaner fuel buses with world class facility,comfort and convinience will reduces environment degradation. 7% users of 2W,10% users of 3W and to some extent 2% users of 4W have shown interest to shift to proposed CNG based mode. Modal split is shown in Figure 6.17(iii)

d) Scenario-3 : Introduction of electric auto rickshaw and CNG 3 wheelers (vikram)

In this scenario, CNG would be introduced as alternative fuel for 3W-Vikram and battery operated E-rickshaw would be introduced in place of 50% of Auto. Survey revealed that 99% users of 3-Wheeler are willing to shift to proposed mode of transport. Due to environment friendliness and easy availability and door to door services 5% users of 2W, and 2% users of bus have shown interest to shift. Modal split is shown in Figure 6.17(iv)

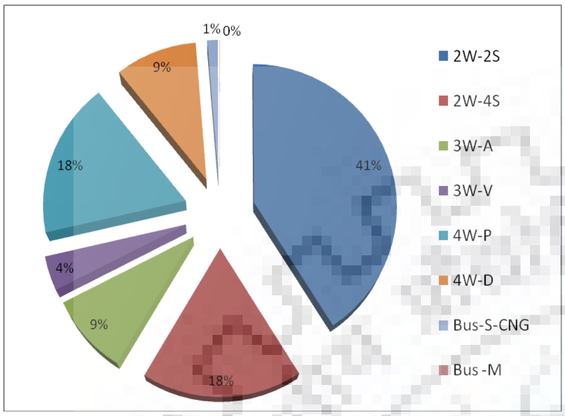


Figure 6.17 (iii) : Modal split in

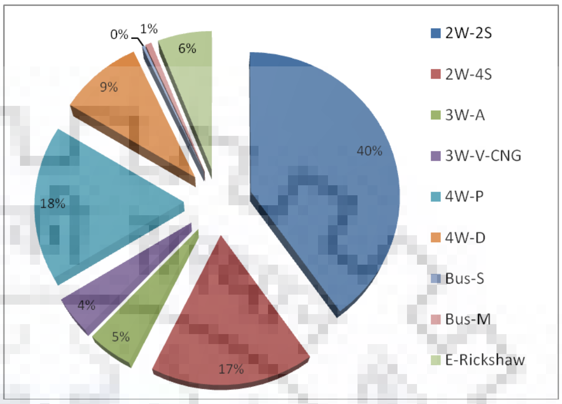


Figure 6.17 (iv) : Modal split in

e) Scenario-4: Personal rapid transit (PRT)

This scenario is targeted the personal transport users. Survey revealed that 10% users of buses, 50% users of 3W, 15% users of 2W, and 35% users of 4W are willing to shift to PRTS as it is congestion free, take less time & no need of parking and safe also. Modal split is shown in Figure 6.17(v)

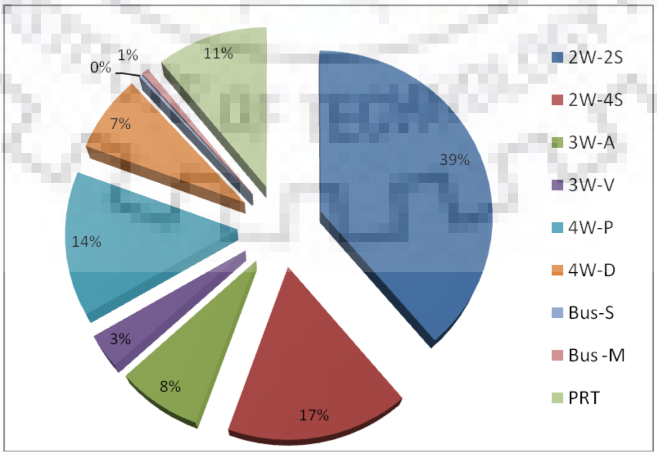


Figure 6.17 (v) : Modal split in scenario-4

6.7.2 Emission Estimation of Scenarios

a) Scenario-1 Enhancement of Public Transport

The emissions of different pollutants are mentioned in Table 6.18 for this scenario. The Figure 6.18 shows the vehicles' category wise emissions for different pollutant

Table 6.18: Estimation of Different Pollutant Emission in Scenario-1

Mode Type	Pollutant (t/year)				
	CO_2	CO	HC	NO_x	PM
2W-2S	4028.5	48.77	87.57	1.70	5.22
2W-4S	1880.0	17.09	7.95	9.53	0.59
3W-A	1663.9	20.98	29.73	2.92	0.86
3W-V	1326.4	2.77	1.03	4.57	0.62
4W-P	5886.6	44.14	7.48	6.03	0.13
4W-D	3776.8	3.07	2.83	7.74	0.68
Bus-S	1870.9	11.16	0.76	25.00	1.43
Bus-M	153.9	1.34	0.49	0.77	0.16

Scenario-2, Introduction of CNG buses

The emissions of different pollutants are mentioned in Table 6.19 for this scenario. The Figures 6.19 shows the vehicles' category wise emissions for different pollutants.

Table 6.19: Estimation of Different Pollutant Emission in Scenario-2

Mode Type	Pollutant (t/year)				
	CO_2	CO	HC	NOx	PM
2W-2S	4028.51	48.77	87.57	1.70	5.22
2W-4S	1880.01	17.09	7.95	9.53	0.59
3W-A	1663.94	20.98	29.73	2.92	0.86
3W-V	1326.43	2.78	1.03	4.57	0.62
4W-P	5827.21	43.70	7.40	5.98	0.13
4W-D	3738.69	3.043	2.81	7.66	0.67
Bus-CNG	2601.89	12.00	12.10	14.02	0.11
Bus-M	38.48	0.34	0.12	0.19	0.04

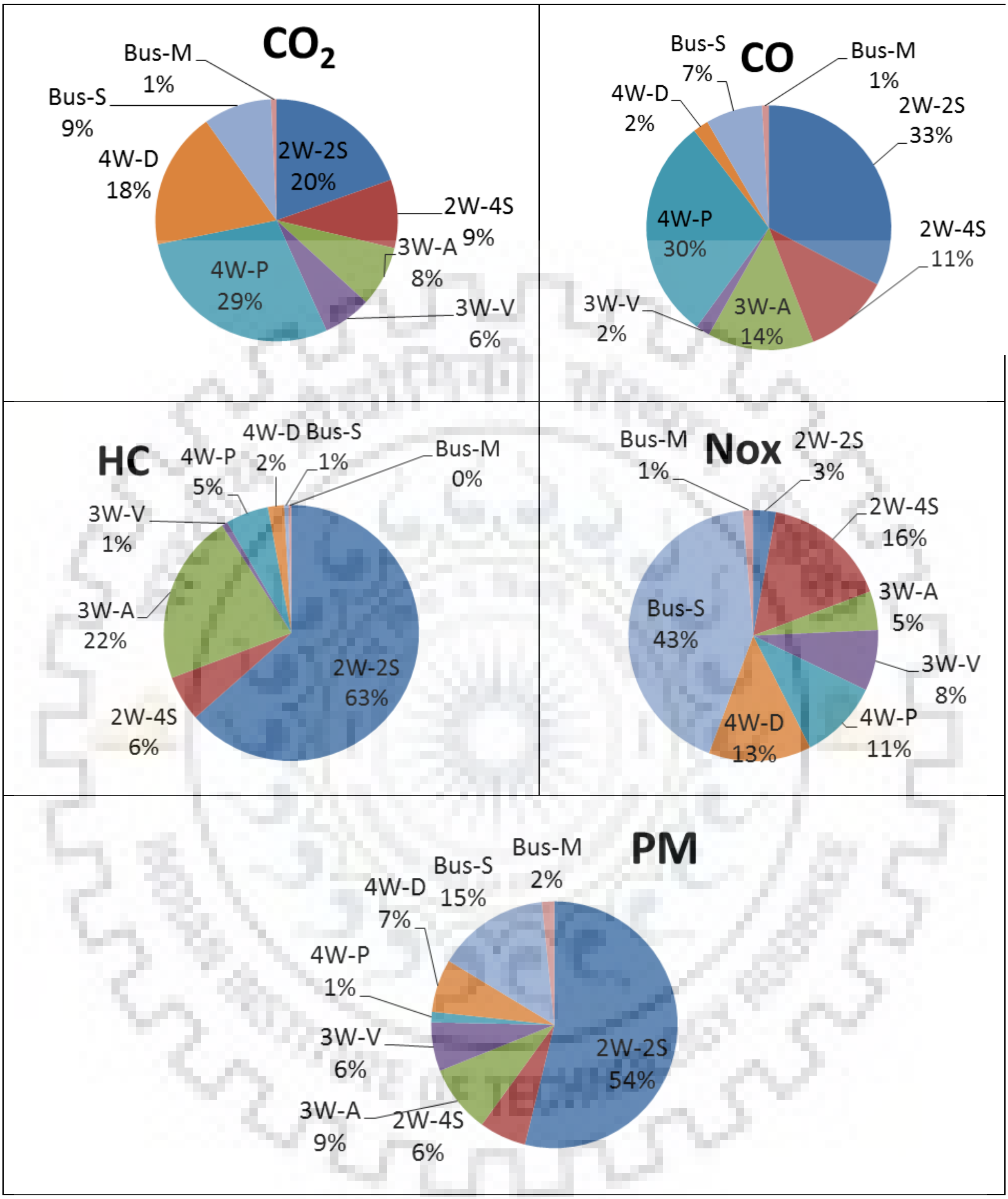


Figure 6.18 : Shares of Different Vehicle Categories in Emissions of Various Pollutants From Road Transport Sector In Scenario -1

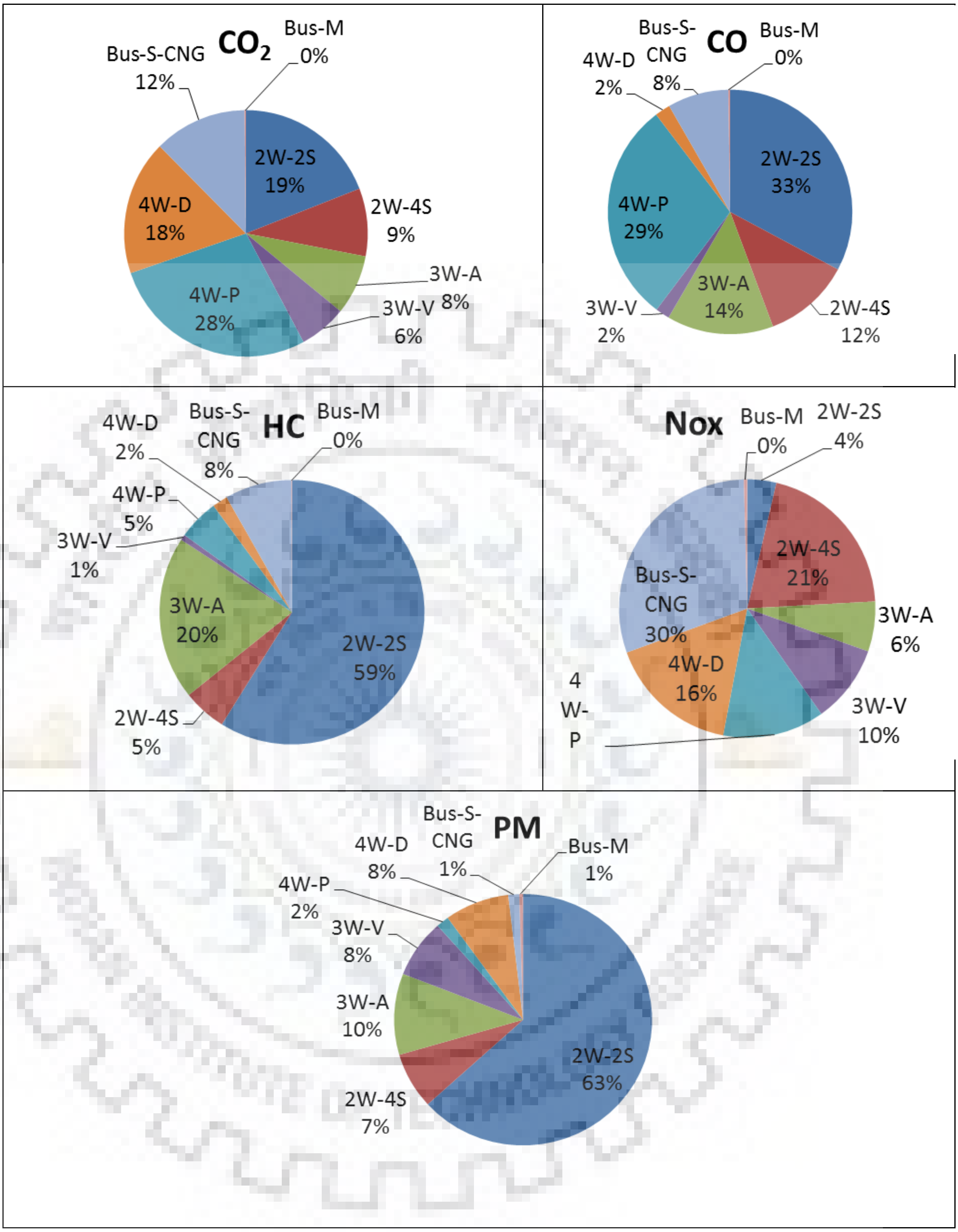


Figure 6.19: Shares of Different Vehicle Categories in Emissions Of Various Pollutants From Road Transport Sector in Scenario -2

Scenario-3: Introduction of E Rickshaw and CNG based 3-Wheeler

The emissions of different pollutants are mentioned in Table 6.20 for this scenario. The Figure 6.20 shows the vehicles' category wise emission for different pollutants.

Table 6.20: Estimation of Different Pollutant Emission in Scenario-3

Mode type	Pollutant (t/yr)				
	CO_2	CO	HC	NOx	PM
2W-2S	4115.14	49.82	89.46	1.74	5.34
2W-4S	1920.44	17.46	8.12	9.74	0.61
3W-A	924.41	11.66	16.51	1.62	0.48
3W-V_CNG	646.25	7.73	23.07	0.02	0.013
4W-P	5946.13	44.59	7.55	6.10	0.13
4W-D	3814.99	3.10	2.86	7.82	0.68
Bus-S	491.74	2.94	0.20	6.57	0.38
Bus-M	754.16	6.58	2.42	3.79	0.77
E-Rickshaw	359.57	0	0	0.79	0.74

Scenario-4: Introduction of PRTS

The emissions of different pollutants are mentioned in Table 6.21 for this scenario. The Figures 6.21 shows the vehicles' category wise emissions for the different pollutants.

Table 6.21: Estimation of Different Pollutant Emission in Scenario-4

Mode Type	Pollutant (t/yr)				
	CO_2	CO	HC	NOx	PM
2W-2S	3681.97	44.58	80.04	1.56	4.77
2W-4S	1718.29	15.62	7.26	8.71	0.55
3W-A	1386.62	17.48	24.77	2.42	0.72
3W-V	1105.36	2.31	0.86	3.80	0.52
4W-P	4459.60	33.44	5.66	4.57	0.10
4W-D	2861.25	2.32	2.15	5.87	0.51
Bus-S	442.56	2.64	0.18	5.92	0.34
Bus-M	707.99	6.17	2.27	3.56	0.73
PRT	1026.55	2.93	0.49	0.39	0.02

Figure 6.21 shows that 2W- 2S contributing maximum PM (58%) and HC (65%) emission. On the other hand, pollutant likes NO_x (24%) and CO (35%) are mainly emitted from 2W and 4W. Petrol based car are main mode to contribute the maximum CO_2 (31%) followed by 2W- 2S.

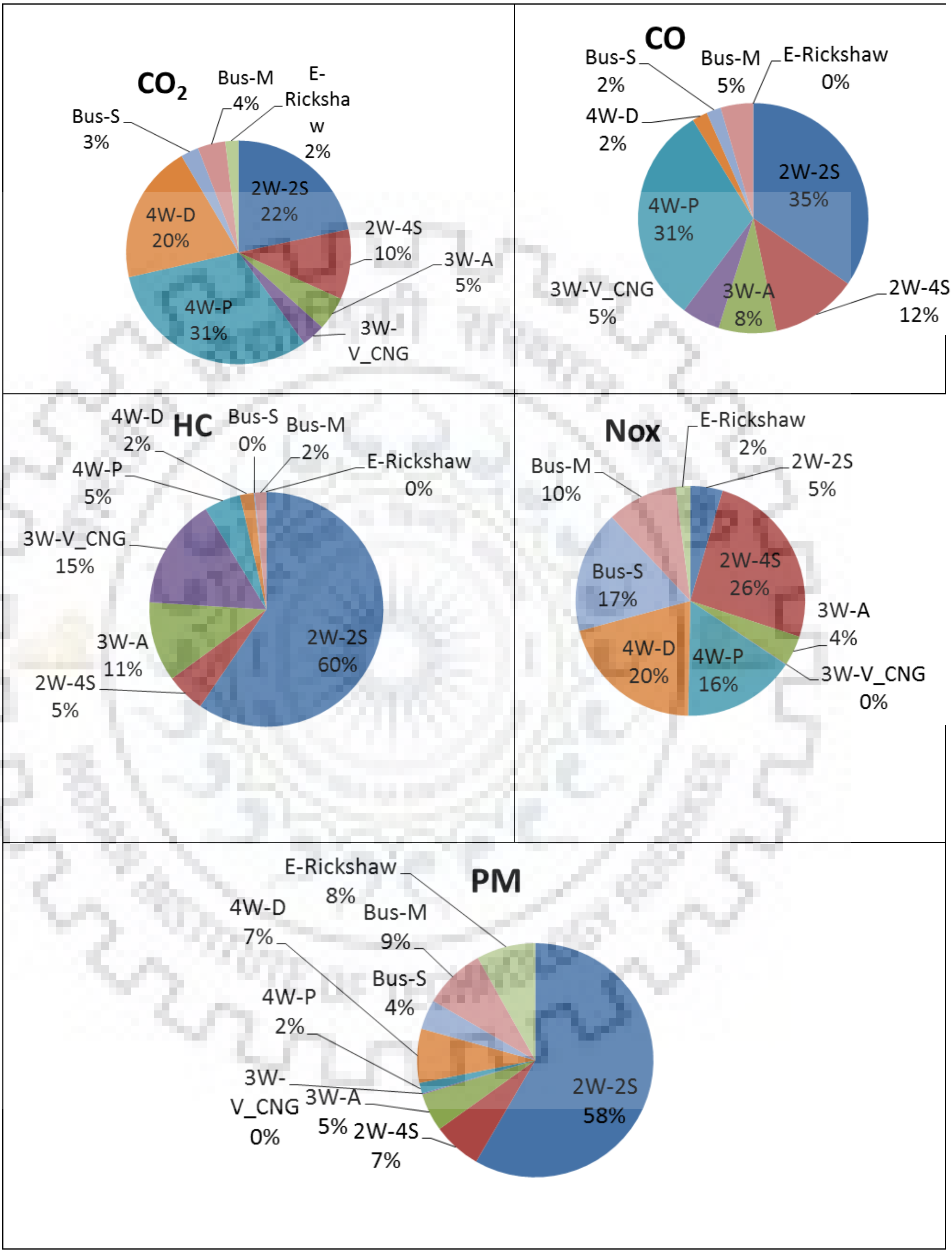


Figure 6.20 : Shares of Different Vehicle Categories in Emissions of Various Pollutant from Road Transport Sector in Scenario -3

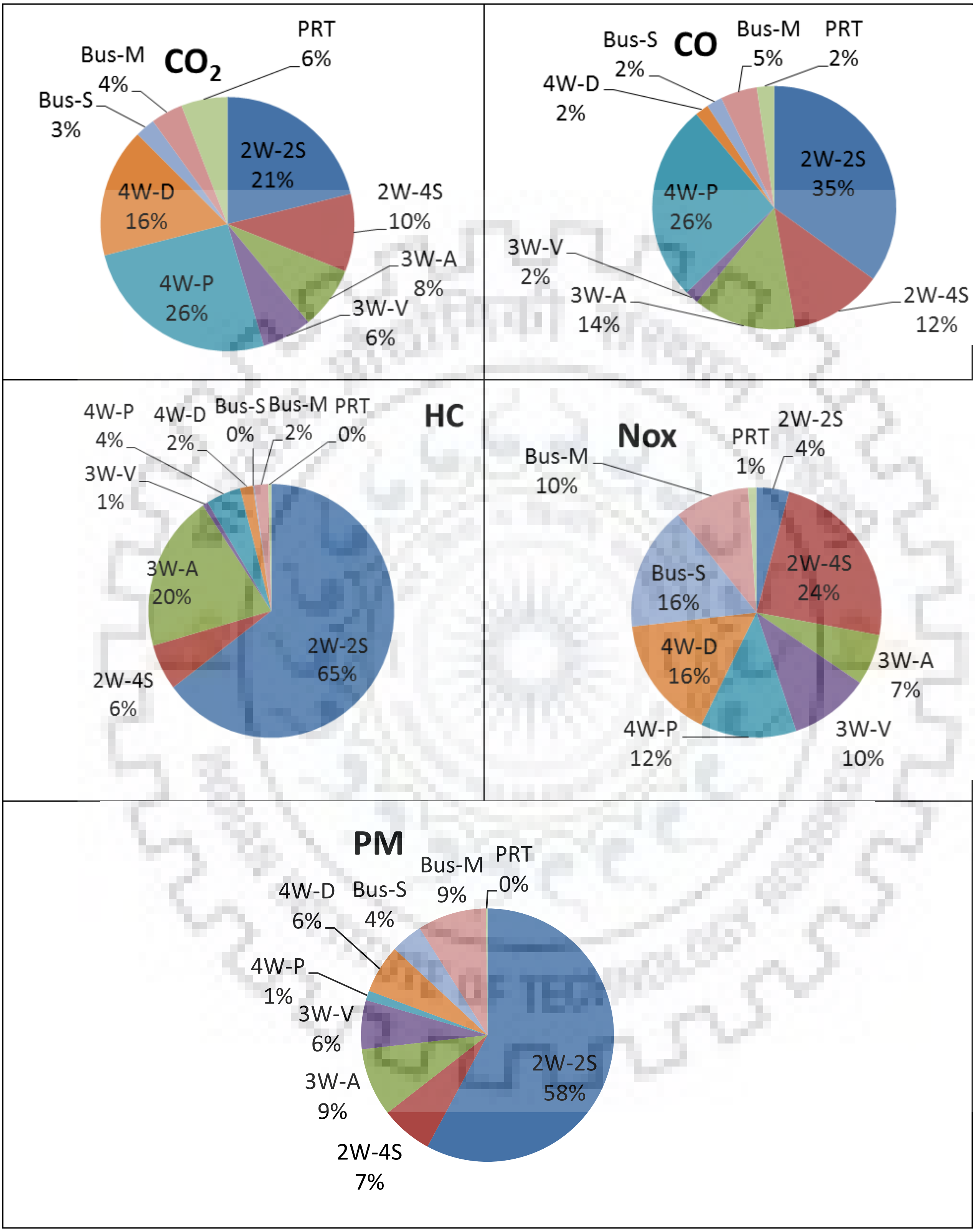


Figure 6.21: Shares of Different vehicle Categories in Emissions of Various Pollutants from Road Transport Sector in Scenario -4

The emission reduction potentials of various alternate scenarios are illustrated in Table 6.22. Figures 6.22, 6.23, 6.24 ,and 6.25 show emission in each scenario for CO_2, CO, HC, NOx and PM pollutants respectively.

Table 6.22: Emission Reduction Potential of Each Alternative Scenario

SCENARIO	Emission (t/yr)					% Reduction				
	CO_2	CO	HC	NO_x	PM	CO_2	CO	HC	NO_x	PM
Base	20698.3	154.57	149.97	44.76	9.89					
Scenario-1	20587.18	149.35	137.84	58.28	9.70	-0.54	-3.37	-8.09	30.21	-1.93
Scenario-2	21105.17	148.70	148.71	46.57	8.26	1.97	-3.79	-0.84	4.06	-16.51
Scenario-3	18972.84	143.87	150.18	38.19	9.14	-8.34	-6.92	0.15	-14.67	-7.53
Scenario-4	17390.18	127.52	123.68	36.81	8.25	-15.98	-11.37	-17.53	-17.76	-16.58

From the table 6.22, it is clear that except NOx all the pollutants reduce with respect to base scenario in scenario-1. NOx increases to 30.21%. It is because maximum commuters travel by Bus-S, which has diesel engine. Diesel engine needs high temperature during combustion process which results to emit high NOx

In scenario-2, except CO_2, & NOx all other pollutants reduce with respect to base scenario. It is because maximum commuters travel by Bus-S-CNG which has CO_2-emission factor more than Bus-S. Since, CNG-engine needs high temperature during the combustion, therefore, emission for NOx is increasing.

In scenario-3, except HC all other pollutants are reducing with respect to base scenario. It is because maximum commuters are travelling 3W-V-CNG and E-Rickshaw.

In scenario-4, all the emissions are reducing with respect to the base scenario. It is because maximum commuters are traveling by PRT whose emissions are small in comparison to other vehicles.

It can be concluded that scenario-4 is the best scenario in terms of all pollutant emission followed by scenario 3 and scenario 2.

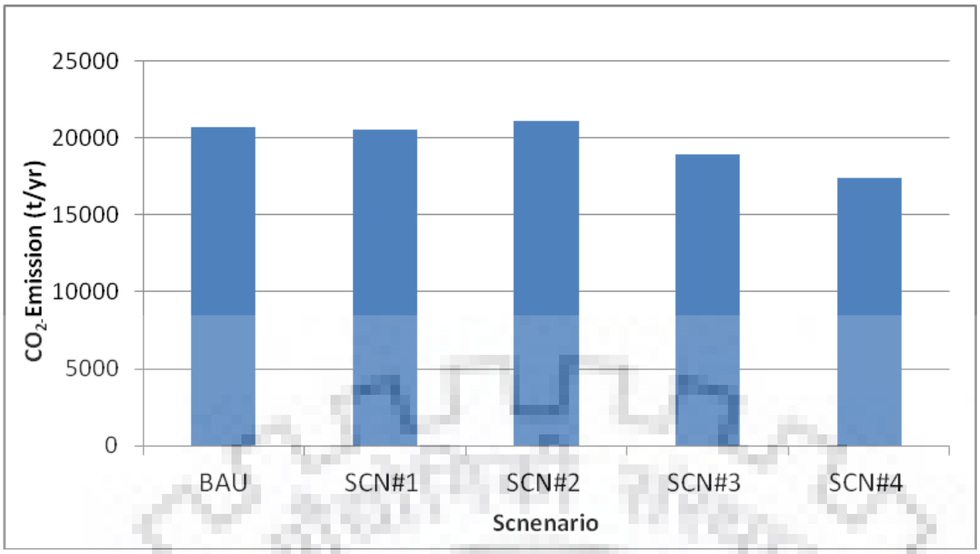


Figure 6.22: CO_2- Emission in Different scenarios

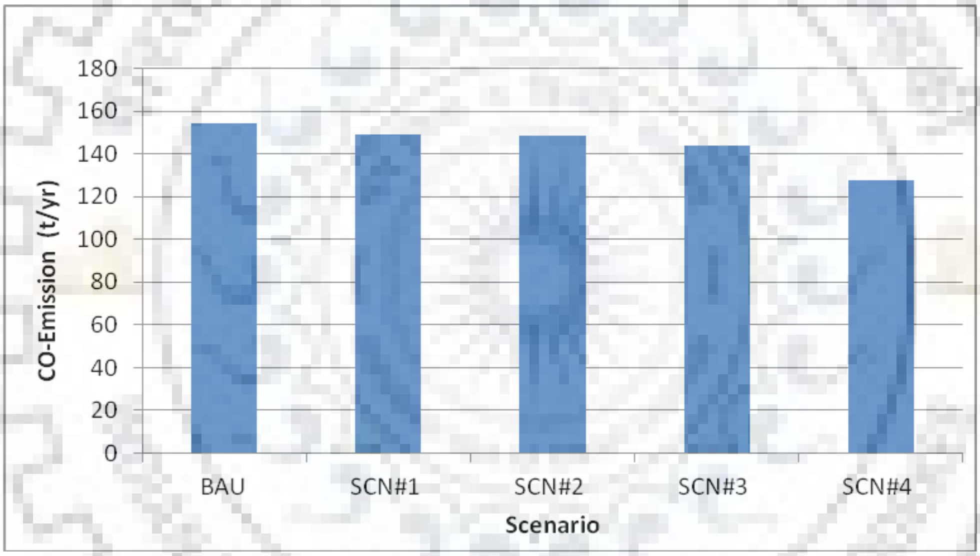


Figure 6.23: CO- Emission in Different Scenarios

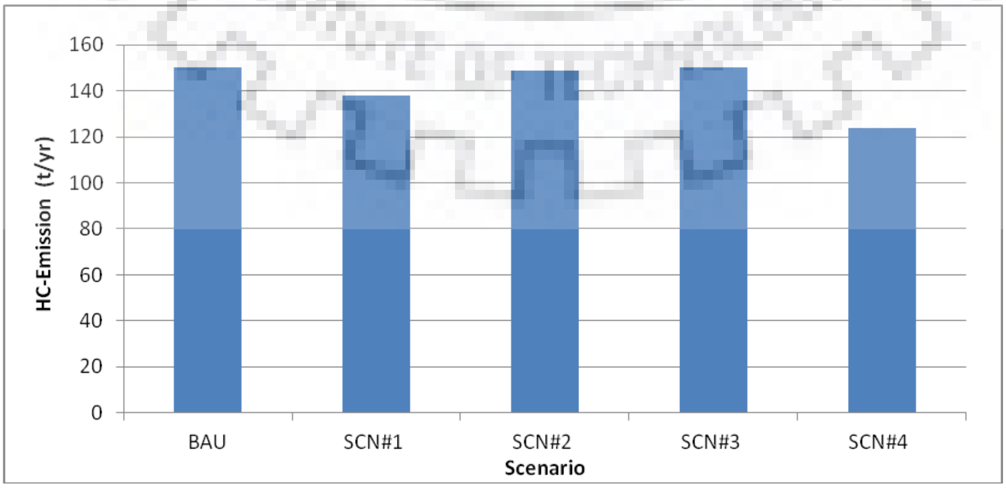


Figure 6.24 : HC-Emission in Different Scenarios

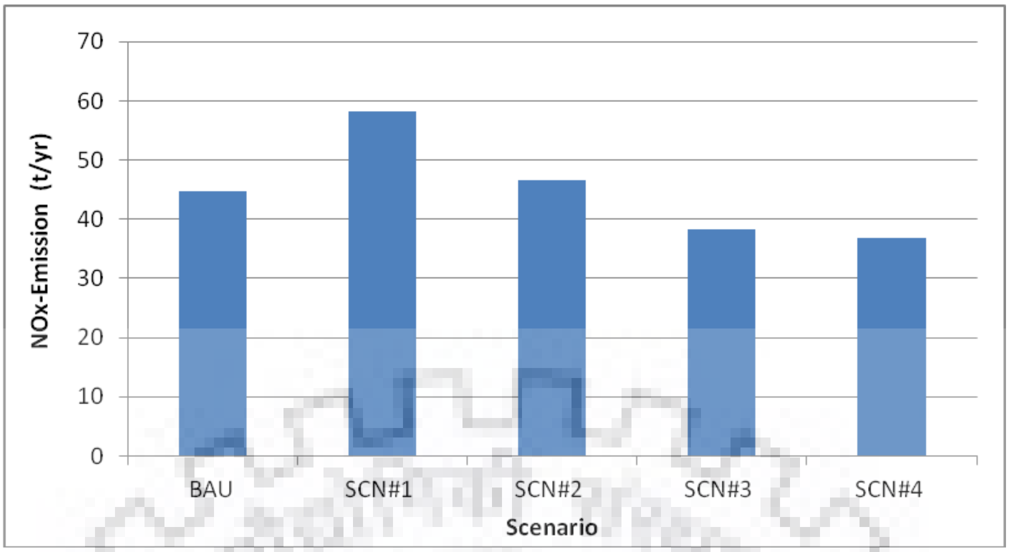


Figure 6.25: NOx- Emission in Different Scenarios

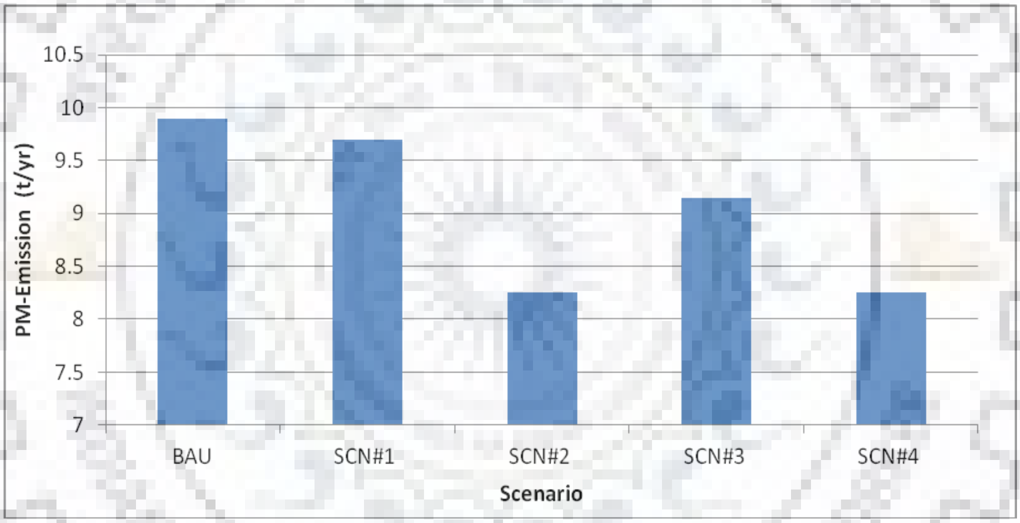


Figure 6.26: PM- Emission in Different Scenarios

6.8 Sensitivity Analysis of Scenarios

In order to explain the charges in emission as a function of commuter shift, fuel type, technology, a sensitivity analysis has been carried out. A spread sheet has been developed to determine the effect on CO_2 ,CO, HC, PM emissions by different percentage of commuters shift and presented in Figure:6.27,6.28,6.29,6.30,6.31, and effect of vehicle disribution based on technology, fuel type, and size is presented in Table 6.23, 6.24, 6.25 for Scenario-1.

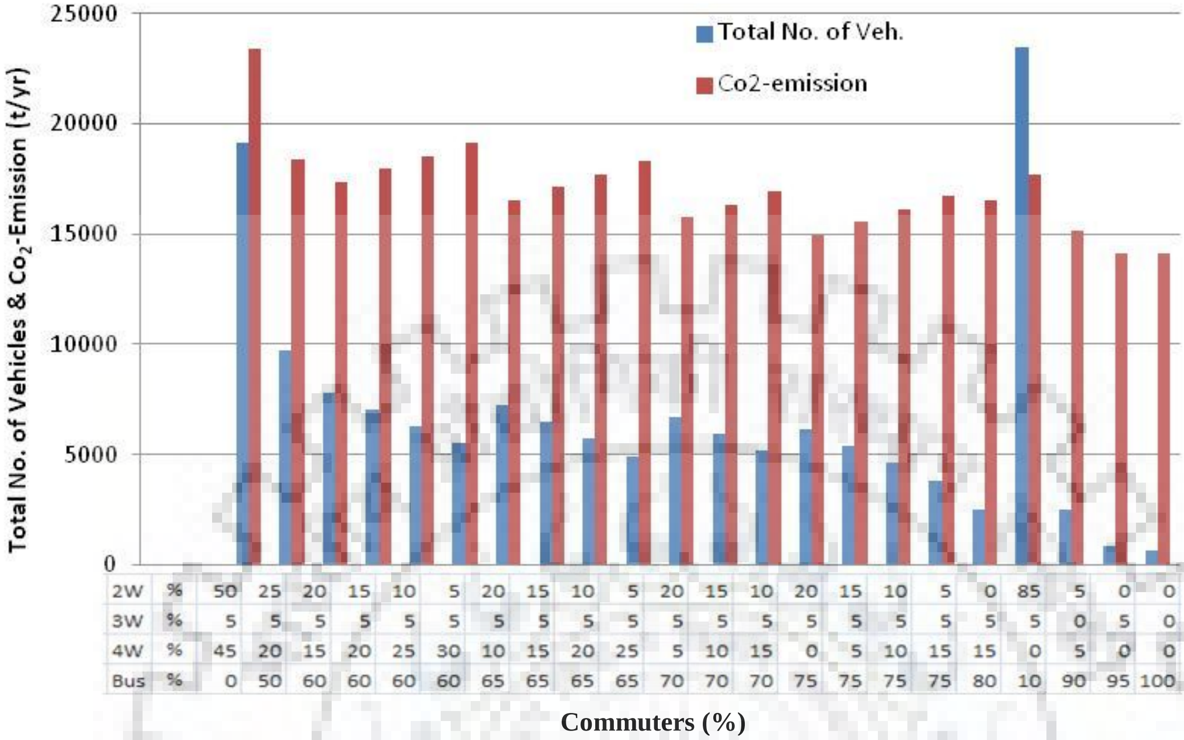


Figure 6.27: Effect on CO_2-Emission due to Commuter shift under Scenario-1

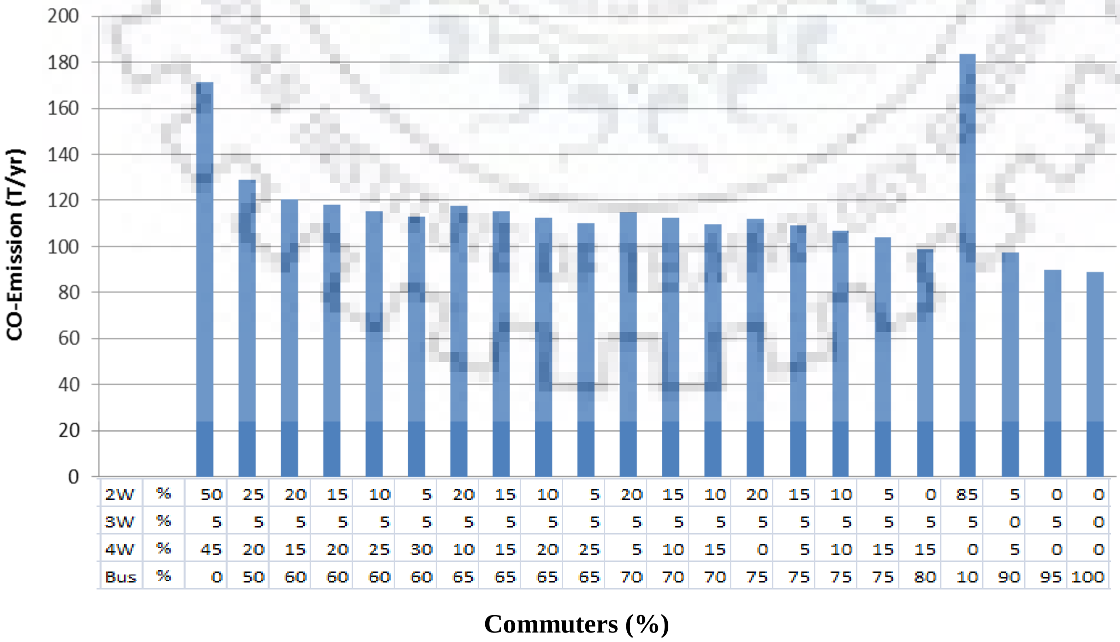
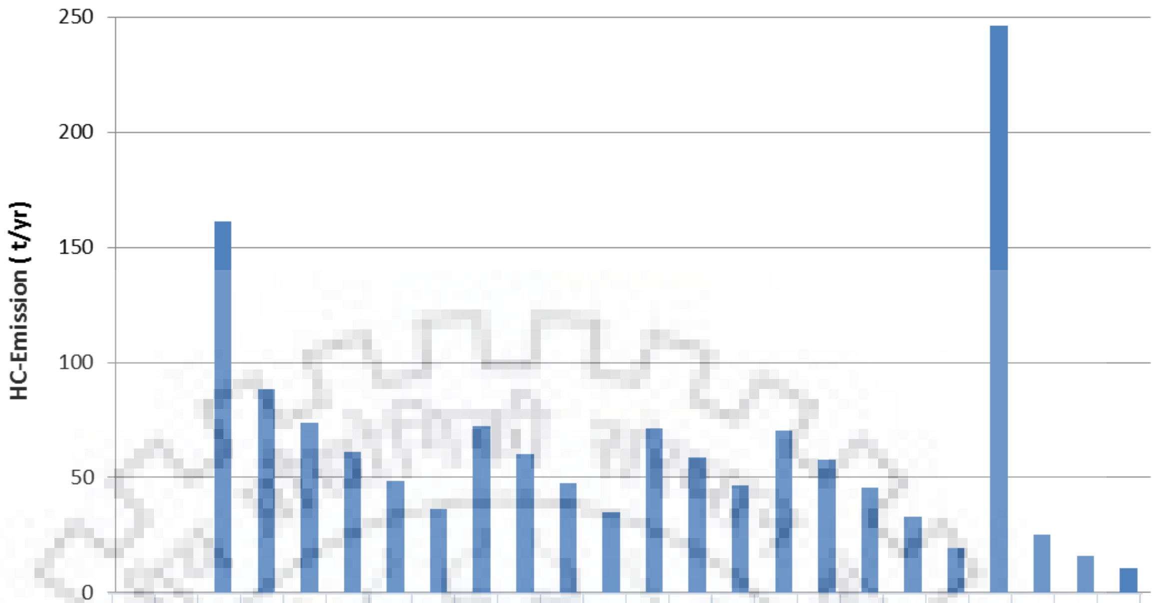


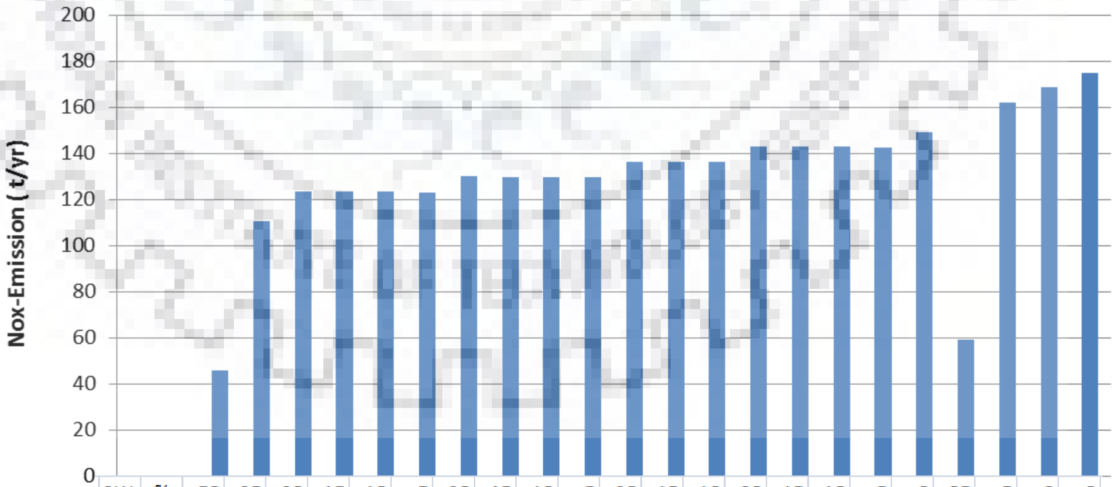
Figure: 6.28: Effect on CO- Emission due to Commuter Shift under Scenario-1



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%)

Figure: 6.29: Effect on HC- Emission due to Commuter Shift under Scenario-1



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%)

Figure 6.30: Effect on NO_x -Emission due to Commuter shift under Scenario-1

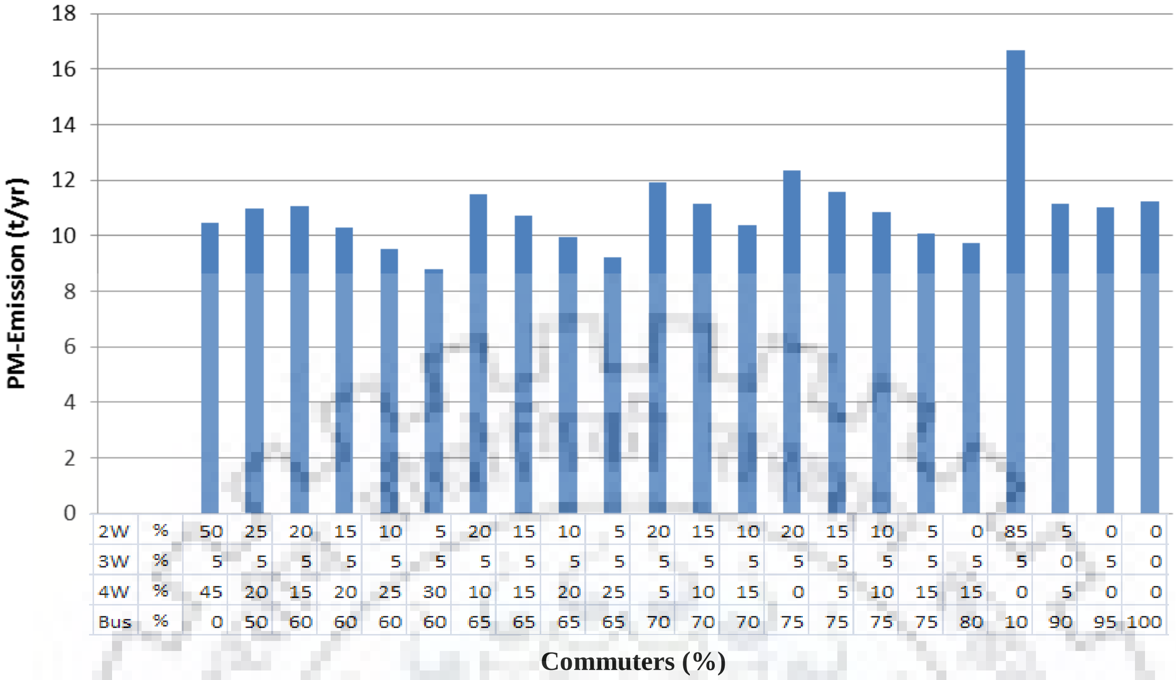


Figure 6.31: Effect on PM-Emission due to Commuter shift under Scenario-1

Figures 6.27,6.28,6.29,6.30, and 6.31 envisage that CO_2, CO and HC- emissions are minimum when all 100% commuters travell by buses, and NOx -emission will be minimum when 50% of commuters, 5% of commuters and 45% of commuters travell by 2W, 3W and 4W respectively. NOx-emission will be minimum when 5% of commuters, 5% of commuters, 45% of commuters and 60% of commuters travell by 2W, 3W, 4W buses bus respectively. Table 6.23, 6.24 and 6.25 represent that 2W-4S, 3W-A and diesel engine emit larger CO_2 and Nox than 2W-2S, 3W-V and petrol engine

Table 6.23 :Effect of Technology of 2W(2S &4S) on Emission under Scenario-1

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	2W		CO_2	CO	HC	NO_x	PM
(%)	(%)	(%)	(%)	2S (%)	4S (%)					
34.03	24.63	32.22	9.13	70	30	20606.56	154.33	145.87	57.55	9.73
				60	40	20638.34	148.08	127.98	61.21	9.15
				50	50	20689.51	146.81	118.12	64.15	8.60
				40	60	20740.68	145.55	108.25	67.08	8.06
				30	70	20791.85	144.28	98.39	70.01	7.51

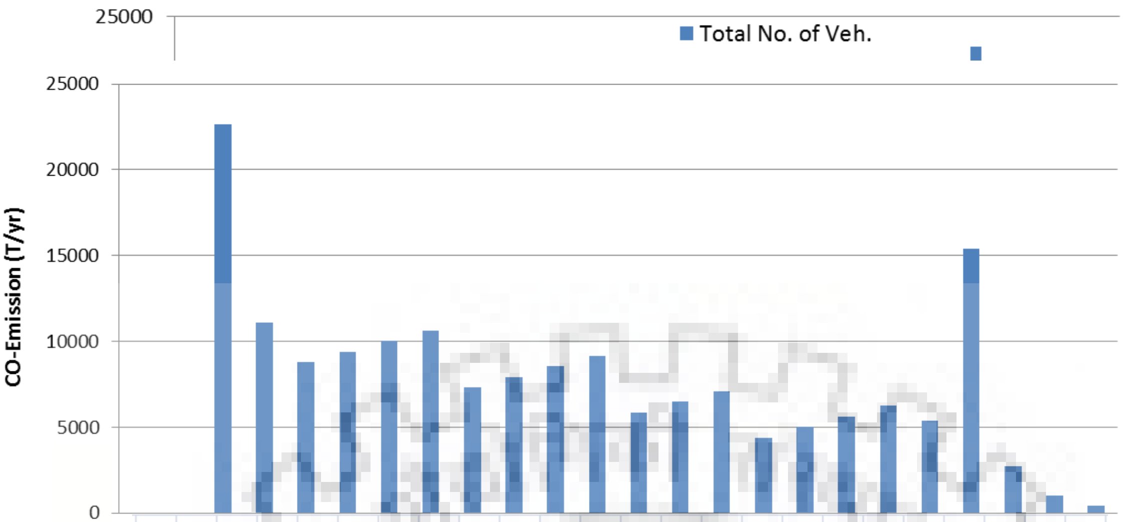
Table 6.24 : Effect of Three Wheeler (Auto & Vikram) on Emission under Scenario-1

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	3W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	A (%)	V (%)					
34.03	24.63	32.22	9.13	70	30	20606.56	154.33	145.87	57.55	9.73
				60	40	20593.97	151.10	140.66	58.02	9.71
				50	50	20581.39	147.87	135.44	58.50	9.69
				40	60	20568.80	144.64	130.22	58.97	9.67
				30	70	20556.21	141.41	125.01	59.44	9.65

Table 6.25: Effect of type of 4W- Petrorl and diesel on emission under Scenario-1

Effect of type of 4W- Petrol and diesel on emission										
Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	4W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	P (%)	D (%)					
34.03	24.63	32.22	9.13	70	30	20500.45	152.31	138.01	57.64	9.61
				60	40	20673.90	146.40	137.67	58.92	9.78
				50	50	20847.36	140.48	137.33	60.20	9.96
				40	60	21020.82	134.57	136.99	61.49	10.13
				30	70	21194.28	128.66	136.65	62.77	10.30

For Scenario-2, the effect on CO_2 ,CO, HC, NO_2, PM emission by different percentage of commuter shift is presented in Figure: 6.32, 6.33, 6.34, 6.35, 6.36 & effect of technology, effect of 3W (Auto and Vikram) and fuel type (diesal and petrol)for 4Ws and on emission is shown in Table 6.26, 6.27, 6.28 respectively.



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%) %)

Figure 6.33: Effect on CO- Emission due to COmmuter shift under Scenario-2

2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%)

Figure 6.34: Effect on HC- Emission due ot Commuter shift under Scenario-2

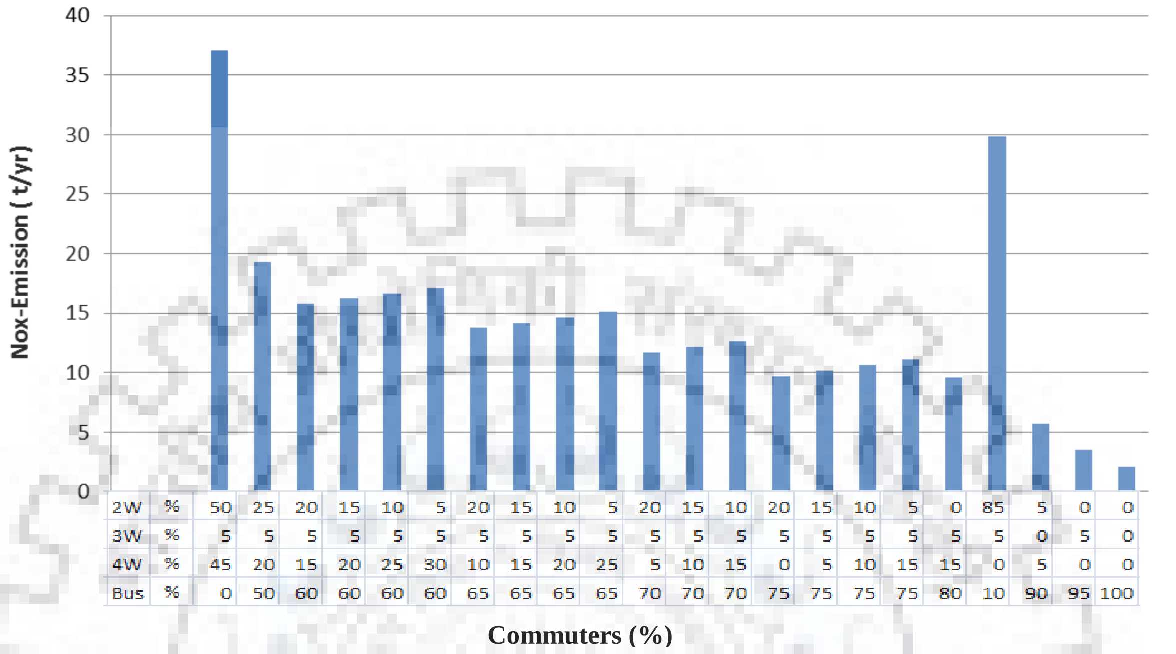


Figure 6.35: Effect on No_x-Emission due to Commuter shift under Scenario-2

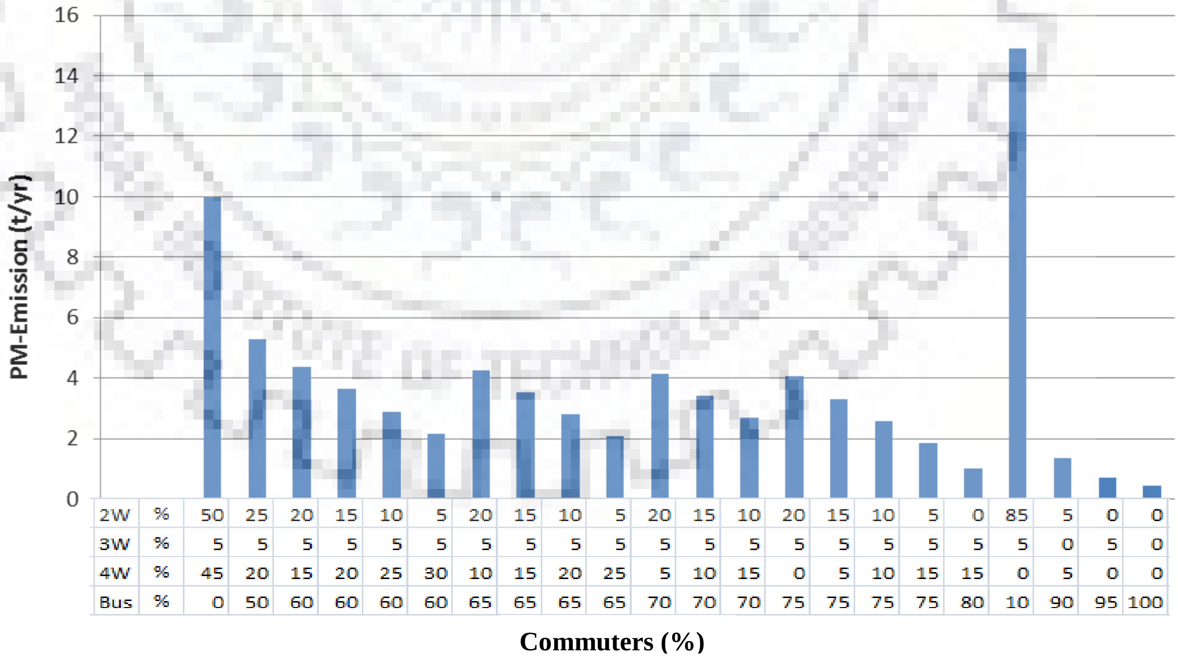


Figure 6.36: Effect on PM -Emission due to Commuter shift under Scenario-2

Figures 6.32,6.33, 6.34,6.35,6.36 envisage that CO_2 , CO, HC, NOx and PM emiission will be minimum if all comuters travell by CNG buses.

Table 6.26 : Effect of Technology of 2W(2S &4S) on Emission under Scenario-2

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	2W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	2S (%)	4S (%)					
34.03	24.63	32.22	9.13	70	30	18522.66	141.68	144.64	31.82	8.18
				60	40	18554.45	135.43	126.75	35.48	7.60
				50	50	18605.62	134.16	116.89	38.42	7.05
				40	60	18656.78	132.90	107.02	41.35	6.50
				30	70	18707.95	131.63	97.16	44.29	5.96

Table 6.27: Effect of Three Wheeler (Auto & Vikram) on Emission under Scenario-2

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	3W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	A (%)	V (%)					
34.03	24.63	32.22	9.13	70	30	18522.66	141.68	144.64	31.82	8.18
				60	40	18510.08	138.45	139.43	32.30	8.16
				50	50	18497.49	135.22	134.21	32.77	8.13
				40	60	18484.90	131.99	128.99	33.24	8.11
				30	70	18472.32	128.76	123.78	33.71	8.09

Table 6.28 : Effect of type of 4W- Petrol and Diesel on Emission underScenario-2

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	4W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	P (%)	D (%)					
34.03	24.63	32.22	9.13	70	30	18417.43	139.63	136.78	31.92	8.06
				60	40	18589.13	133.78	136.44	33.19	8.23
				50	50	18760.84	127.92	136.10	34.46	8.40
				40	60	18932.54	122.07	135.77	35.73	8.57
				30	70	19104.25	116.22	135.43	37.00	8.74

For Scenaario-3, the effect on CO_2 ,CO, HC, NO_2, PM-emissions by different percentage of commuter shift is shown in Figure:6.37,6.38,6.39,6.40,6.41 & the effect of technology , fuel type (diesal and petrol)for 4Ws and effect of 3W on emission are pressented in Table 6.29, 6.30, 6.31 .

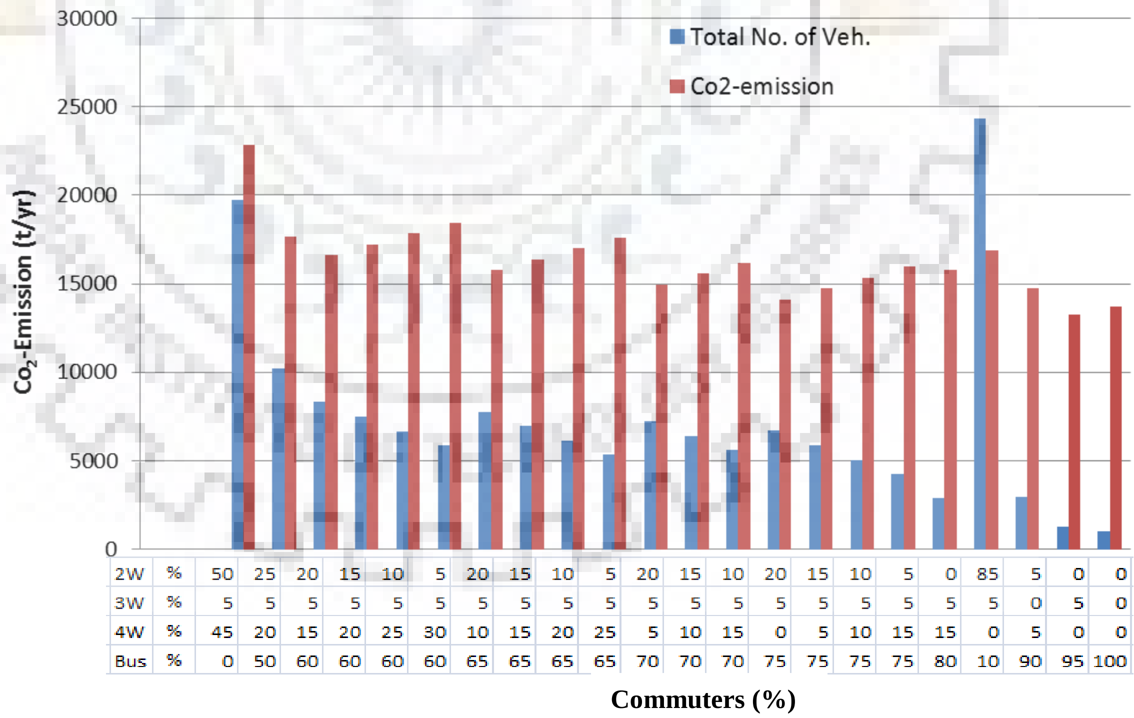
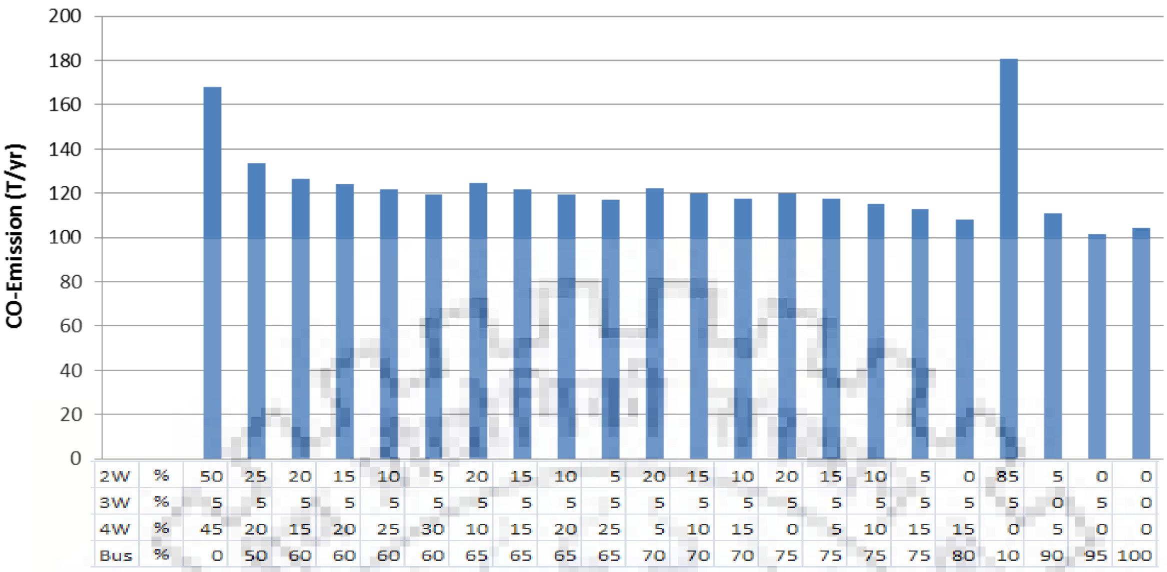
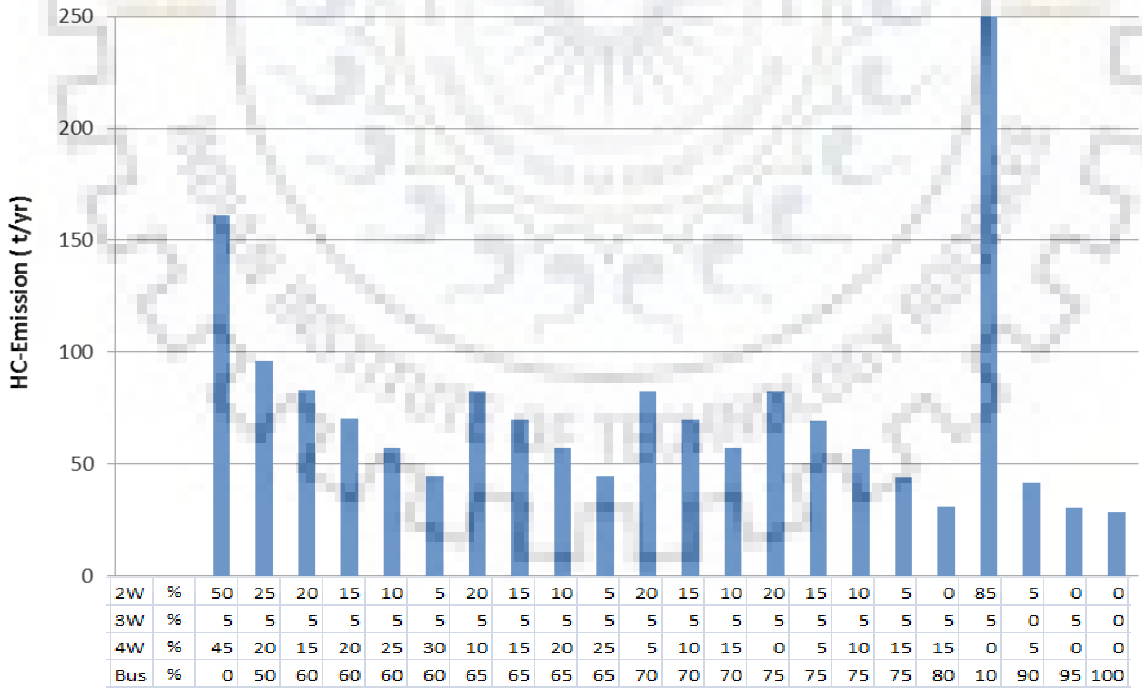


Figure 6.37: Effect on CO_2 -Emission due to Commuter shift under Scenario-3



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Figure 6.38: Effect on CO -Emission due to Commuter shift under Scenario-3



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Figure 6.39: Effect on HC- Emission due to Commuter shift under scenario-

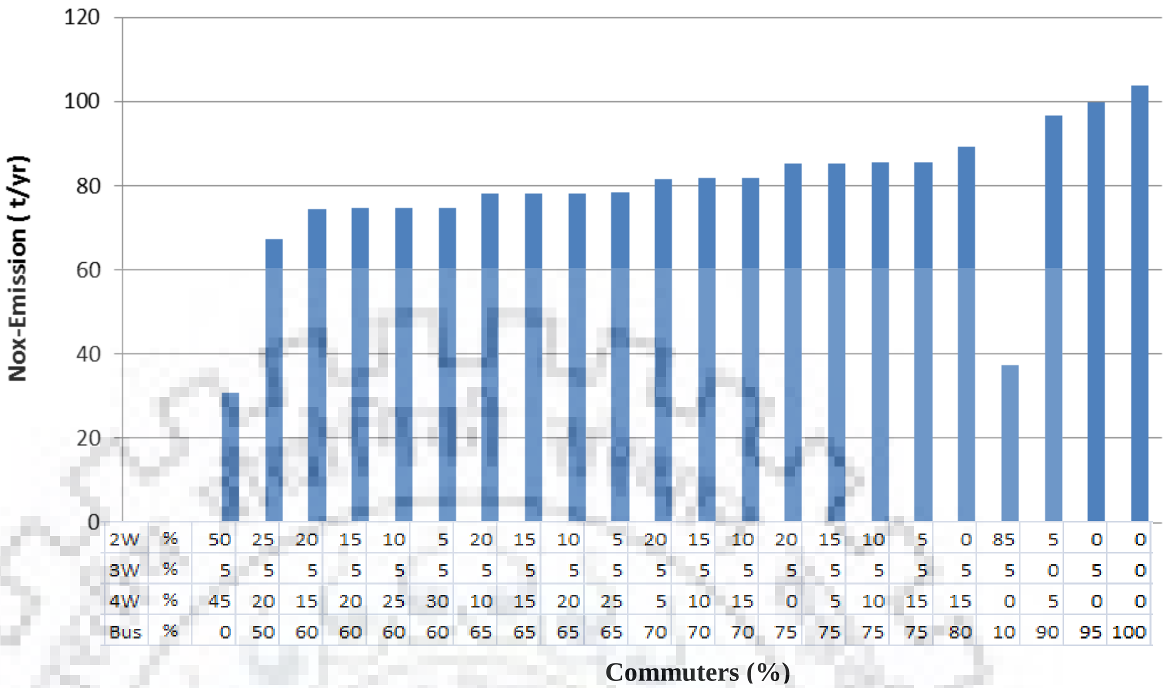


Figure 6.40: Effect on No_x -Emission due to Commuter shift under Scenario-3

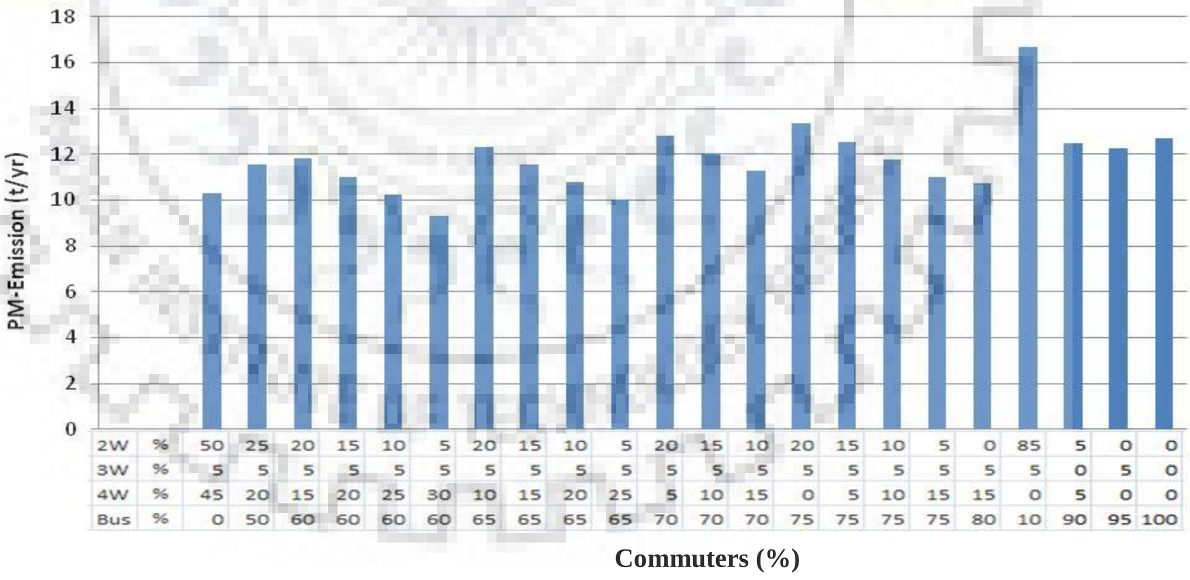


Figure 6.41: Effect on PM- Emission due to Commuter shift under Scenario-3

Figures 6.37,6.38,6.39,6.40,6.41 envisages that minimum PM emission will be minimum if commuters travell as 2W-5%,3W-5%,4W 30%,bus-60% a nd minimum

CO_2 emission can be achieved by maximum buses. but HC and NO_2 is increased due to increment of 2W.

Table 6.29 : Effect of Technology of 2W(2S &4S) on Emission under Scenario-3

Commuters (%)						Emission (t/yr)				
2W	3W	4W	Bus	2W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	2S (%)	4S (%)					
34.03	24.63	32.22	9.13	70	30	18667.18	139.43	131.77	38.80	9.43
				60	40	18378.86	134.85	117.04	41.17	8.57
				50	50	18431.13	133.55	106.97	44.16	8.01
				40	60	18483.39	132.26	96.90	47.16	7.46
				30	70	18535.66	130.96	86.82	50.16	6.90

Table 6.30 : Effect of Three Wheeler (Auto & Vikram) on Emission under Scenario-3

Commuters (%)						Emission (t/yr)				
2W	3W	4W	Bus	3W		CO_2	CO	HC	NO_2	PM
(%)	(%)	(%)	(%)	A (%)	V (%)					
34.03	24.63	32.22	9.13	70	30	18667.18	139.43	131.77	38.80	9.43
				60	40	18446.02	137.30	128.75	38.39	9.24
				50	50	18224.85	135.16	125.73	37.98	9.04
				40	60	18003.69	133.03	122.70	37.57	8.85
				30	70	17782.53	130.90	119.68	37.16	8.65

Table 6.31 :Effect of type of 4W- Petrorl and Diesel on Emission under Scenario-3

Commuters (%)						Emission (t/yr)				
2W	3W	4W	Bus	4W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	P (%)	D (%)					
34.03	24.63	32.22	9.13	70	30	18238.98	139.13	127.29	37.52	9.04
				60	40	18414.19	133.16	126.94	38.82	9.22
				50	50	18589.40	127.19	126.60	40.12	9.39
				40	60	18764.61	121.22	126.26	41.41	9.57
				30	70	18939.82	115.24	125.91	42.71	9.74

For Scenario-4, the effect on CO_2 ,CO, HC,NO_2,PM emission by different percentage of commuter shift are presented in Figure:6.4 ,6.43,6.44,6.45,6.46 and the effect of technology , fuel type (diesal and petrol)for 4Ws and effect of 3W on emission are pressented in Table 6.32, 6.33, 6.34 .

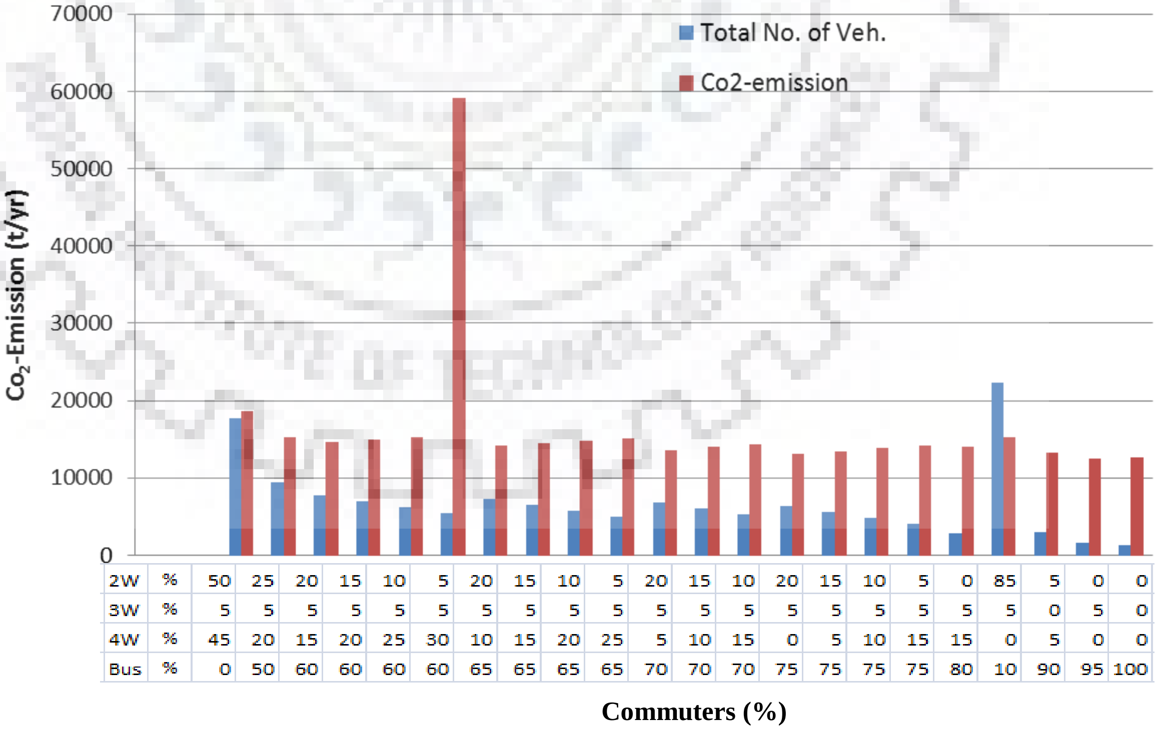
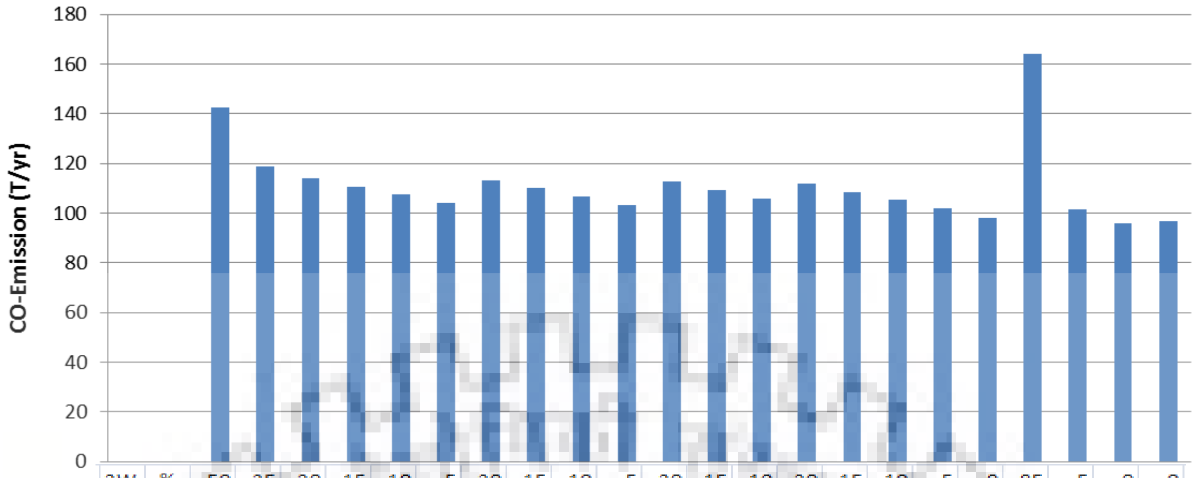


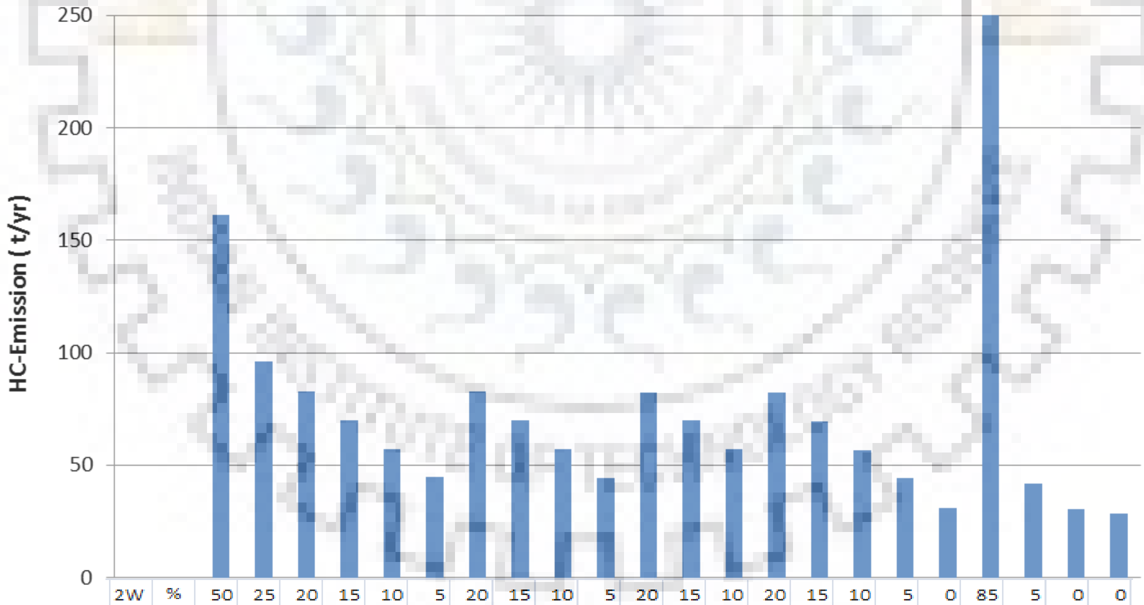
Figure 6.42: Effect on CO_2 -Emission due to Commuter shift under Scenario-4



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%)

Figure 6.43: Effect on CO -Emission due to Commuter shift under Scenario-4



2W	%	50	25	20	15	10	5	20	15	10	5	20	15	10	20	15	10	5	0	85	5	0	0
3W	%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	5	0
4W	%	45	20	15	20	25	30	10	15	20	25	5	10	15	0	5	10	15	15	0	5	0	0
Bus	%	0	50	60	60	60	60	65	65	65	65	70	70	70	75	75	75	75	80	10	90	95	100

Commuters (%)

Figure 6.44: Effect on HC-Emission due to Commuter shift under Scenario-4

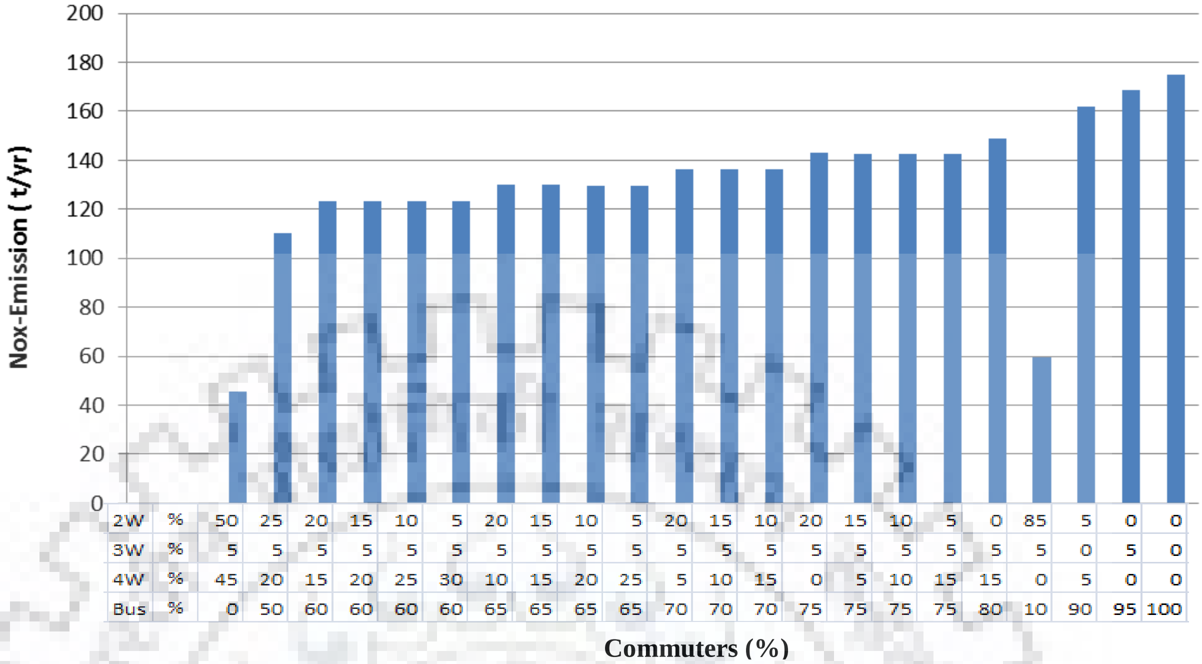


Figure 6.45-:Effect on NO_x- Emission due ot Commuter shift under Scenario-4

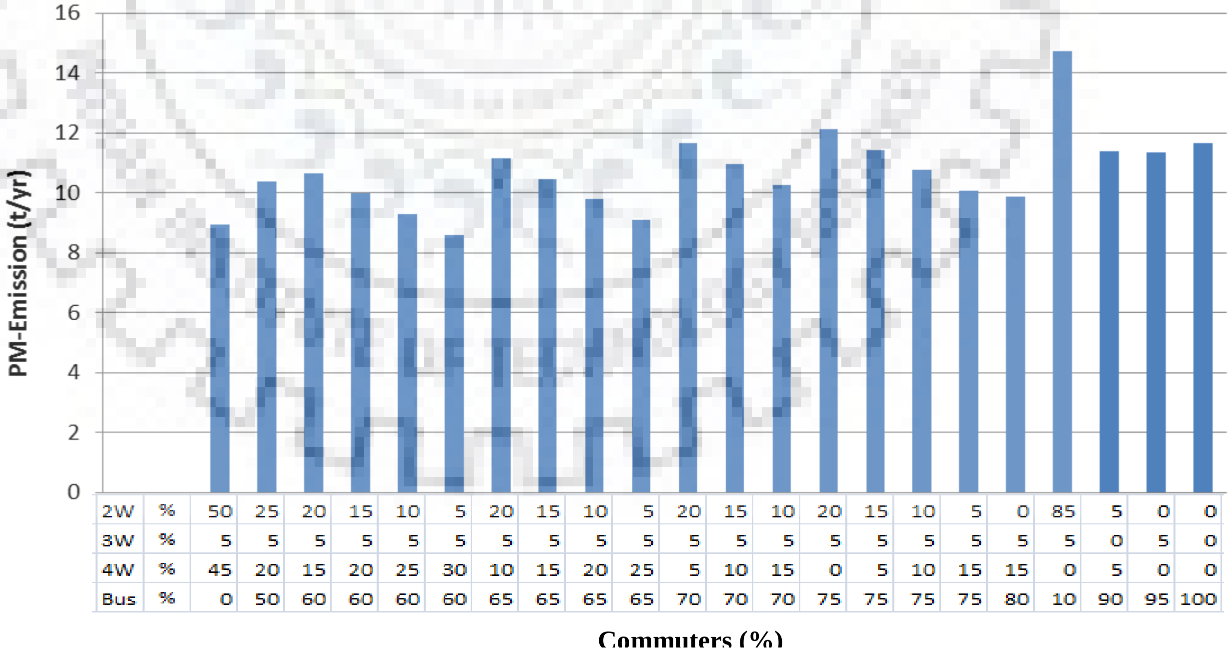


Figure 6.46: Effect on PM- Emission due to Commuter shift under Scenario-4

Figures envisages that PM emiission will be minimum if commuters travell by 2W-5%,3W-5%,4W-30%,bus-60%,. minimum CO_2 & CO emission can be achieved by using maximum buses. NOx will be minimum if commuters travell by 2W-50%,3W-5%,4W-45%.

Table 6.32 : Effect of Technology of 2W (2S &4S) on Emission under Scenario-4

Commuters (100%)						Emission (t/yr)				
2W	3W	4W	Bus	2W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	2S (%)	4S (%)					
34.03	24.63	32.22	9.13	70	30	16379.79	128.73	129.89	35.81	8.26
				60	40	16410.40	123.43	114.18	39.10	7.73
				50	50	16457.17	122.27	105.17	41.78	7.23
				40	60	16503.93	121.11	96.15	44.46	6.73
				30	70	16550.70	119.95	87.14	47.15	6.23

Table 6.33: Effect of Three Wheeler Auto &Vikram on Emission under Scenario-4

Commuters (%)						Emission (t/yr)				
2W	3W	4W	Bus	3W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	A (%)	V (%)					
34.03	24.63	32.22	9.13	70	30	16379.79	128.73	129.89	35.81	8.26
				60	40	16369.30	126.04	125.54	36.21	8.24
				50	50	16358.81	123.35	121.19	36.60	8.23
				40	60	16348.32	120.66	116.85	36.99	8.21
				30	70	16337.83	117.96	112.50	37.39	8.19

Table 6.34 : Effect of type of 4W- Petrol and Diesel on Emission under Scenario-4

Commuters (%)						Emission (t/yr)				
2W	3W	4W	Bus	4W		CO_2	CO	HC	Nox	PM
(%)	(%)	(%)	(%)	P (%)	D(%)					
34.03	24.63	32.22	9.13	70	30	16298	127	123	35.9	8.2
				60	40	16429	122	123	36.9	8.3
				50	50	16561	118	123	37.8	8.4
				40	60	16692	113	123	38.8	8.6
				30	70	16824	109	123	39.8	8.7

6.9 : Result and Discussion

Estimation of the different type of pollutant from various vehicle categories in BAU, and different scenarios have been estimated for year 2017and 2032 .This has been observed that emission estimation for BAU scenario for all the pollutant are higher than the corresponding estimates of pollutant for identified scenarios.

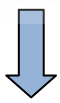
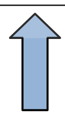
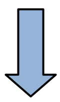
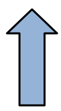
For example CO_2 emission in BAU scenario are 8.3 % higher than scenario 3 and 15.98% higher than scenario 4. About 10-11% of difference is observed between BAU and scenario 3 and 4 estimates for CO.The difference is 14.6% & 17.76 % for NO_2 emission with scenario 3 and 4. Introduction of CNG based public transport system could reap tremendous benefits in terms of PM emission in Dehradun city i.e. 16.5% reduction in PM emission.Introduction of PRT system in the city also noticed 16.5 % reduction in PM emission, 16% CO_2 ,11% CO & 17.7% NO_2.hence this scenario has potential to maintain the COmpliance of emission in real COndition.

The highest difference of all pollutant is found in scenario 4.It revealed that Personal rapid transit can reduced 16% CO_2 and 17% PM.

Sensitivity analysis for emission of various pollutant from various vehicle categories have been carried out for year 2017.On the basis of above it is concluded that public tranport play an important role to reduce the emission in Dehradun city.

From Table 6.35, it is very clear that technology and fuel type play an important role to reduce the emission. So when making the policy to mitigate the carbon emission we need to focus on 2 wheeler 4 strokes , pertrol driven vehicle and vikram. Which is respnsible to reduce the PM, HC, CO, CO_2 substantially

Table 6.35:Emission Trend in Different Scenario

Scenario 1	2W -4S	PM HC CO 	NO_x CO_2 
	3W-V	PM HC CO CO_2 	NO_x 

	4W-P	PM NO_2 CO_2 ↓	HC CO ↑
Scenario 2	2W -4S	PM HC CO ↓	NO_x CO_2 ↑
	3W-V	PM HC CO CO_2 ↓	NO_x ↑
	4W-P	PM NO_2 CO_2 ↓	HC CO ↑
Scenario 3	2W -4S	PM HC CO CO_2 ↓	NO_x ↑
	3W-V	PM HC CO CO_2 , NO_2 ↓	
	4W-P	PM NO2 CO_2,HC ↓	CO ↑
Scenario 4	W -4S	PM HC CO CO_2 ↓	NO_x ↑
	3W-V	PM HC CO CO_2 , ↓	NO_2 ↑
	4W-P	PM NO_2 CO_2, ↓	CO HC ↑

Genetic algorith is used to determine number of different catageories of vehicles and their districbution in order to minimise the CO_2-emission. Optimisation study revels that 3W-V and buses should be used to contol the emission of CO_2. However, if there is upperlimit on PM-emission then 3W-V and 4W-P should be used for transport . If there is no upper limit on PM-emission and all categories of vehicles are allowed , then maximum number of commuters (74.74%) should be travelled by Bus-M followed by 2W-2S (10.42%), 3W-V (9.75%) and 4W-P (5.35%).

6.10 Summary

In this chapter, a methodology framework has been evolved for road transport vehicles in order to estimate the emission and key strategies are identified to reduce the carbon emission through optiation and scenario analysis. Firstly, a fuel station survey is carried out to get age profile of vehicle, vehicle occupancy, Vehicle km traveled, road length etc.in order to calculate the emission in present and projected year 2032. Further, optimisation and a senstivity analysis have been conducted with the effect of percentages of commuters, engine technology, and fuel type.

Consistsly 4 key strategies are identified as scenario and a scenario analysis has been performed to identify the strategy in terms of emission.And further, a sensitivity analysis has performed for each scenario.Which reveals that effect of commuter shift, engine technology, and fuel type. As per scenario analysis, PRT is the most environmentally sustainable strategy which reduce all the pollution substantially

CHAPTER—7

DETAILED PROPOSAL AND RECOMMENDATION

7.1 Introduction

This chapter summarizes findings to develop detailed proposal for the design and implementation of the sustainable urban transport solution in Dehradun city. It contains detailed proposals, policy recommendations, improvement schemes, and different approaches to improve the accessibility and mobility issues and to achieve environmental and social sustainability. The proposal is generated by several case studies, field survey results and analyzing overall situation of the city and the selected study area. In this chapter physical planning proposal and policy, recommendations are developed to achieve the sustainable goal.

7.2 Approach Towards Framing Proposal

Before formulating the proposal for the city mobility, it is imperative to briefly recollect and list down all the mobility-oriented planning objectives which are mentioned as below:

- Reduction in congestion, vehicular ownership, and trip length.
- Improving mobility for non-drivers, cycling infrastructure, and pedestrian environment
- Improve public transit travel by making it affordable, convenient, compact, safe and reliable.
- Ensure adequate parking facilities and traffic management
- Pollution reduction and clean environment
- Land use Integration and telecommuting

In order to achieve the above objectives, it is critical to focus on various factors impacting the travel and behavior of the user. For that, it is required to investigate the transport impact factors and define the domain to be worked upon to define strategies for developing highly integrated sustainable urban transport solution. The key points of highly integrated sustainable transport solution (ISTS) proposal are mentioned as :

- Intra city public transportation
- Public transport infrastructure improvement such as ITS, stops, interchange terminals
- Personal rapid transit system
- Provision for pedestrian facility
- Parking management
- Relocating places
- Road widening
- Others - Marking, signages, preferential transit

7.3 Planning and Designing for the City

7.3.1 Intra City Public Transport by 3-Wheeler (Vikram)

Presently intra city public transport system of the city comprises Mini buses, Standard size buses and Vikram (3W) with a little share of city buses for short, medium distance trips but as the city population increases and city expand, it becomes difficult for present Public transport to meet the travel need so there is a need to replace with a better sustainable public transport solution, which is affordable, safe, and environmentally friendly to meet the travel demand. There are currently 875 Vikrams (IPT mode) are operating on 10 routes in the city of Dehradun. These routes are decided by RTO and presented in Table 7.0.

Table 7.0 : Routes Operated by IPT Mode Vikram (3-Wheeler)

Route no.	Route name	Route length (kms)	Number of vehicles(3W-vikram) permitted on the routes
1	Rajpur to Ashley Hall	7	80
2	Darshanlal Chowk to IT Park	11.7	70
3	Rispana bridge to Ghanta Ghar	5.3	140
4	Lachchiwala to Rispana bridge	9.3	100
5	Kanak theatre hall to ISBT	8	285
6	CISF to Connaught Place	6.1	20
7	Prem Nagar to Connaught Place	8.0	50
8	ISBT to Rajpur	15.3	60
9	Garhi to Connaught Place	8.5	20
10	Prem Nagar to Tehsil	8.4	50
	Total		875

Table 7.0 dictates that maximum patronage of traffic by Vikram is on the route Kanak Theatre to ISBT by issuing maximum permit of 285.The other important routes is Rispana Bridge to Ghanta Ghar. The Vikram routes plying in the city are presented in Figure 7.1.

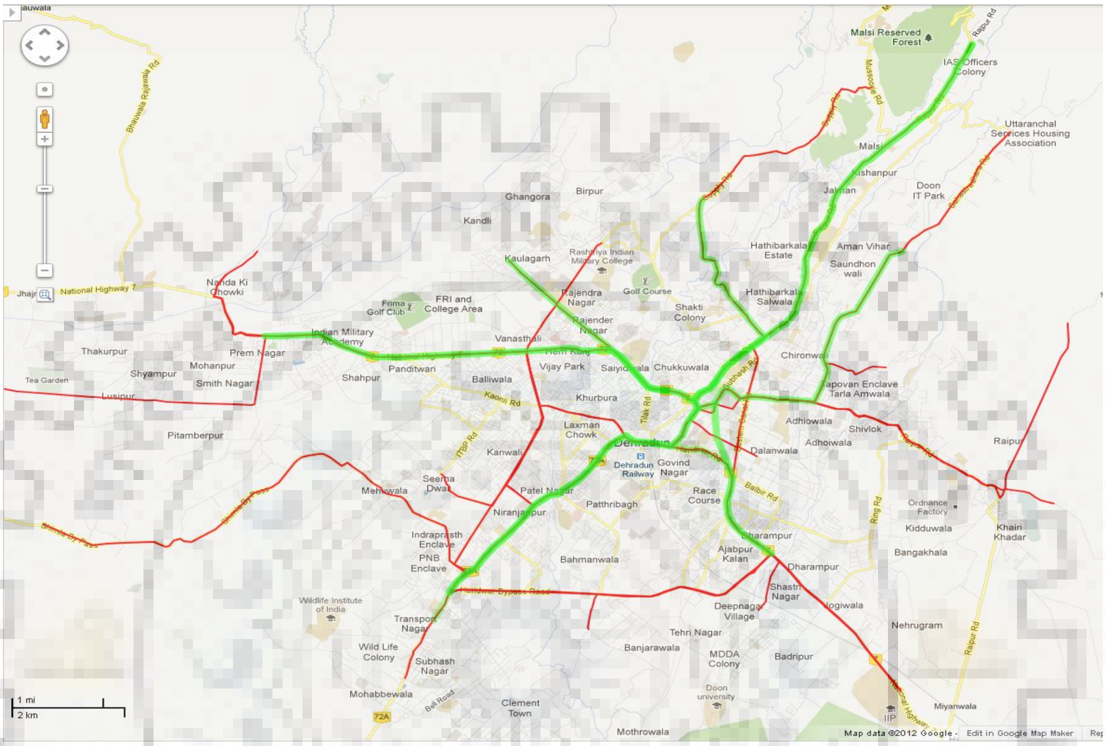


Figure 7.1: Routes Operated by Vikrams

7.3.1.1 Proposals for 3-Wheeler (Vikram)

The bus system of Dehradun is not adequately provided to cater the demand of the commuters and this gap is being met by Vikrams. Vikram in the form of Intermediate Public Transport should act as the feeder to the public transport system and not as the competitive mode to it. Vikram should be operated in the routes where the buses cannot reach due to physical constraints in terms of non- availability of road space, inadequate geometrics of junctions, etc. But these 3-Wheelers (Auto and Vikram) create congestion in the city causing pollution in the city. As the bus fleet does not cater the requirement of the commuters, the Vikram can be allowed to operate in their existing routes for time being and has to be phased out as and when the bus fleet size increases. But in order to achieve the maximum reduction of emission from transport sector, auto should be replaced by electric powered rickshaw and all Vikrams should switch to CNG fuel.

7.3.2. Public Transport Infrastructure Improvement

In order to improve the ridership of public transport system, comfortable, easily accessible, user-friendly, and highly efficient services have to be provided such as adequate number of bus stops, terminals, and ITS system.

7.3.2.1 Bus/ Vikram Stops

It has been observed that due to non-availability of bus stops, passengers have to face problems in boarding/ alighting from a bus. It has also been observed that in the absence of these stops, the operators/ drivers tend to stop at intermediate points on a route and thus creating congestion on the roads. Proper bus stops with bus bays have to be provided along all the routes. On average these bus/ vikram stops have to be provided at every 500m distance. A total of 200 bus stops have to be provided for the 22 routes currently operated. Later for the horizon year - 2032 it is advisable to add another 80 bus stops to serve the new routes. These stops have to be developed to serve both bus and vikram passengers.

7.3.2.2 Terminal/ Interchange Points

To avoid long distance route length for the public transport system, suitable interchange points should be proposed in and around Dehradun City for convenient transfer. Also, terminal locations with depots and warehouse facilities should be provided for intra-city buses and vikrams. The major bus-rail interchange is at Dehradun Railway Station. This interchange provides bus and taxi services for the Mussoorie. Since there are large number of international/domestic tourists visiting Dehradun throughout the year so there is a need to develop a major interchange point at Dehradun Railway Station. A detailed plan needs to be prepared for providing interchange facilities at the stations.

7.3.2.3 Intelligent Transportation System (ITS)

Intelligent Transportation System (ITS) in terms of Automatic Vehicle Location (AVL), Automatic Fare Collection System (AFCS), Real Time Passenger Information System and central control station can be provided to improve the performance of the public transport system. Reduction in waiting times, fuel consumption, operational costs, traffic congestion, increase in safety of users, etc. are some advantages of ITS that will help to meet all core dimensions of sustainable transport solution. i.e. economic, social and environmental sustainability.

7.3.3 Personal Rapid Transit System

According to CMP, Dehradun road network is over-stressed and congested which is reiterated from the high volume capacity ratio of the major arterial roads for the year 2032. It is expected that the peak hour peak direction traffic on the major corridor will reach up to 20,000 trips. It is apparent that the existing capacity of roads will not be able to cope up with the anticipated traffic. Efforts are needed to reserve land for the proposed medium capacity mass rapid transit system in reducing congestion on roads and mitigating the pollution level. But due to scarcity of adequate right of way on major roads, on grade dedicated bus rapid transit system is not possible so an off grade elevated PRTS (Personal Rapid Transit System) is proposed to cater the travel demand in the future year with planned stops and stations. The concept of the corridor is to cover maximum travel demand of education and work and recreational trips. This system is safe, environment-friendly and time saving system. It is targeting the personal vehicle users to reduce the percentage of 2W and 4W on road and to increase the road space for bus fleet as well. The auto-rickshaws and vikrams will act as a feeder to this system from suitable interchange points.

The proposed corridor is planned in such a way that it covers all major roads, cater the maximum need which cross from Clock Tower. The first corridor run along Haridwar Road (NH-72) – Eastern Canal Road – Cross Road – Chakrata Road upto Prem Nagar with a total length of 17.4 Km. The corridor‟s catchment area includes Mohkampur, Jogiwala, Shastri Nagar, Dharampur, Ajabpur Kalan, Race Course, Dalanwala, Parade Ground, Clock Tower/ Paltan Bazaar, Yamuna Colony, Doon School, Kailashpuri, Ram Vihar, Raj Vihar, Panditwari, FRI, IMA and Prem Nagar.

This Corridor traverses along Rajpur Road – Paltan Bazar Road – Saharanpur Road starting at Rajpur upto Mohabbewala with a total length of 18.2 Km. The corridor's catchment area includes Rajpur Village, Kishanpur, Hathibarkala, Dobhalwala, Chukkuwala, Clock Tower/ Paltan Bazaar, Railway Station, Patel Nagar, Niranjanpur, Majra, ISBT, Subash Nagar and Mohabbewala. The proposed corridors are shown in Figure.7.2.

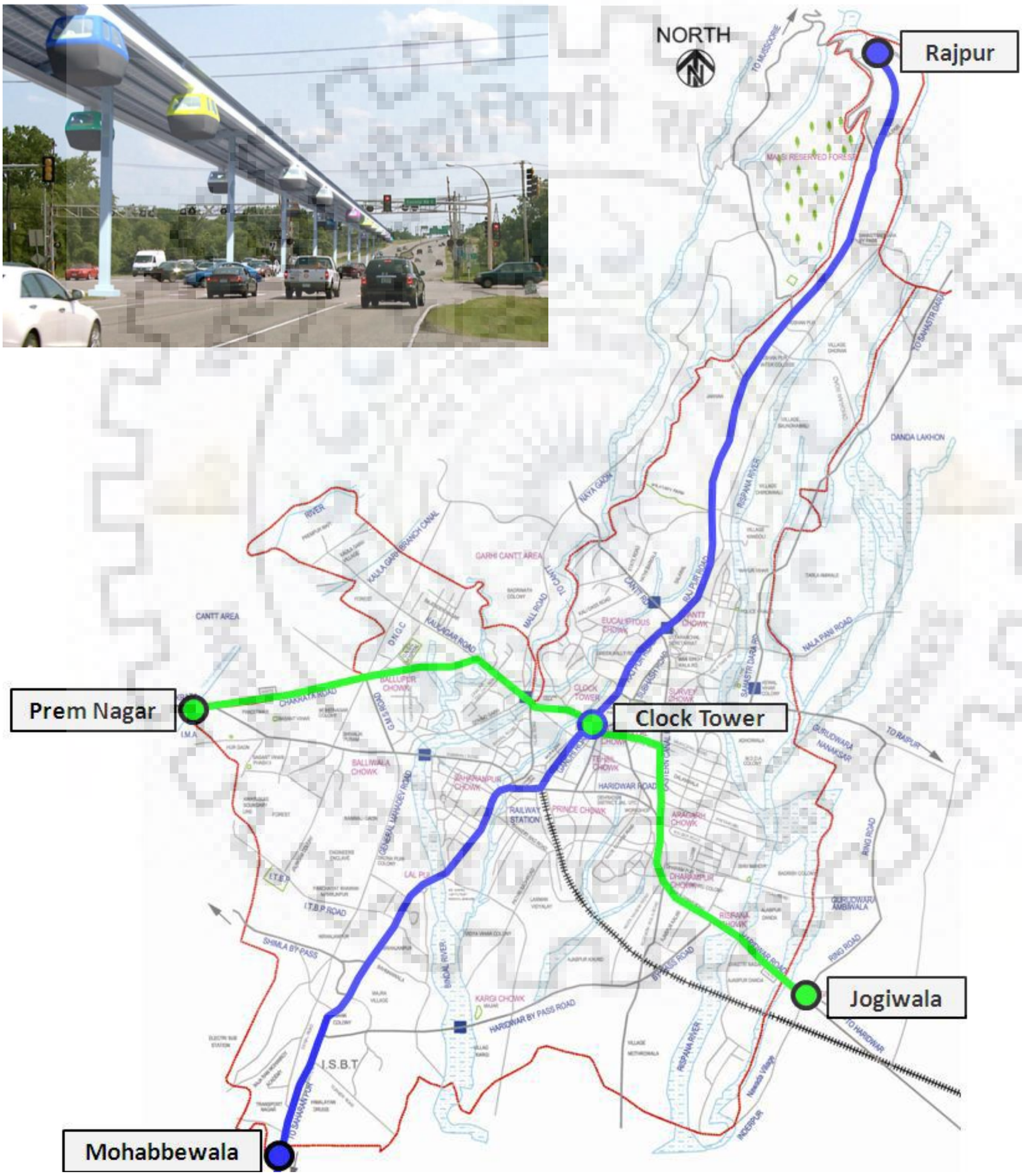


Figure7.2: Proposed Route for Rapid Transit System

7.3.4 Provision of Pedestrian Facility

As per study, the pedestrian trip share is 35% which is low as compared to the other cities in India that have share of 55% (Gati 2017). The user experiences poor pedestrian infrastructure and facilities and lacking any services for physically challenged people. Footpath are provided on major roads in the city like NH-72, NH-72a, SH-55 but missing on most of the road or encroached by hawkers and parking so pedestrians are forced to use road space. Some measures have to be taken for pedestrians' mobility are

1. Footpath should have minimum 1.5 m width and it should be increased at bus stop and recreational area.
2. Zebra crossing should be provided on each intersection and every 300 m distance with proper traffic signal for pedestrian and NMT.
3. Footpath should be above the road level and it should be accessible to physically disabled.
4. In order to make encroachment free footpath, guard rail are provided to segregate it from traffic

Due to non-availability of right of way, it is difficult to provide grade separated facilities on all roads. Heavy foot fall is observed near Railway station, Clock Tower and Prince Chowk, so the grade separated cross ways (Foot over bridge /subway) has to be provided on these intersections.(refer Figure 7.3)

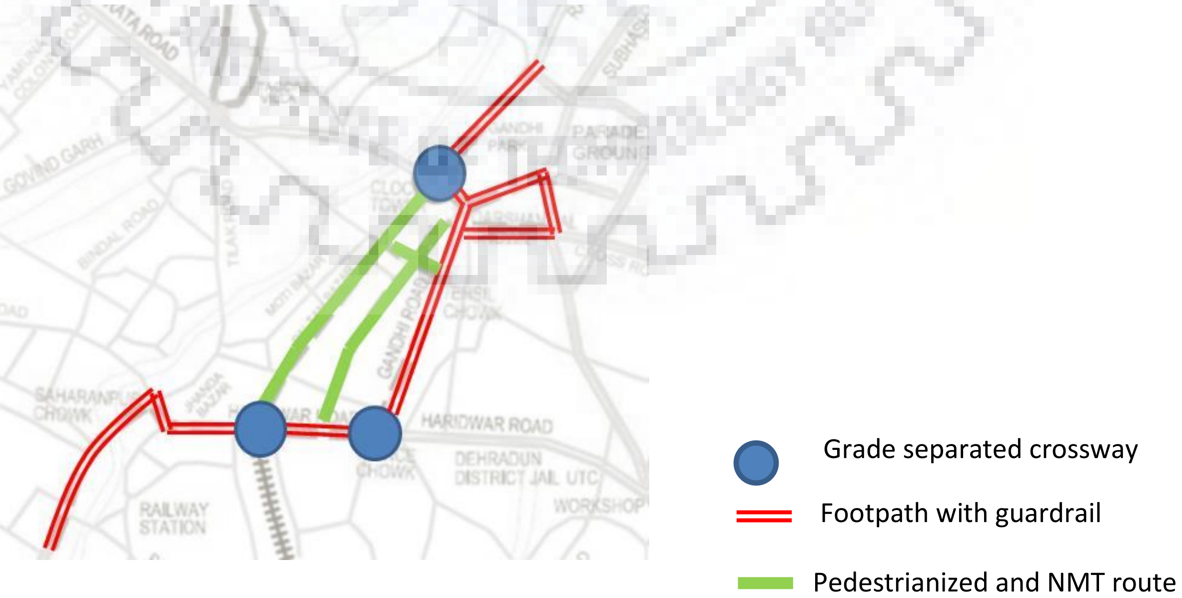


Figure 7.3 : Layout of Pedestrian Facility

7.3.4.1 Pedestrianization

Paltan Bazar is in the heart of the city, very congested with high footfall, lack of basic facilities for pedestrian movement, high economic generating capacity, looping it up with various MLCPs. So this area is proposed for vehicle free zone. The restriction can be put for evening hour, on weekdays or full time. In Paltan Bazar, main stretch will have central 4m carriage way for NMT and both side pedestrian walkways having average width 3m with facilities of sitting areas at 50m intervals. Permissible time for vehicles for loading & unloading of goods will be 10 pm to 6 am to avoid the kiosk in day time. Figure 7.4 and 7.5 show the existing and proposed street for Paltan Bazar.

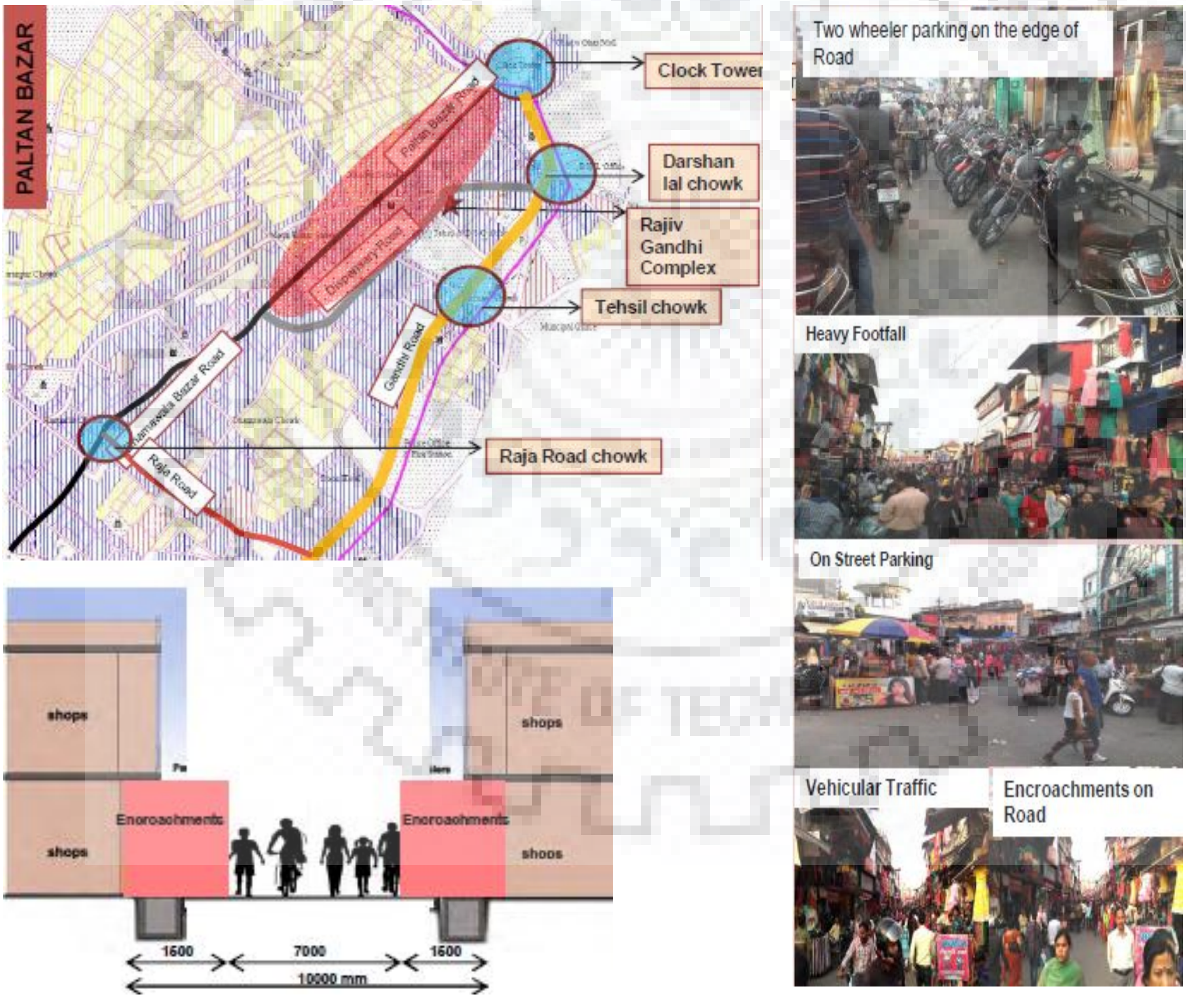


Figure 7.4: Existing Condition of Paltan Bazar

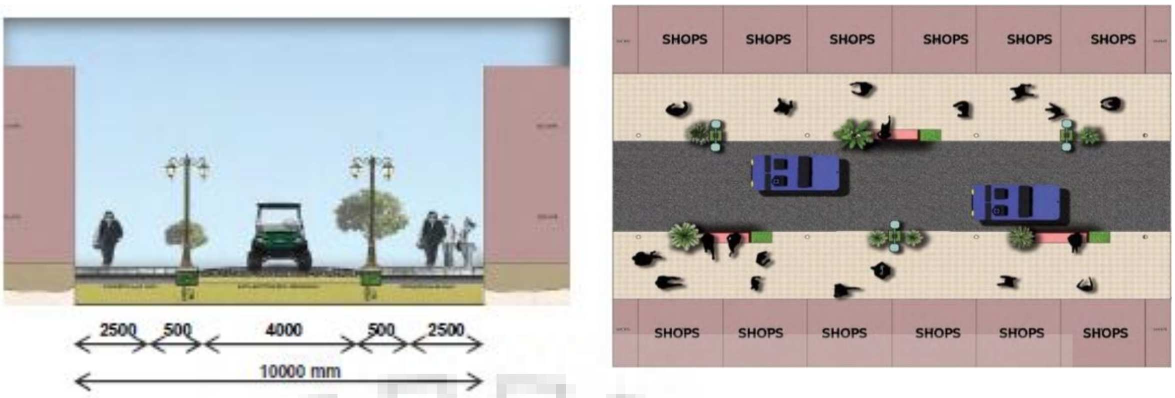


Figure 7.5 Proposed Street of Paltan Bazar

7.3.5 Parking Management

Parking has become a chronic problem in the city. Lack of organized parking has resulted in traffic choking near commercial areas and on major arterial roads. Inadequate availability of parking spaces near major commercial area leads to parking spill over. This spill over creates reduction of carriageway width/ bottleneck for the smooth flow of traffic.

Following measures are adopted to cope up with this problem are:

1 .Multilevel parking lots are essential to handle the parking issues.

2. Designated auto rickshaw parking

3. Control on personal vehicle usage by enforcing high parking charges and congestion tax etc.

4. Parking lots to be planned in such a way that it would integrate the public transport system around major intersections.

7.3.5.1 On Street Parking

For short term, the parking can be managed by restricting on-street parking on major intersection like clock tower, Saharanpur road, ISBT Chowk, Prince Chowk and Darshanlal chowk and Bindalpur Chowk.

7.3.5.2 Off Street Parking

On street parking is creating a problem for smooth flow of traffic so there is a need to identify certain areas where vehicles can be parked. MDDA is building multilevel car parking at two locations: (i) near Clock Tower (600 ECS) and (ii) near Tehsil on Dispensary Road (200 ECS). These parking locations will cater to the parking demand of the entire CBD area (Paltan Bazar, Clock Tower, and Connaught Place). However, there is a requirement to identify parking lots in other areas of the city where the on-street parking is observed. So, considering the requirement for off-street parking lots some areas have been identified. Areas, where parking can be provided, are shown in Figure 7.6**.** Dehradun District Old Jail Old Bus Stand near Hotel Drona are the areas, which can be developed as multi-story parking areas but initially can be used for at-grade parking of vehicles to cater the parking need of Paltan Bazar. Parade Ground ranges college ground can be acquired to park the vehicles. Nagar Nigam near Dilaram Chowk can be developed as parking lot to dissolve the parking issue

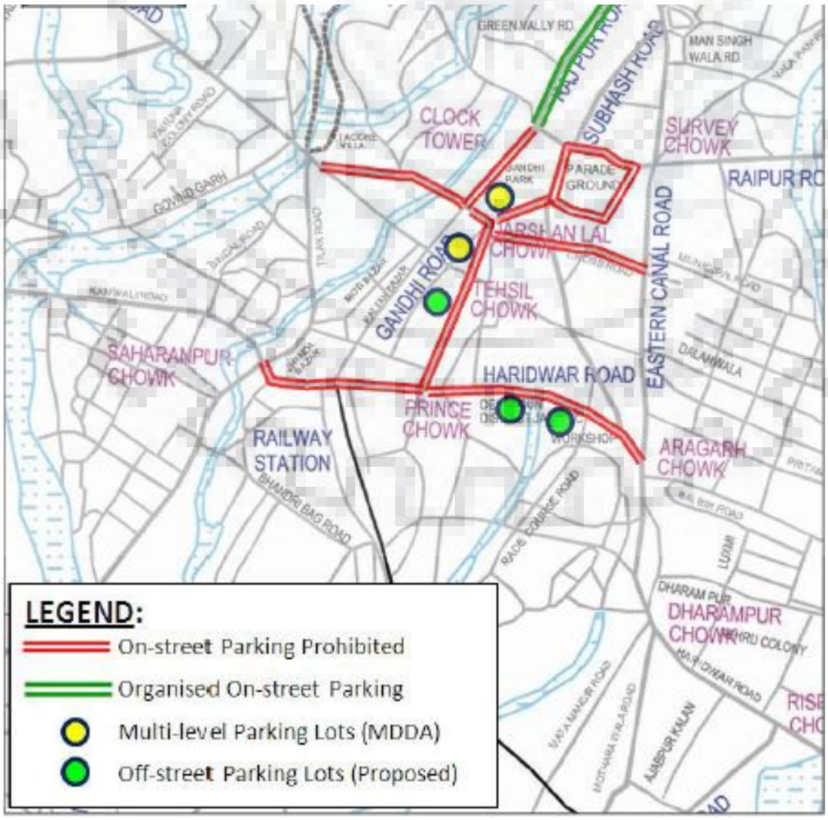


Figure 7.6: Parking Management

7.3.6 Relocation of the Places

- Arhat bazar can be shifted to the outskirts of the city
- Roadway workshops can be shifted to ISBT.
- Railway station can be shifted from city core to the space of the present railway station.

7.3.7 Road Widening

Road widening could be utilized to increase the capacity of road. At present, all major roads are single lane or 2 lanes. The encroachment should be removed, and carriageway should be widened wherever required with proposed cross sections as shown in Figure 7.7 & Figure 7.8. Some road that needs road widening are mentioned below:

- Road widening of Arhat bazar
- Prince chowk to Sahranpur chowk
- Prince chowk to Darshanlal chowk
- Rispana bridge to Dharanpur chowk
- Survey chowk to Sahasthdhara crossing
- Aaraghar to Dharampur chowk
- Bani to Kanak chowk etc.

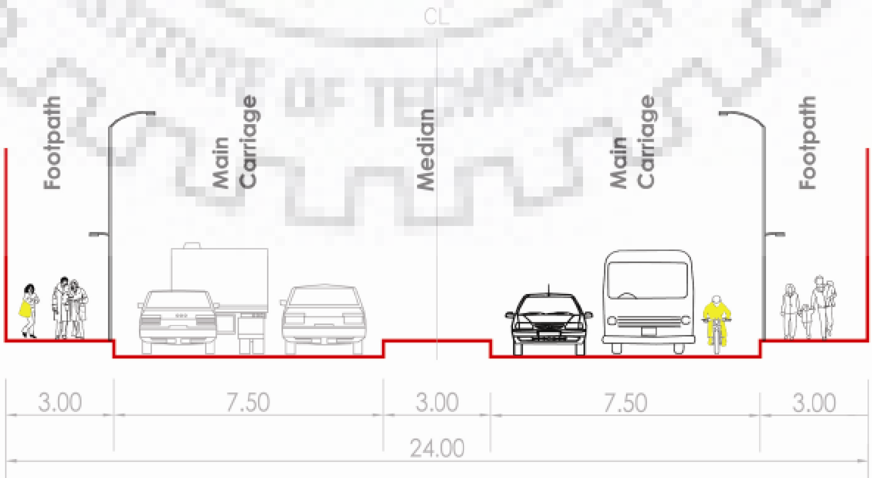


Figure 7.7: Cross Section for 24 m Road

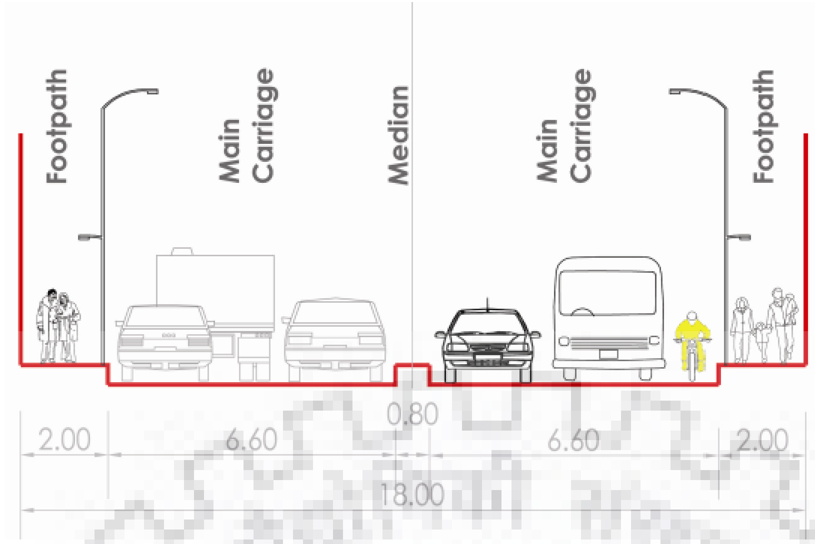


Figure 7.8: Cross Section for 18 m. Road

7.3.8 Other Proposal Made

a) Road marking

At present, approximately 60% roads in Dehradun do not have proper lane marking. Suitable road marking like zebra crossing on all intersection should be marked along with markings for parking and stopping.

b) Signages

Proper regulatory and mandatory signages with Indian Road Congress (IRC) norms/standard to be provided on all major roads of the city for driver information. These signages includes compulsory right or left turn, speed limit, parking and other information. It is very helpful in night as nearby land uses are not visible in the night.

Plantation should be made along the footpath to provide shade to pedestrians.

C) Preferential Transit Mode

Restricting private vehicles for certain time of the day when the schools start in the morning and when the school gets over. Create separate lanes for heavy and light vehicles to speed up the traffic movement. These strategies will help in reducing the peak hour trip generation.

7.4 Summary

Dehradun city is an important urban center and capital city of Uttarakhand state. The significant increase in traffic experienced in the city of Dehradun after its emergence as the capital of Uttarakhand. Rapid industrial and commercial development activities have resulted in manifestation of problems like congestion, delay, accident, and pollution.

Transportation plays a very critical role in the overall development of the city of Dehradun. During the past several years, there have been some investments for the development of transportation network for different modes. However there was mostly address to individual component development without considering the mobility of the city as on single use. To meet the future demand, there is a need to establish an integrated transport system for supporting the new growth in a way so that all operational mode of transportation functions in a complementary manner. The key strategies under integrated sustainable transport solution should be implemented in short term, medium term and long term depending on their effectiveness and ease of implementation as shown below in Table 7.1

The goal of increasing mobility in Dehradun city is to develop a balanced integrated and multimodal system which provides equity, accessibility, and mobility to all users, thereby serving the existing and future need of the Dehradun city in a sustainable manner, yielding the good not for only transportation but also for better quality of life for users.

Table 7.1: The Key Sustainable Transport Strategies in Phases

Short term measures (0-2 year)	Medium term measures(2-5 years)	Long term measures(>5 years)
• Installation of Traffic Signs • Installation/ Repairing of traffic signals • Installation of (CCTV) • Removal and rehabilitation of road side encroachments at bazaars, main roads and intersections. • Provision of footpath and other pedestrian facilities. • Provision of guard-rails at major corridors. • Lane marking and pedestrian crossing marking. • Road surface marking • Promoting Pedestrian shopping experience: Paltan Bazar	• Road Widening • Provisions to de-congest the Core of the City • FOBs • Multistoried car parking • Electric Buses • Bus stops	Rapid Transit Corridors Interchange terminals

CHAPTER 8

CONCLUSIONS & RECOMMMENDATION

8.1 Conclusion

This chapter dealts with the salient findings of the study. It encapsulates the major findings present in previous chapters and shows how the aims and objectives have been met. It also identifies the limitations and implication of the research. Then, it concludes with the future scope of the research.

8.1.1 Assessment of Public Transportation Operation in Dehradun City

In this study, service level benchmarking method has been used to assess the existing public transport operation in Dehradun city. After collecting the data (primary and secondary) against each parameter of public transport facility mentioned in SLB guidebook. The level of services (LOS) of each indicator has been identified where “1” being the highest and “4” being lowest to measure performance benchmark. Following are the findings drawn from this study:

- The presence of public transport system in Dehradun city is 8.64% which comes below the range of 20%, thus marking the LOS (level of service) 4. This implies that there is a lack of good quality of organized public transport in Dehradun.
- The extent of supply/availability of public transport ratio in Dehradun is 0.583 per 1000 people which has been calculated as LOS2 this means that the number of buses required for the public is less than the demand so there is an immediate need to increase the number of buses in the city.
- Calculated Average waiting time for public transport users was 9.21 minutes that makes this parameter to level of service 3. This is one of factors for commuters while choosing the mode of transportation.
- The level of comfort in public transport in Dehradun city is calculated as LOS1, however there are some stops like Clock tower, Balliwala chowk where the passenger count in buses have displayed increased intensely and some routes where seat are vacant in buses. Seat availability is considered

to find out the level of comfort however the quality of buses in terms of suspensions, comfortable seats, cleanliness etc. needs to be improved.

- The standard bus fleet is only 19.57% and marks it as the level of services 4 to this parameter.
- The overall level of service of public transport operation in Dehradun city is calculated 17 and marked LOS3. It means there is a considerable improvement is needed in terms of frequency of buses their service coverage with world class quality buses.

8.1.2 Impact of User Behavior on Sustainable Transport Strategies

The findings of socio economic characteristics and user behavior towards influencing parameters of sustainable strategies are as follows:

- Income is highly correlated to choose the mode to commute. Higher income user preferred personal vehicles (Car) as key transport mode.
- Trip length and travel time are also significant factors to choose the mode of transport. The study evident that for shorter distance 2-Wheelers are mostly used and for longer trip length buses and cars are the key transport mode to travel in Dehradun city.
- Dehradun is the hub of many prestigious educational and government institute where from the survey it is evident that buses are mostly used by the students and due to inadequate public transport 3-Wheelers and Cars are the key transport modes for work and shopping purpose. Around 31% of the users have to spend more than 50 Rs for their trips and willing to pay a reasonable amount of money for good public transport system. Hence a reliable, comfortable and improved public transport with increased route coverage has to introduce in the study area.
- The study evident that the main issues that impact the city are; Congestion, Air pollution and Noise pollution. To reduce the air pollution in the city, public transport enhancement and transport management system are most socially acceptable sustainable solution for Dehradun city. This is followed by other viable options like non-motorized transport planning and alternative fuel and technology; traffic calming and vehicle restriction measures which reduce the air pollution in Dehradun city.

- Safety, cleanliness and fare equity are the main concern of users followed by priorities intersection for buses, increased bus frequency and dedicated bus lanes to enhance the performance and ridership of public transport operation.
- Non-motorized transport movement in the city can be improved by providing dedicated non-motorized transport (NMT) network with proper service station at regular intervals. The bike design improvement and proper parking lots near transit are other parameters that encourage users to opt non-motorized transport.
- Users become more sensitive towards the environment, comfort, and safety when walking on pathways. Proper pedestrian pathway network with streetscape and adequate signages are a primary concern to improve the pedestrian movement. Streetscape with street furniture and landscape is the most scoring factor to improve the pedestrian movement means users are more fascinating towards aesthetic and want road as a public space so that they can enjoy walking.
- Safety is the main concern for pedestrian and NMT users. Pavement condition and traffic condition and weather are the also influencing parameters for pedestrian and NMT users. Therefore a planned dedicated network with proper lighting and signages and street furniture need to proposed for pedestrians and NMT users.
- The road condition, road geometry and speed are major contributing factors for improvement in the safety. Another important aspect includes use of proper lighting and informative signages to reduce the accident in the city.
- Some fiscal measures like cess on petrol, limit the parking space near CBD area and subsidy for shared /public transport can discourage the use of private vehicles. By increasing the parking fee and restricting motor vehicle in CBD, private vehicle can be reduced to some extent.
- The studies elucidate that to reduce the noise pollution in the city; there is a need to improve the road condition and vehicle design first then after noise barrier works fast.
- It is evident that there is a dire need to improve the public transport system with proper transport system management which discourage users to use personal vehicles .Road infrastructure and intersection should also be upgraded to reduce the enchroachment and accident in the city. To

encourage the ridership of Public transport, transit has to plan in such of way that is highly accessible to all group of society .IPT modes are used as feeder to the transit. All transit should be equipped with parking lots for private vehicle.

8.1.3. Evaluation of Sustainable Transport Strategies

- Develop a Sustainable urban transport solution framework (SUTSF) to evaluate the alternative sustainable transport strategies in sustainability framework.
- Based on the total evaluated score of six alternative strategies, enhancement of public transport is identified as most sustainable key strategy to design and implement in Dehradun City as it has scored high and remain in top three in all sustainable dimensions: economic, social, environmental and risks.
- Out of 6 alternate sustainable transport strategies transit-oriented development (TOD) is most economical effective (score 1.72) strategy followed by enhancing public transport (score 1.66) and pedestrian facility movement (score 1.62). Transit oriented development (TOD) is most economic effective strategy as it impacts on affordability of transportation and integrated land use planning development with effective public transport. As high density transit-oriented development with integrated land use planning will reduce the trip length and trip time. Hence it impacts on accessibility of transit which increases the ridership of economical effective transit. Therefore a dedicated transit network has been proposed along a high density & mixed landuse corridor to cater the daily travel need of users.
- Transit oriented development strategy is socially acceptable & sustainable strategy. This result depict that users/commuters are more in favor of transit that is in their close proximity and easily accessible so that they can reduce the trip length and time. Alternative fuel and technology .Alternative fuel and technology (AFT) strategy is least socially sustainable as this strategy will not directly impact on user’s safety, security & convenience and not provide any benefits for disadvantaged and vulnerable group.
- Alternative fuel and technology(AFT) and enhancing public transport (PT) are the most environment-friendly strategy. They have tremendous environmental

impact on climate by reducing emissions. Reducing number of personal vehicles by enhancing public transport will also help in reducing GHG emissions.

- Improvement in pedestrian and public transport facilities scored high in risks to sustainability that indicates that there is minor chance of occurrence of events associated with design, cost overruns, implementation and operations that may impact costs or benefits over 20% or cause delay of over one year.

8.1.4. Estimation of Improvement in Emission in Different Scenarios

- The emission of road transport has been calculated for year 2017 and projected for year 2032. The result revealed that total emission in the city will increase two-fold from 2017-2032. Whereas CO_2 emission increases upto 99.7% . 2W-2stroke and petrol driven cars are responsible for maximum PM & CO_2.emission respectively.
- Sensitivity anlysis has been performed in order to observe the effect of vehicle categories wise commuter percentage, fuel and technology. The analysis envisaged that maximum participation of public transport(bus) leads to maximum reduction in CO_2, CO, HC.However it increases the content of NO_x & PM emission to some extent. NO_x emission can be reduced by contributing 2W in road transport.
- The 2-wheeler 4 strokes engine technology emits more CO,NOx emission however it reduced the CO_2, HC & PM emission substaintially.
- Reduction in percentage of Auto will reduce the emission of pollutants.and petrol driven vehicles(car) are responsibles for increament in CO_2, CO, HC.but reduced PM & NO_x to some extend.
- The size of vehicle also a factor for contributing in emission.this implies that larger buses emits more CO_2 and NOx but responsible to reduced CO, PM emission.
- An optimisation analysis is performed in order to achieve a minimum level of CO_2 emission by optimum combination of vehicle category wise commuters percentage. It is evident that maximum share of 3-wheelers are responsible to reduced the CO_2 emission to maximum limit.The set of commuters (2W-0.43%,3W-93.23%,,4W-0.11%, bus-6.22%) are responsible for minimum CO_2.

If constraint is imposed on PM-emission then 48.88% commuters should travel by 3W-V and 50.6% commuters should travel by 4W-P and rest with other vehicles. It is because CO_2-emission and PM-emission have inverse relationship (i.e., the vehicles which emits higher CO_2, emits lower PM and vice versa. If all categories of vehicles are compulsory for the transportation, then maximum number of commuters (74.74%) will travel by Bus-M followed by 2W-2S (10.42%), 3W-V (9.75%) and 4W-P (5.35%).

- Out of 4 identified scenarios (Enhancement of public transport, Introduction of CNG buses, Introduction of E-rickshaw and PRT), to improve the public transport system in the city, Scenario 4(Introduction of PRT) is the best scenario in terms of minimum emission of all pollutant followed by scenario 3 (introduction of E-rickshaw and CNG based 3-wheeler) and scenario 2 (CNG based buses) respectively.
- Introduction of CNG based public transport system could reap tremendous benefits in terms of PM emission in Dehradun city i.e. 16.5% reduction in PM emission.
- Introduction of PRT system in the city also notice 16.5 % reduction in PM emission, 16% CO_2 ,11% CO & 17.7% NO_x.Hence this scenario has potential to maintain the compliance of emission in real condition.
- Personal vehicles (2W,4W) are responsible for maximum share of CO_2 emission out of other vehicle categories, whereas 4 strokes 2 wheeler and petrol driven car are emitting more CO_2.Therefore appropriate policy measures are required to promote more use of public transport in Dehradun city. Moreover technology interventions are required to reduce the emission from personal vehicles.
- Introduction of personal rapid transit (PRT) and electric vehicles, alternative fuel(CNG) can reduce emission substantially and provide a better environment and quality of life.

8.2 Contribution of the Research

This research will add to existing knowledge in the field of research and will guide urban and transport planners and design engineers for qualitative assessment of sustainable strategies and quantitative assessment of emission. The research contributes to the current literature by exploring significant factors influencing

sustainable urban transportation. The research has proposed the methodology, a data set extracted from sources and survey to estimate the emission in Dehradun city and thereby proposes alternative scenario to judge the environmental sustainability of the strategy. Further the research will assist in confirming the feasibility of the
project in sustainable framework before implementation. Proposed hierarchical framework can be used for evaluation of the transport strategies in a sustainable framework. The research comprehends the most influencing factors of sustainable transportation strategies.

8.3 Limitation of the Research

Being the first study on the emission estimation in Dehradun city there is a limitation regarding the representativeness of the study sample. There is no published data from transport planning agencies for Dehradun with which samples can be compared. Moreover due to the limited amount of time available and few resources, the study is carried out for certain parts of the city & not for the whole city. Also, the sample size is small and therefore reflects the perception of commuters to a limit.

8.4 Application of the Research

The research helps the urban planner and transport planner to evaluate the impact of the strategy in sustainability framework prior to the implementation of any project. This helps to reduce the adverse impact on the environment and social habitat.It helps the planner to understand the user behavior towards various strategies before formulating the policy measures, project and proposal.

The estimation of emission of various pollutants from different categories of vehicles helps the planner to make the policy in such of way that reduces the emission content in environment by restricted polluted vehicles and encourages public transport. It also helps to decide the priority of the project in the city.

8.5 Future Scope

- In the present study due to the scarcity of data availability, only the assessment of existing public transport operation in the city is carried out. While service level benchmarking tool is based on 10 areas of intervention. Therefore there is a scope to extend this study further by considering the remaining parameters.
- There is a need to undertake time-series variation in service level benchmarking. It will be worthwhile to explore if this method is applied for cities of different population series.

- In the present study, framework for sustainable strategies has evaluated qualitatively by the expert survey. Further, each criterion can be quantified by collecting data against it, which give this framework more strength.

- In the present study model, only CO_2, CO, PM, NOx, HC pollutant and few vehicle categories are considered because of scarcity of data availability. Therefore there is an opportunity for future researcher to modify in such of way that it can include more pollutant, vehicle categories and other parameters like inspection and maintenance, road condition, driving patterns to widen the scope.

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ANNEXURE-I HEAD WAY ESTIMATION AT BUS STOPS

City		**Date**	
Bus route Name		**Time**	

Time	Bus stop name	Bus 1(Time)	Bus2(Time)	Bus2(time)

Bus Type: 1- Mini Bus, 2-standard Conventional bus (entry + 3 steps), 3-private bus),

ANNEXURE-II BUS OCCUPANCY SURVEY

City		Date	
Route name		Start time	
Bus type		End time	
No of seats(Excluding driver)		Origin	
		Destination	

Bus stop name	Boarding	Alighting	standing	Remarks

ANNEXURE –III **USER SURVEY QUESIONNAIRE**

PART-A: PERSONAL INFORMATION

A1- Name ……………………………………..

A2- Gender (mark only one circle)

Male ☐ Female ☐

A3- Age Group

<18	18-25	26-35	36-45	46-60	61-65	>65

A4- In which sector you belong:

Business	Gov. services	Private sector	Education sector	Public health sector

A5- Income (per month)

<10,000	10,000-20,000	20000-50000	50000-1lac	>1lac

A6- Mode of Transport

Bicycle	2-W	4-W	Auto /vikram	Bus

PART-B: YOUR DAILY TRAVEL ACTIVITIES (TRAVEL DIARY OF WORKING DAY) .

In this section please mention your travelling with in the city

B1- Purpose of trip

Home	Residences	School	Work place	Shopping	Recreational

B2- Total time taken for travelling per day (including all destinations))

<10	10-20	20-20	30-45	45-60	>60

B3- Travel trip length (kilometer)

0-2	2-5	5-10	10-20	>20

B4- **Total travelling cost/day (in Rs)**

<5	5-10	10-20	20-30	30-40	40-50	>50

B5- User Perception on Existing Infrastructure.

Modes	Mode	Very easy	Easy	Ok	Difficult
2W					
Bus					
Car					
Vikram					
Auto					
Minibus					

B6 How much are you willing to pay for good public transport a *one-way* ride to or from work?

<10 Rs.	Rs 10 -15	Rs 15-20	Rs 20-30	>30

PART-C SUGGESTION ON MOBILITY SYSTEM IN CITY …

C1- What is your primary means of transportation ?

Walk	Bicycle	Rickshaw 3-w	Bike	Car	Public Transport/Bus	Other

C2- **Mention your criteria for using particular mode of transport** (multiple answer)

	Very important	Moderately important	Not important
Fare			
Travel time			
Riding comfort			
Frequency of service			
Availability of transport			
Special coverage of mode			

Rate the following on 5 point scale (Likert scale)				
Least imp	**Less important**	**Average**	**More imp**	**Extremely important**
1	**2**	**3**	**4**	**5**

C4. Rate the following on your pedestrian/ bicycle travel in the city.

Safety	1	2	3	4	5
Pavement condition	1	2	3	4	5
Lighting	1	2	3	4	5
Surrounding elements	1	2	3	4	5
Weather	1	2	3	4	5
Traffic condition	1	2	3	4	5

C5. Rate the following to reduce adverse impact of transportation in the city.

Reduced VMT	1	2	3	4	5
Improve and encourage PT	1	2	3	4	5
Visual surrounding	1	2	3	4	5
Reduce congestion	1	2	3	4	5
Reduce noise	1	2	3	4	5
Reduce pollution	1	2	3	4	5

C6. Rate the following to improve safety (reduce accident) in the city.

Road condition& Road geometry	1	2	3	4	5
Weather	1	2	3	4	5
Street lighting	1	2	3	4	5
Traffic condition (Congestion)	1	2	3	4	5
Access control.	1	2	3	4	5
Proper Signage &ITS	1	2	3	4	5
Speed reduction	1	2	3	4	5
ATIS	1	2	3	4	5
Safety protection	1	2	3	4	5
*ATIS= automated travel information system					

C7. Rate the following to improve public transport use the city.

World class facility of PT	1	2	3	4	5
Dedicated bus lanes	1	2	3	4	5
Frequency of bus(waiting time)	1	2	3	4	5
Cleanliness and comfort	1	2	3	4	5
Safety and security	1	2	3	4	5
Prioritization to bus at intersection (time saving)	1	2	3	4	5
Affordable transportation(fare equity)or monetary cost	1	2	3	4	5
Accessible to all (children, elder, disable etc.)	1	2	3	4	5

Integration of transport(interchange terminals)	1	2	3	4	5
Mix land use scheme	1	2	3	4	5
Transit oriented development(high density development around transit)					
ATIS	1	2	3	4	5

C8.How important are these measure to reduces private vehicles in the city.

Increase parking fees	1	2	3	4	5
Limited parking space in CBD.	1	2	3	4	5
Parking relocation	1	2	3	4	5
Increase in taxes for private vehicles	1	2	3	4	5
Cess on petrol	1	2	3	4	5
Restrict motor vehicles in CBD.	1	2	3	4	5
Subsidy for shared / public transport.	1	2	3	4	5
Road congestion charging	1	2	3	4	5
Integration of transportation	1	2	3	4	5

C9. How important are these measures to improve pedestrian movement in the city.

Pedestrian network	1	2	3	4	5
Signage's and information to way finding	1	2	3	4	5
Comfort and safety	1	2	3	4	5
Shading trees and design.	1	2	3	4	5
Street scape (street furniture and landscape)	1	2	3	4	5
Barrier free design(accessible for disables)	1	2	3	4	5
Pedestrian oriented land use planning (Reduction the distance between facilities.)	1	2	3	4	5

C10 .How important are these measures to improve Non-Motorized transport movement in the city.

Dedicated bicycle/NMT network	1	2	3	4	5
Full service station	1	2	3	4	5
Parking facilities open and covered (near transit also)	1	2	3	4	5
Introduced innovative design to bicycle.(electric bicycle).with music	1	2	3	4	5
Subsidy or loan for bicycle)	1	2	3	4	5
Integrate with transit(cycle/transit integration)	1	2	3	4	5

Traffic calming and vehicle restriction.	1	2	3	4	5

C11 .How important are these measures to reduce air pollution in the city.

Improvement in public transport	1	2	3	4	5
Non-motorized transport planning	1	2	3	4	5
Transportation system management	1	2	3	4	5
Transit oriented development	1	2	3	4	5
Measures to discourages use of private vehicle.	1	2	3	4	5
Cess and levy on fuel to use Alternate type of fuel	1	2	3	4	5
Alternate type of engines in vehicles.	1	2	3	4	5
Traffic calming and vehicle restriction.	1	2	3	4	5

C12. How important are these measures to reduce noise pollution in the city.

Vegetation along road	1	2	3	4	5
Noise barrier	1	2	3	4	5
Restriction of vehicles	1	2	3	4	5
Improve road condition	1	2	3	4	5
Vehicle design and maintenance	1	2	3	4	5
Encourage public transport	1	2	3	4	5
Limiting traffic speed	1	2	3	4	5

ANNEXURE-IV QUESTIONNAIRE FOR URBAN PRACTITIONERS AND EXPERTS

PART –I- **RELATIVE WEIGHTAGE OF 3 SUSTAINABLE TRANSPORT OBJECTIVES**

(Example)

1. *If you think the relative weightage of 3 sustainable transport objective: economic development , environmental quality and social equity are 0.3,0.3 & .4 please fill in the table below.*

Sustainability	*Economic development*	*Environment Quality*	*Social equity*
	**.3*	**0.3*	**0.4*

**0.3+0.3+.4=1.0*

Sustainability	Economic development	Environment Quality	Social equity

PART –II **THE IMPORTANCE OF SUSTAINABLE TRANSPORT INDICATOR OR OBJECTIVES.**

Scale for rating the importance of different transport indicator

Scale	Least important	Less important	Average	More important	Extremely important
	1	2	3	4	5

(Example)

Objectives	*Sustainable urban transport*					
Public transport improvement	*Economic development*	☐ *1*	☐ *2*	☐ *3*	☐ *4*	☐ *5*
	Environment Quality	☐ *1*	☐ *2*	☐ *3*	☐ *4*	☐ *5*
	Social equity	☐ *1*	☐ *2*	☐ *3*	☐ *4*	☐ *5*

It implies

The named indicator { *Less Important, Average. More important* } *in achieving* { *Environment Economic Social* } *objective of sustainable transport.*

Scale for rating the importance of different transport indicator

Scale	Least important	Less important	Average	More important	Extremely important
	1	2	3	4	5

Indicator	**Sustainable Urban Transport**					
Land use impacts - Per capita land devoted to transportation facilities	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Establishment of local business activities(retail,shop,bank)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Provision of basic public facilities (school, health care and sport facility)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Alternate use of fuel	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Air Pollution - Frequency of air pollution standard violations	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Noise Pollution - Portion of population exposed to high levels of traffic noise	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Per capita crash costs (costs associated with accidents)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
% of travel by various efficient travel modes	*Economic development*	☐ *1*	☐ *2*	☐ *3*	☐ *4*	☐ *5*

	Environment Quality	☐ *1* ☐ *2* ☐ *3* ☐ *4* ☐ *5*
	Social equity	☐ *1* ☐ *2* ☐ *3* ☐ *4* ☐ *5*
Vehicle speed	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Per capita motor-vehicle mileage in urban area	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Driver education and behaviour	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Water Pollution - Per capita vehicle fluid losses	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Per capita traffic congestion delay	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Priorty signal system for the public transportation	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Per capita expenditures on roads, parking and traffic facilities	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Road safety, capacity, traffic signal and street lighting	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Indicator	**Sustainable urban transport**	
Quality of transport services for commercial users	Economic development	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
		☐ ☐ ☐ ☐ ☐

	Social equity	1	2	3	4	5
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Dedicated Bus lane and stations (BRTS)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Commute time	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Land use planning for more acessible multi-modal communities	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Security against crimes	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Provision of Trees and Planters	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilties	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Individual Cost expenditure on transport	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Convenience efficiency and safety of public transport users	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Availability of transport	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Affordability - Portion of budget spent on transport by lower income households	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Affordability - Portion of household budget devoted to transport	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Quality of transport facilities and services disabled, elderly or children	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Community involvement in decision making	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Availability of Street Furniture	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Convenience efficiency and safety of drivers	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Convenience efficiency and safety of pedestrian	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Habitat protection	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Habitat fragmentation	*Economic*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

	development	
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Per capita fatalities and injuries	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Inclusive planning to include disadvantaged and vulnerable groups	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Availability of appropriate electronic communication facility (Internet service)	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Cultural preservation	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Freight Efficiency - Speed and affordability of freight and commercial transport	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Appearance of pedestrian routes	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Quantity and quality of delivery services	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
User satisfaction for the current transport system	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
GPS System	*Economic development*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Environment Quality	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Access to work	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Access to transit	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Portion of travel to school and other local destinations by walking and cycling	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)	*Economic development*	1 1	2 2	3 3	4 4	5 5
	Environment Quality	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
	Social equity	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Environment Quality	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
	Social equity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Mobility management (network that allows working	*Economic development*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

of mobile phones) to address problems and increase transport system efficiency	*Environment Quality*	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Social equity	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Part-III. Personal Information

a) Gender(mark only one circle)

Male Female

b) Age

<18	18-25	26-35	36-45	46-60	61-65	>65

c) Education level

Graduate	Post graduate	PhD	Pursuing Phd

d) Experience

Fresher	0-5 years	6-10years	>10 years

e) In which field you belong:

Urban planning	Transport planning	Architecture	Environment planning	Construction/private

ANNEXURE-IV : MEAN SCORE CALCULATION

3.20	4.00	3.40	4.00	2.30	4.40	2.30	4.50	4.33	3.80	2.90	3.50	4.00	4.65	4.00	4.00	4.30	3.50	4.00	3.00	3.75	3.70	3.70	3.30	2.35	2.20	3.00	1.00	2.30	2.95	2.95	2.05	3.30
3.45	3.00	3.40	3.40	3.70	4.60	2.30	4.50	4.67	3.20	3.30	4.60	3.65	4.30	4.00	4.00	3.30	2.60	3.40	3.00	3.75	3.35	4.30	4.00	2.65	2.20	3.70	3.70	3.70	4.00	4.00	2.05	4.00
3.00	3.15	3.40	4.00	3.70	4.00	3.70	4.50	4.67	2.90	3.20	3.60	4.50	4.20	3.00	4.10	3.40	2.90	4.00	3.00	4.00	4.40	4.00	3.00	3.00	2.20	3.10	3.60	3.70	3.75	3.75	2.05	3.00
3.15	3.85	3.00	4.30	4.00	4.00	3.70	4.00	4.67	3.20	3.30	5.00	5.00	4.00	4.00	4.00	4.40	2.90	4.00	3.00	5.00	4.30	4.50	4.00	2.00	2.40	4.00	3.70	3.70	3.60	3.60	2.30	4.00
3.85	3.40	3.70	4.00	4.70	3.20	2.70	4.30	4.00	3.20	2.30	5.00	3.85	2.60	4.00	4.10	4.40	2.90	4.00	3.00	4.65	4.65	3.80	3.00	2.65	2.00	4.00	3.70	3.70	2.70	2.70	2.45	3.00
5.00	4.70	4.00	3.70	4.00	2.00	4.00	4.00	5.00	3.40	2.00	5.00	5.00	5.00	4.00	4.10	3.00	3.80	3.00	3.00	5.00	4.65	5.00	4.05	3.00	2.60	5.00	3.00	3.70	1.95	1.95	2.40	4.05
5.00	4.70	3.40	4.00	4.70	1.40	3.40	4.00	5.00	1.90	2.60	3.90	4.15	3.45	5.00	3.20	2.80	2.20	3.00	3.00	4.00	4.30	4.80	3.00	1.70	2.20	3.00	3.60	2.70	1.00	1.00	2.05	3.00
2.70	3.00	3.40	3.70	3.70	1.80	2.30	4.00	5.00	1.70	2.70	2.90	4.00	4.10	4.00	4.30	4.00	4.40	5.00	3.00	5.00	4.40	4.80	3.70	2.65	2.40	3.90	3.00	3.65	2.20	2.20	1.95	3.00
2.85	3.40	3.40	4.70	3.70	3.00	4.00	4.00	5.00	3.90	3.40	3.50	2.70	4.10	4.00	4.30	4.00	5.00	4.00	3.00	1.70	5.00	4.50	4.65	2.35	2.60	4.60	3.00	4.00	2.00	2.00	2.65	4.65
3.40	4.30	3.00	3.60	3.70	2.80	3.00	4.00	5.00	3.90	3.10	3.40	3.85	4.10	4.00	4.00	4.40	4.00	4.00	3.00	3.70	4.00	3.70	3.40	2.30	2.40	3.80	3.00	3.30	1.65	1.65	2.55	3.40
3.00	4.20	3.70	3.00	4.70	1.80	1.70	4.20	5.00	1.80	1.70	3.60	3.05	4.35	4.00	4.40	4.40	4.10	4.00	3.00	3.65	4.40	5.00	3.35	2.05	2.80	3.90	3.00	3.70	4.00	4.00	2.10	3.35
3.30	2.95	3.10	3.20	2.70	2.60	2.00	4.30	5.00	1.60	3.00	4.00	4.00	3.40	4.00	4.10	2.80	2.60	4.00	3.00	3.00	4.35	3.80	3.70	2.20	1.80	2.40	2.80	2.30	2.55	2.55	2.00	3.70
2.50	3.40	3.10	3.10	2.20	2.20	4.00	4.00	5.00	1.60	3.00	2.40	3.85	3.40	4.00	4.10	2.80	2.90	4.00	2.25	3.10	3.10	3.90	3.70	2.20	1.80	3.80	2.80	2.30	2.55	2.55	2.00	3.70
3.75	2.80	3.00	3.90	2.90	1.40	4.70	4.00	5.00	1.30	2.70	4.60	3.85	4.65	4.00	4.00	3.70	4.60	4.00	3.00	3.00	3.10	4.00	3.05	2.60	1.60	3.40	4.00	3.30	2.50	2.50	1.75	3.05
3.30	3.15	3.00	3.60	3.70	2.60	3.70	4.50	5.00	3.30	2.30	3.40	3.50	4.00	4.00	4.10	3.00	2.60	4.00	3.00	5.00	4.00	4.30	3.35	2.30	2.60	2.40	2.00	1.90	1.00	1.00	2.90	3.35
2.70	3.75	3.70	3.40	3.20	1.40	1.30	4.50	5.00	2.70	2.30	2.60	4.35	4.35	4.00	4.10	4.40	4.30	4.00	3.00	4.00	2.90	3.50	3.05	2.25	2.80	3.50	2.60	3.05	1.50	1.50	2.10	3.05
2.70	3.70	2.70	3.90	2.60	1.40	3.40	4.50	5.00	1.90	2.00	2.60	3.00	3.95	4.00	4.10	5.00	3.50	4.00	3.00	2.00	3.40	3.50	3.35	1.90	2.40	3.50	2.10	3.30	2.60	2.60	2.30	3.35
3.70	3.30	2.70	3.00	3.70	1.00	1.30	3.00	5.00	1.60	3.00	3.90	4.35	4.20	4.00	4.10	4.60	3.60	4.00	3.00	4.00	2.75	4.50	3.35	1.35	1.20	3.20	2.60	3.30	2.35	2.35	1.65	3.30
2.80	3.40	2.70	5.00	2.80	2.60	3.70	4.50	5.00	2.10	1.30	2.30	2.15	4.00	4.00	4.10	3.90	2.90	4.00	3.00	4.35	3.25	3.30	3.70	3.80	4.20	3.70	4.00	3.70	3.10	3.10	4.00	3.95
3.20	3.55	2.70	5.00	4.00	3.40	3.70	2.70	5.00	1.60	3.70	2.60	2.30	4.00	4.00	4.10	3.80	4.00	4.00	3.00	5.00	3.60	4.60	3.30	2.05	2.20	3.70	3.70	3.05	3.20	3.20	2.05	4.35

3.40	4.00	3.70	4.70	4.00	2.60	1.70	4.30	5.00	3.80	3.00	1.60	3.70	5.00	4.00	4.10	3.90	4.40	4.00	3.00	5.00	4.35	2.80	3.00	1.35	1.00	3.80	2.70	3.35	4.25	4.25	1.35	2.95
3.95	3.00	3.00	4.40	4.10	1.80	2.70	4.50	5.00	2.40	3.00	3.60	4.35	3.20	4.00	4.00	3.60	4.00	4.00	3.00	3.00	4.70	4.30	3.35	2.75	3.80	2.70	1.70	2.70	2.60	2.95	2.15	3.00
2.30	3.00	3.40	3.90	3.70	1.40	3.00	3.20	4.67	1.90	2.00	4.60	3.00	4.45	4.00	4.00	3.00	3.90	4.00	3.00	4.00	4.70	4.30	2.65	2.40	1.80	3.20	2.90	4.05	2.45	2.45	1.80	2.65
3.40	3.40	2.40	2.00	2.80	3.20	3.30	3.50	4.00	2.20	2.40	4.00	3.15	4.25	4.00	4.60	3.00	3.90	4.00	3.00	5.00	4.30	4.50	3.00	2.35	2.60	4.50	2.60	2.35	2.45	2.45	3.10	3.00
3.00	2.50	2.40	2.60	3.20	2.20	2.40	4.50	5.00	2.70	3.20	3.30	4.70	4.10	3.60	4.10	4.00	4.00	4.40	3.70	3.95	2.90	2.90	3.00	3.10	3.00	3.20	2.50	2.05	1.35	1.35	2.90	3.30
3.00	3.25	3.10	4.70	2.00	2.80	1.70	4.50	5.00	2.60	2.30	2.60	4.35	5.00	4.00	4.00	4.60	3.90	4.00	3.00	3.25	2.60	2.60	4.35	3.30	4.00	3.00	3.80	3.60	2.70	2.70	4.35	4.65
3.20	2.95	3.30	2.80	2.50	3.40	2.30	4.50	5.00	2.50	3.50	4.60	3.85	4.20	4.00	4.00	4.30	2.20	2.80	3.70	1.70	2.55	3.80	3.75	2.60	1.60	3.50	3.10	2.55	2.35	2.35	2.00	3.75
3.00	3.00	2.70	3.00	2.50	2.20	2.00	4.50	5.00	2.60	3.00	4.20	3.65	5.00	4.00	4.00	4.20	2.20	4.00	3.00	3.60	3.25	4.50	5.00	2.05	2.20	3.40	2.30	2.65	2.05	2.70	2.10	3.60
3.10	3.00	3.10	4.10	3.70	2.40	2.50	4.50	3.00	3.10	2.60	3.00	4.00	3.50	2.30	4.00	3.20	3.60	3.80	3.00	2.60	3.25	3.30	4.70	3.95	2.80	3.50	3.80	3.95	2.80	3.15	3.15	5.00
2.15	3.70	2.70	2.00	2.80	1.00	1.70	4.50	5.00	2.20	2.00	3.60	2.85	4.65	4.00	4.00	4.00	2.50	4.00	3.00	5.00	4.00	4.50	3.35	2.55	2.00	3.50	4.10	3.30	3.30	3.30	2.40	4.35
2.70	3.55	2.00	3.90	3.50	4.20	3.00	3.20	4.33	2.50	2.50	4.00	3.15	3.90	3.10	4.10	3.20	2.90	2.50	3.00	3.95	2.55	4.00	3.35	2.40	1.80	2.70	2.40	2.75	2.50	3.30	1.80	3.30
3.30	3.25	2.40	4.70	4.10	3.80	1.70	4.50	5.00	2.10	2.00	4.60	3.65	4.65	4.00	4.30	5.00	3.20	4.00	3.00	5.00	1.95	4.30	4.35	3.05	2.20	3.70	3.10	3.65	3.35	2.95	2.60	3.60
3.15	2.30	2.10	4.00	3.70	3.80	4.00	4.50	5.00	1.90	2.00	1.60	3.50	4.80	4.00	4.30	4.20	3.60	4.00	3.00	4.00	1.60	4.10	3.30	2.70	2.60	3.90	3.20	2.70	2.60	2.60	2.85	3.70
2.50	4.00	1.90	3.20	2.50	4.00	2.30	4.50	5.00	3.20	1.40	4.00	4.00	5.00	4.00	3.90	4.30	3.60	4.00	3.00	4.30	1.30	4.80	4.30	1.70	2.20	4.30	3.70	2.95	3.60	3.60	2.20	3.95
3.40	2.00	3.40	4.10	4.00	3.80	1.30	4.50	5.00	1.70	1.00	3.00	3.65	4.80	4.00	4.10	5.00	3.10	4.00	3.00	3.75	2.90	4.30	4.35	1.35	1.80	4.00	3.50	2.70	3.60	3.60	1.75	4.30
3.00	2.90	2.30	4.70	2.60	4.00	3.40	4.50	5.00	2.10	2.30	3.00	4.00	4.45	4.00	3.70	4.00	3.60	4.00	3.00	2.35	2.95	3.60	4.00	3.00	1.80	3.70	3.60	3.30	3.65	3.65	1.80	4.30
3.00	3.10	1.70	3.40	4.10	3.80	1.30	4.50	5.00	1.90	2.70	3.00	3.70	4.45	4.00	4.30	3.60	3.60	4.00	3.00	4.70	2.90	3.60	4.00	3.70	3.20	4.20	3.70	4.00	3.15	3.15	3.20	3.95
3.55	2.65	2.30	3.90	3.40	4.00	2.30	4.50	5.00	2.40	1.30	4.40	3.35	4.45	4.00	3.40	3.30	3.50	4.00	3.00	5.00	4.35	5.00	4.65	3.00	2.80	4.20	4.00	3.35	2.80	2.80	2.85	3.95
4.00	3.00	2.00	3.00	2.50	3.20	1.30	4.50	5.00	1.80	3.00	3.60	2.85	5.00	4.00	4.00	3.70	2.90	4.00	3.00	4.05	4.35	4.30	3.65	1.70	1.80	4.30	3.40	3.35	3.15	3.15	1.80	4.35
4.30	2.75	2.60	2.00	2.80	4.00	1.70	4.50	5.00	1.90	1.00	3.00	2.80	4.80	4.00	4.00	4.20	2.80	4.00	3.00	3.25	3.95	4.50	3.65	1.70	1.80	3.20	3.20	2.35	3.30	3.30	1.80	3.65
4.00	4.25	2.70	4.00	2.50	4.00	1.70	4.50	5.00	1.90	2.70	3.20	1.45	5.00	4.00	4.00	5.00	2.80	4.00	3.00	4.35	4.30	5.00	3.65	1.70	1.80	4.20	3.50	3.05	3.45	3.45	1.80	3.65

2.65	4.00	2.80	4.00	3.10	3.80	1.00	4.50	5.00	1.40	2.00	4.40	4.50	5.00	4.00	4.00	3.60	4.70	4.00	3.35	3.00	4.40	3.30	3.35	2.75	2.60	4.00	3.80	3.05	3.80	3.80	2.55	3.65
5.00	4.30	2.40	4.40	3.40	3.60	2.70	4.50	5.00	3.30	3.30	5.00	4.30	4.80	4.00	3.90	4.60	3.50	4.00	4.00	4.30	2.35	4.60	4.35	1.65	1.80	4.00	3.40	2.30	2.30	2.30	1.80	3.30
3.80	3.45	3.00	4.40	3.50	4.00	2.30	4.50	4.00	1.90	1.00	4.00	2.70	4.45	4.00	4.00	4.20	2.60	4.00	3.00	3.65	4.70	3.00	4.05	2.55	1.80	4.00	3.80	3.60	3.20	3.20	2.00	4.65
3.30	3.55	2.40	4.10	3.70	2.80	2.30	3.20	2.67	2.90	2.20	2.80	3.35	3.40	3.60	4.00	3.30	3.90	3.40	2.30	3.05	3.65	3.80	3.65	2.35	2.60	4.20	3.20	2.65	2.95	2.15	1.90	3.25
2.65	3.05	2.80	4.40	3.20	3.60	3.70	4.50	5.00	3.40	1.70	3.80	4.30	4.10	4.00	4.30	5.00	4.10	4.00	3.00	4.70	4.00	4.40	4.70	2.70	2.60	4.00	4.00	4.00	3.20	3.20	3.10	4.65
4.00	3.60	2.80	3.50	3.00	3.60	4.00	4.50	5.00	2.50	2.00	3.60	4.50	4.80	4.00	3.90	4.60	3.20	4.00	3.00	4.70	5.00	4.40	4.70	2.20	1.80	4.00	1.90	3.30	2.80	2.80	2.00	4.65
1.00	3.60	2.80	3.80	2.60	3.60	4.00	4.50	5.00	2.80	1.00	4.40	4.50	4.80	4.00	3.90	4.60	4.10	4.00	3.35	4.70	3.65	4.60	4.05	2.20	1.80	4.00	3.00	3.60	2.80	2.80	2.00	4.35
1.70	3.35	2.80	3.80	3.70	3.60	4.70	4.50	5.00	2.50	3.00	4.40	4.15	4.80	4.00	3.90	4.60	3.50	4.00	3.35	4.70	4.30	3.20	4.35	2.20	1.80	4.00	3.40	3.25	2.80	2.80	2.00	4.00
1.45	3.15	2.80	3.00	3.30	2.40	4.70	4.50	5.00	2.50	2.00	5.00	4.50	5.00	5.00	3.90	4.60	4.70	4.00	3.65	4.70	4.35	4.30	4.35	2.20	1.80	4.00	4.70	3.25	3.20	3.20	2.00	4.35
3.45	4.05	2.40	3.00	2.60	3.60	2.30	4.50	5.00	2.20	3.20	5.00	3.85	5.00	5.00	3.90	5.00	4.70	4.00	3.30	3.40	4.35	4.80	4.00	2.55	2.20	4.20	3.90	1.00	2.05	2.05	2.35	4.35
4.10	3.05	2.80	2.50	2.30	3.60	2.40	4.50	5.00	2.70	2.70	1.80	3.15	4.35	5.00	3.90	4.00	4.70	4.00	3.35	3.95	4.35	4.40	4.70	2.55	1.60	4.20	3.40	1.00	2.35	2.35	2.35	4.30
5.00	3.70	2.10	2.00	2.00	3.60	4.00	4.50	5.00	1.90	2.70	1.80	3.00	5.00	4.00	3.90	3.60	4.70	4.00	3.35	4.30	3.40	3.80	5.00	2.90	2.00	4.20	4.40	3.00	3.35	3.35	2.40	4.65
3.40	3.85	2.80	4.00	2.00	3.60	2.00	3.50	5.00	2.70	3.00	2.80	4.65	4.80	4.00	3.90	4.40	4.70	4.00	3.30	3.75	5.00	4.60	5.00	2.90	2.40	4.40	3.00	3.65	2.35	2.35	2.25	5.00
5.00	4.05	2.80	4.40	2.50	3.80	1.00	4.50	5.00	2.90	3.20	2.80	5.00	4.80	4.00	4.00	5.00	3.80	4.00	3.35	4.40	4.30	4.60	3.35	2.90	2.20	4.40	2.70	2.60	2.75	2.75	2.35	4.70

Criteria	R40	R41	R42	R43	R44	R45	R46	R47	R48	R49	R50	R51	R52	R53	R54	R55	R56	R57	R58	R59	R60	Mean Average
User satisfaction for the current transport system, Mean	2.50	4.65	2.60	3.80	4.70	4.10	4.80	4.45	3.65	2.40	4.40	4.20	4.30	3.60	4.20	4.50	3.30	4.35	3.95	4.50	3.45	**3.6**
Access to transit, Mean	2.80	3.70	3.05	3.80	3.70	4.40	4.60	4.45	3.05	2.35	4.70	3.10	4.65	3.10	3.10	4.50	3.20	3.70	3.70	4.50	2.90	**3.65**
Commute time, Mean	3.00	4.30	3.10	2.70	3.10	4.00	3.80	4.45	3.65	3.35	4.70	2.80	4.65	2.80	2.80	4.50	3.50	3.70	3.70	4.50	2.90	**3.59**
Access to work, Mean	2.80	5.00	2.80	2.00	3.10	2.90	3.60	4.00	3.35	1.65	4.70	3.40	4.65	3.45	3.40	4.00	1.70	3.35	3.70	4.00	2.90	**3.65**
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area, Mean	3.50	5.00	3.10	4.10	4.00	4.10	3.20	3.30	4.30	2.35	2.90	3.10	3.05	3.55	3.10	2.80	3.60	3.75	3.90	2.80	3.05	**3.57**
Provision of basic public facilities (school, health care and sport facility), Mean	4.00	5.00	3.10	5.00	4.30	4.30	3.40	4.00	2.70	2.70	5.00	3.50	5.00	4.05	3.50	4.00	3.40	3.45	3.55	4.00	3.55	**3.83**
Availability of appropriate electronic communication facility (Internet service), Mean	2.50	5.00	2.55	3.10	4.10	4.40	2.60	4.00	4.00	2.05	5.00	2.20	5.00	2.85	2.20	4.00	1.50	3.75	3.80	4.00	2.40	**3.33**
Per capita motor-vehicle mileage in urban area, Mean	2.30	2.30	2.65	3.40	4.10	3.00	1.80	4.00	3.65	2.00	5.00	3.80	5.00	3.30	3.80	4.00	2.50	3.05	3.65	4.00	2.90	**3.46**
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.), Mean	3.50	5.00	2.85	3.35	4.10	4.00	4.00	4.00	4.30	2.70	5.00	3.20	5.00	4.25	3.20	4.00	3.00	4.35	3.90	4.00	3.30	**3.77**
% of travel by various efficient travel modes, Mean	2.70	4.65	2.30	2.00	3.60	3.70	2.80	4.00	4.30	2.30	5.00	4.60	5.00	3.80	4.60	4.00	2.50	3.70	3.85	4.00	4.10	**3.61**
Per capita traffic congestion delay, Mean	3.00	4.30	1.80	3.60	2.60	4.70	1.80	2.80	3.65	1.70	5.00	3.80	5.00	2.80	3.80	2.70	2.80	3.40	3.70	2.70	2.70	**3.41**
Affordability - Portion of household budget devoted to transport, Mean	3.50	2.65	2.00	2.70	4.00	2.70	2.60	4.30	2.90	1.90	5.00	2.20	5.00	2.35	2.20	4.30	1.80	3.35	2.80	4.30	2.00	**3.14**
Individual cost expenditure on transport, Mean	3.50	3.00	2.00	2.70	2.90	2.20	2.60	4.00	2.90	2.55	5.00	2.20	5.00	1.75	2.20	4.00	1.80	2.05	2.00	4.00	2.00	**3.06**
Per capita expenditures on roads, parking and traffic facilities, Mean	2.70	4.00	2.80	2.70	3.60	2.90	3.00	4.00	2.95	2.60	5.00	4.60	5.00	2.00	4.60	4.00	2.10	2.05	2.00	4.00	3.50	**3.42**
Quantity and quality of delivery services, Mean	2.60	4.00	2.30	2.65	3.30	3.70	3.00	4.45	3.65	2.30	5.00	2.80	5.00	2.95	2.80	4.50	2.20	2.05	3.55	4.50	2.90	**3.31**
Quality of transport services for commercial users, Mean	4.00	5.00	2.40	4.05	2.80	3.50	1.40	4.45	3.70	2.55	5.00	4.70	5.00	3.45	4.70	4.50	1.60	3.40	4.05	4.50	3.70	**3.47**
Per capita crash costs (costs associated with accidents), Mean	3.50	3.65	2.10	2.00	3.90	2.60	1.80	4.45	3.30	2.25	5.00	3.90	5.00	2.35	3.90	4.50	1.60	2.70	2.40	4.50	3.85	**3.29**
Freight Efficiency - Speed and affordability of freight and commercial transport, Mean	3.00	4.30	1.35	3.60	3.00	2.90	1.40	3.10	2.60	1.00	5.00	3.40	5.00	2.40	3.40	3.00	1.30	2.70	2.35	3.00	2.35	**3.12**

Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency, Mean	3.20	4.30	4.00	2.00	5.00	4.10	3.80	4.45	3.00	3.80	5.00	4.60	5.00	2.75	4.60	4.50	4.20	2.70	2.55	4.50	2.35	**3.67**
Efficient Pricing and Prioritization (Roads/Parking/Insurance/Fuel etc), Mean	3.70	4.00	2.85	2.35	5.00	4.40	3.80	2.65	2.90	2.75	5.00	3.50	5.00	2.35	3.50	2.70	2.50	4.00	2.80	2.70	2.50	**3.48**
Land use planning for more accessible multi-modal communities, Mean	3.80	4.00	1.40	3.95	4.70	4.00	2.60	4.30	2.95	1.65	5.00	4.30	5.00	2.90	4.30	4.30	1.50	4.00	3.55	4.30	4.25	**3.58**
User rating, Mean	2.70	3.65	2.55	2.65	2.90	3.80	2.20	3.10	3.05	2.40	4.10	3.20	3.95	2.60	3.20	3.00	2.30	3.65	3.20	3.20	3.30	**3.31**
Per capita fatalities and injuries, Mean	3.80	3.70	2.50	3.45	3.90	3.70	1.40	3.35	3.40	2.40	4.70	4.00	4.65	3.65	4.00	3.20	2.50	3.65	4.15	3.20	4.10	**3.35**
Community involvement in decision making, Mean	3.20	3.60	2.30	2.05	2.20	2.00	2.60	4.45	4.00	2.35	4.40	3.40	3.95	3.55	3.40	3.00	2.40	3.70	2.60	4.50	3.60	**3.29**
Cultural preservation, Mean	3.30	4.30	3.45	2.70	2.60	3.20	2.60	4.45	3.30	2.75	5.00	2.60	5.00	2.60	2.60	4.50	3.40	4.35	3.20	4.50	2.80	**3.33**
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions), Mean	3.20	5.00	3.35	3.10	4.40	2.00	2.80	4.45	3.05	3.60	5.00	4.70	5.00	3.05	4.70	4.50	4.10	5.00	3.55	4.50	3.70	**3.72**
Affordability - Portion of budget spent on transport by lower income households, Mean	3.80	3.00	1.75	3.95	2.80	3.00	3.80	3.40	1.90	2.25	5.00	2.90	5.00	3.15	2.90	4.80	1.60	3.05	3.35	2.40	3.80	**3.22**
Quality of transport facilities and services for disabled, elderly or children, Mean	2.50	3.30	1.40	2.35	2.60	2.90	2.20	3.10	2.05	1.35	5.00	3.20	5.00	2.45	3.20	1.90	2.00	3.45	2.40	2.10	2.25	**3.11**
Portion of travel to school and other local destinations by walking and cycling, Mean	3.20	5.00	3.55	3.75	4.10	4.10	2.80	4.70	3.40	3.60	2.65	4.40	2.75	4.50	4.40	4.50	3.10	5.00	4.25	4.70	4.50	**3.67**
Inclusive planning to include disadvantaged and vulnerable groups, Mean	3.20	4.40	2.35	2.35	2.00	2.40	1.40	4.45	2.75	2.25	3.65	3.60	3.40	2.45	3.60	4.50	3.30	3.75	2.55	4.50	3.70	**3.29**
Priority signal system for the public transportation, Mean	3.70	3.60	2.95	1.65	3.90	3.50	3.80	3.35	3.05	1.65	4.05	3.80	4.00	3.20	3.40	3.70	3.10	3.70	3.55	3.00	3.70	**3.24**
Road safety, capacity, traffic signal and street lighting, Mean	3.60	4.65	2.70	2.05	4.30	4.10	3.40	4.00	3.05	2.00	3.80	2.90	4.30	3.20	2.90	3.00	1.80	4.10	2.45	3.00	3.30	**3.43**
Vehicle Speed, Mean	4.80	4.65	2.65	1.65	4.00	4.10	4.20	4.45	2.35	2.70	5.00	3.80	5.00	2.10	3.80	4.50	1.90	4.65	1.65	4.50	3.45	**3.43**
Driver Education and Behaviour, Mean	2.40	5.00	1.70	2.40	2.60	2.50	3.20	4.45	2.00	2.00	5.00	2.20	5.00	2.80	2.20	4.50	1.00	5.00	1.80	4.50	1.70	**3.27**
Dedicated Bus lane and stations (BRTS), Mean	4.20	4.65	1.35	2.70	3.50	4.40	4.20	4.45	3.40	1.70	5.00	4.40	5.00	2.80	4.40	4.50	1.30	4.65	3.55	4.50	2.90	**3.51**
GPS System, Mean	5.00	4.30	2.95	2.00	4.70	2.60	4.00	4.45	3.70	3.35	5.00	3.60	5.00	3.45	3.60	4.50	2.50	4.35	3.45	4.50	3.70	**3.63**

Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles), Mean	5.00	4.65	3.30	1.70	3.40	3.50	4.20	4.45	2.05	3.70	5.00	4.60	5.00	2.95	4.60	4.50	3.10	4.65	2.85	3.80	3.95	**3.66**
Security against crimes, Mean	4.80	4.30	2.65	2.75	3.90	3.80	4.20	4.45	2.40	2.70	5.00	3.20	5.00	2.60	3.20	4.50	2.40	4.35	2.45	2.10	3.30	**3.54**
Convenience efficiency and safety of drivers, Mean	4.70	5.00	1.35	1.70	3.00	2.80	3.20	4.45	2.35	1.70	5.00	2.50	5.00	2.95	2.50	4.50	1.60	5.00	2.45	2.30	2.65	**3.29**
Convenience efficiency and safety of pedestrians, Mean	4.50	4.30	1.70	2.35	2.00	3.20	4.20	4.45	2.35	1.70	5.00	3.60	5.00	2.95	3.60	4.50	1.60	4.30	2.45	2.30	3.70	**3.25**
Convenience efficiency and safety of public transport users, Mean	4.50	4.65	1.70	2.35	3.30	2.80	4.20	4.45	2.35	1.70	5.00	3.60	5.00	2.95	3.60	4.50	2.30	4.65	2.45	2.60	3.70	**3.47**
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area), Mean	4.00	4.05	4.05	2.60	3.50	3.70	3.80	4.20	2.90	3.65	4.40	3.90	3.95	2.50	3.90	4.50	3.40	4.00	2.45	3.80	3.85	**3.59**
Provision of Trees and Planters, Mean	3.40	4.30	1.60	2.40	4.40	3.40	4.40	4.45	2.40	1.35	5.00	3.80	5.00	2.30	3.80	4.50	2.00	4.35	2.40	3.80	3.90	**3.53**
Availability of Street Furniture, Mean	4.60	4.35	2.40	2.70	3.60	3.50	4.20	4.45	2.75	2.75	2.65	3.30	3.05	3.90	3.30	3.90	2.20	2.70	3.50	3.40	3.95	**3.43**
Appearance of Pedestrian Routes, Mean	3.80	3.60	1.95	1.70	2.50	3.40	2.40	3.10	2.40	1.65	4.40	2.80	3.95	2.85	2.80	2.50	1.30	3.75	2.55	2.60	2.90	**3.00**
Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions, Mean	4.20	4.65	2.65	2.40	4.40	3.50	3.60	4.45	2.70	2.70	5.00	2.60	5.00	3.45	2.60	4.50	2.10	4.65	3.45	3.60	2.60	**3.67**
Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.), Mean	2.40	4.35	2.00	3.10	3.50	3.30	4.00	4.45	2.70	1.90	5.00	2.60	5.00	3.05	2.60	4.50	2.30	4.35	2.40	3.60	2.60	**3.49**
Air Pollution - Frequency of air pollution standard violations, Mean	1.60	4.35	2.00	2.70	3.20	2.60	3.20	4.45	2.70	1.90	5.00	2.60	5.00	3.05	2.60	4.50	2.60	4.35	2.65	3.60	2.60	**3.42**
Noise Pollution - Portion of population exposed to high levels of traffic noise, Mean	1.40	4.05	2.00	3.10	4.10	4.10	3.20	4.45	2.70	2.55	5.00	2.60	5.00	3.05	2.60	4.50	2.30	4.00	2.40	3.80	2.60	**3.48**
Water Pollution - Per capita vehicle fluid losses, Mean	1.70	4.05	2.00	3.10	3.00	2.70	2.40	4.45	2.05	2.20	5.00	2.60	5.00	3.05	2.60	4.50	1.80	4.00	2.40	3.80	2.60	**3.45**
Land use impacts - Per capita land devoted to transportation facilities, Mean	1.60	4.70	2.40	2.35	2.70	2.90	3.20	4.45	2.55	2.55	5.00	3.50	5.00	2.50	3.50	4.50	2.30	4.65	3.10	3.40	3.45	**3.50**
Habitat protection, Mean	2.90	4.30	2.40	3.10	2.50	2.30	3.60	4.45	2.70	2.55	5.00	3.80	5.00	2.45	3.80	4.50	2.60	4.35	2.80	3.40	3.80	**3.41**
Habitat fragmentation, Mean	4.10	3.45	2.75	2.05	2.00	2.00	3.60	4.45	2.35	1.90	5.00	3.50	5.00	2.45	3.50	4.50	2.60	3.25	2.65	3.40	3.15	**3.37**
Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilities, Mean	1.90	4.30	2.75	2.75	4.00	2.90	4.00	3.35	2.70	2.90	5.00	3.50	5.00	2.45	3.50	3.50	1.80	4.30	2.65	3.20	3.10	**3.52**
Alternate use of fuel, Mean	4.10	4.10	2.40	2.75	4.40	2.80	3.80	4.45	2.70	2.90	5.00	3.80	5.00	2.55	3.80	4.50	2.10	3.95	2.65	4.10	3.45	**3.62**

Annexure VI

A) Correlation Analysis for Economic Criteria:

Criteria	Access to work	Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area	Individual cost expenditure on transport	Affordability - Portion of household budget devoted to transport	Land use impacts - Per capita land devoted to transportation facilities
Access to work	1				
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area	0.69	1.00			
Individual cost expenditure on transport	0.57	0.54	1.00		
Affordability - Portion of household budget devoted to transport	0.57	0.70	0.82	1.00	
Land use impacts - Per capita land devoted to transportation facilities	0.67	0.50	0.48	0.64	1.00
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)	0.22	0.34	0.60	0.58	0.39
% of travel by various efficient travel modes	0.51	0.40	0.45	0.42	0.49
User satisfaction for the current transport system	0.44	0.40	0.34	0.49	0.59
Freight Efficiency - Speed and affordability of freight and commercial transport	0.52	0.60	0.65	0.67	0.58
Land use planning for more acessible multi-modal communities	0.32	0.46	0.56	0.51	0.31
Access to transit	0.67	0.65	0.54	0.70	0.54
Commute time	0.66	0.70	0.74	0.77	0.44
Availability of appropriate electronic communication facility (Internet service)	0.52	0.63	0.62	0.61	0.43
Per capita motor-vehicle mileage in urban area	0.53	0.58	0.82	0.75	0.59
Per capita expenditures on roads, parking and traffic facilities	0.48	0.56	0.69	0.74	0.48
Per capita crash costs (costs associated with accidents)	0.42	0.56	0.65	0.66	0.56
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	0.33	0.35	0.50	0.36	0.37
Per capita traffic congestion delay	0.41	0.58	0.56	0.59	0.65
Quantity and quality of delivery services	0.64	0.69	0.80	0.74	0.56
Quality of transport services for commercial users	0.46	0.45	0.51	0.46	0.51
Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	0.40	0.51	0.67	0.59	0.37
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	0.66	0.62	0.60	0.79	0.77

Criteria	Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)	% of travel by various efficient travel modes	User satisfaction for the current transport system	Freight Efficiency - Speed and affordability of freight and commercial transport	Land use planning for more acessible multi-modal communities
Access to work					
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area					
Individual cost expenditure on transport					
Affordability - Portion of household budget devoted to transport					
Land use impacts - Per capita land devoted to transportation facilities					
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)	1.00				
% of travel by various efficient travel modes	0.59	1.00			
User satisfaction for the current transport system	0.41	0.64	1.00		
Freight Efficiency - Speed and affordability of freight and commercial transport	0.50	0.50	0.42	1.00	
Land use planning for more acessible multi-modal communities	0.48	0.55	0.60	0.61	1.00
Access to transit	0.26	0.36	0.51	0.32	0.34
Commute time	0.48	0.37	0.52	0.48	0.58
Availability of appropriate electronic communication facility (Internet service)	0.38	0.34	0.11	0.66	0.40
Per capita motor-vehicle mileage in urban area	0.61	0.51	0.45	0.83	0.71
Per capita expenditures on roads, parking and traffic facilities	0.58	0.37	0.17	0.70	0.37
Per capita crash costs (costs associated with accidents)	0.67	0.59	0.40	0.59	0.39
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	0.51	0.25	0.29	0.49	0.47
Per capita traffic congestion delay	0.60	0.58	0.48	0.72	0.56
Quantity and quality of delivery services	0.43	0.49	0.45	0.58	0.50
Quality of transport services for commercial users	0.39	0.60	0.54	0.75	0.69
Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	0.61	0.47	0.55	0.49	0.58
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	0.60	0.59	0.72	0.60	0.62

Criteria	Access to transit	Commute time	Availability of appropriate electronic communication facility (Internet service)	Per capita motor-vehicle mileage in urban area	Per capita expenditures on roads, parking and traffic facilities
Access to work					
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area					
Individual cost expenditure on transport					
Affordability - Portion of household budget devoted to transport					
Land use impacts - Per capita land devoted to transportation facilities					
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)					
% of travel by various efficient travel modes					
User satisfaction for the current transport system					
Freight Efficiency - Speed and affordability of freight and commercial transport					
Land use planning for more acessible multi-modal communities					
Access to transit	1.00				
Commute time	0.70	1.00			
Availability of appropriate electronic communication facility (Internet service)	0.46	0.47	1.00		
Per capita motor-vehicle mileage in urban area	0.37	0.62	0.55	1.00	
Per capita expenditures on roads, parking and traffic facilities	0.28	0.51	0.67	0.70	1.00
Per capita crash costs (costs associated with accidents)	0.24	0.48	0.55	0.59	0.71
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	0.38	0.40	0.42	0.57	0.44
Per capita traffic congestion delay	0.26	0.43	0.53	0.77	0.49
Quantity and quality of delivery services	0.67	0.71	0.67	0.73	0.61
Quality of transport services for commercial users	0.21	0.35	0.44	0.68	0.48
Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	0.52	0.53	0.43	0.61	0.53
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	0.61	0.69	0.40	0.70	0.54

Criteria	Per capita crash costs (costs associated with accidents)	Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	Per capita traffic congestion delay	Quantity and quality of delivery services
Access to work				
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area				
Individual cost expenditure on transport				
Affordability - Portion of household budget devoted to transport				
Land use impacts - Per capita land devoted to transportation facilities				
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)				
% of travel by various efficient travel modes				
User satisfaction for the current transport system				
Freight Efficiency - Speed and affordability of freight and commercial transport				
Land use planning for more acessible multi-modal communities				
Access to transit				
Commute time				
Availability of appropriate electronic communication facility (Internet service)				
Per capita motor-vehicle mileage in urban area				
Per capita expenditures on roads, parking and traffic facilities				
Per capita crash costs (costs associated with accidents)	1.00			
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)	0.32	1.00		
Per capita traffic congestion delay	0.72	0.38	1.00	
Quantity and quality of delivery services	0.61	0.57	0.59	1.00
Quality of transport services for commercial users	0.62	0.33	0.71	0.49
Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	0.59	0.72	0.43	0.75
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	0.54	0.31	0.64	0.56

Criteria	Quality of transport services for commercial users	Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)
Access to work			
Establishment of local business activities (retail, shop, bank etc.) in the vicinity of residential area			
Individual cost expenditure on transport			
Affordability - Portion of household budget devoted to transport			
Land use impacts - Per capita land devoted to transportation facilities			
Diversity in Transportation Modes (Walking/Cycling/Ride sharing/Public Transportation etc.)			
% of travel by various efficient travel modes			
User satisfaction for the current transport system			
Freight Efficiency - Speed and affordability of freight and commercial transport			
Land use planning for more acessible multi-modal communities			
Access to transit			
Commute time			
Availability of appropriate electronic communication facility (Internet service)			
Per capita motor-vehicle mileage in urban area			
Per capita expenditures on roads, parking and traffic facilities			
Per capita crash costs (costs associated with accidents)			
Efficiet Pricing and Priortization (Roads/Parking/Insurance/Fuel etc)			
Per capita traffic congestion delay			
Quantity and quality of delivery services			
Quality of transport services for commercial users	1.00		
Mobility management (network that allows working of mobile phones) to address problems and increase transport system efficiency	0.53	1.00	
Density or Floor Area Ratio (F.A.R) (dwelling units allowed per unit of lot area)	0.55	0.49	1.00

B) Correlation Analysis for Social Criteria:

Criteria	Provision of basic public facilities (school, health care and sport facility)	Cultural preservation	Quality of transport facilities and services for disabled, elderly or children	Affordability - Portion of budget spent on transport by lower income households
Provision of basic public facilities (school, health care and sport facility)	1.00			
Cultural preservation	0.54	1.00		
Quality of transport facilities and services for disabled, elderly or children	0.58	0.71	1.00	
Affordability - Portion of budget spent on transport by lower income households	0.47	0.70	0.80	1.00
Driver Education and Behaviour	0.48	0.69	0.78	0.76
Community involvement in decision making	0.65	0.63	0.65	0.54
Convenience efficiency and safety of public transport users	0.36	0.37	0.67	0.46
Security against crimes	0.60	0.52	0.70	0.55
Portion of travel to school and other local destinations by walking and cycling	0.37	0.48	0.48	0.39
Road safety, capacity, traffic signal and street lighting	0.44	0.57	0.68	0.67
Convenience efficiency and safety of pedestrains	0.41	0.50	0.64	0.65
Per capita fatalities and injuries	0.66	0.40	0.45	0.21
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	0.25	0.70	0.58	0.69
Priorty signal system for the public transportation	0.54	0.46	0.49	0.52
GPS System	0.38	0.71	0.67	0.70
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	0.46	0.76	0.70	0.63
Availability of Street Furniture	0.53	0.47	0.66	0.55
Appearance of Pedestrian Routes	0.43	0.44	0.61	0.56
User rating	0.69	0.66	0.60	0.44
Dedicated Bus lane and stations (BRTS)	0.44	0.66	0.68	0.66
Inclusive planning to include disadvantaged and vulnerable groups	0.66	0.68	0.83	0.55
Vehicle Speed	0.36	0.70	0.60	0.55
Convenience efficiency and safety of drivers	0.56	0.63	0.80	0.56

Criteria	Driver Education and Behaviour	Community involvement in decision making	Convenience efficiency and safety of public transport users	Security against crimes	Portion of travel to school and other local destinations by walking and cycling
Provision of basic public facilities (school, health care and sport facility)					
Cultural preservation					
Quality of transport facilities and services for disabled, elderly or children					
Affordability - Portion of budget spent on transport by lower income households					
Driver Education and Behaviour	1.00				
Community involvement in decision making	0.70	1.00			
Convenience efficiency and safety of public transport users	0.61	0.72	1.00		
Security against crimes	0.70	0.78	0.72	1.00	
Portion of travel to school and other local destinations by walking and cycling	0.39	0.21	0.22	0.36	1.00
Road safety, capacity, traffic signal and street lighting	0.77	0.68	0.71	0.75	0.33
Convenience efficiency and safety of pedestrains	0.63	0.73	0.76	0.67	0.15
Per capita fatalities and injuries	0.31	0.68	0.42	0.59	0.07
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	0.56	0.39	0.38	0.36	0.48
Priorty signal system for the public transportation	0.70	0.58	0.48	0.63	0.45
GPS System	0.72	0.55	0.56	0.70	0.51
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	0.81	0.72	0.61	0.77	0.54
Availability of Street Furniture	0.58	0.69	0.76	0.81	0.40
Appearance of Pedestrian Routes	0.56	0.69	0.64	0.81	0.45
User rating	0.38	0.66	0.50	0.65	0.50
Dedicated Bus lane and stations (BRTS)	0.72	0.60	0.70	0.71	0.47
Inclusive planning to include disadvantaged and vulnerable groups	0.66	0.81	0.70	0.71	0.30
Vehicle Speed	0.75	0.57	0.62	0.59	0.39
Convenience efficiency and safety of drivers	0.66	0.83	0.85	0.84	0.37

Criteria	Road safety, capacity, traffic signal and street lighting	Convenience efficiency and safety of pedestrains	Per capita fatalities and injuries	Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)
Provision of basic public facilities (school, health care and sport facility)				
Cultural preservation				
Quality of transport facilities and services for disabled, elderly or children				
Affordability - Portion of budget spent on transport by lower income households				
Driver Education and Behaviour				
Community involvement in decision making				
Convenience efficiency and safety of public transport users				
Security against crimes				
Portion of travel to school and other local destinations by walking and cycling				
Road safety, capacity, traffic signal and street lighting	1.00			
Convenience efficiency and safety of pedestrains	0.68	1.00		
Per capita fatalities and injuries	0.37	0.35	1.00	
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)	0.61	0.48	0.15	1.00
Priorty signal system for the public transportation	0.72	0.33	0.25	0.34
GPS System	0.73	0.59	0.32	0.75
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	0.78	0.58	0.32	0.60
Availability of Street Furniture	0.68	0.67	0.47	0.53
Appearance of Pedestrian Routes	0.67	0.73	0.42	0.55
User rating	0.48	0.56	0.69	0.52
Dedicated Bus lane and stations (BRTS)	0.90	0.66	0.36	0.66
Inclusive planning to include disadvantaged and vulnerable groups	0.60	0.56	0.73	0.40
Vehicle Speed	0.72	0.56	0.23	0.59
Convenience efficiency and safety of drivers	0.70	0.76	0.57	0.50

Criteria	Priorty signal system for the public transportation	GPS System	Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	Availability of Street Furniture
Provision of basic public facilities (school, health care and sport facility)				
Cultural preservation				
Quality of transport facilities and services for disabled, elderly or children				
Affordability - Portion of budget spent on transport by lower income households				
Driver Education and Behaviour				
Community involvement in decision making				
Convenience efficiency and safety of public transport users				
Security against crimes				
Portion of travel to school and other local destinations by walking and cycling				
Road safety, capacity, traffic signal and street lighting				
Convenience efficiency and safety of pedestrains				
Per capita fatalities and injuries				
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)				
Priorty signal system for the public transportation	1.00			
GPS System	0.60	1.00		
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)	0.71	0.74	1.00	
Availability of Street Furniture	0.56	0.70	0.62	1.00
Appearance of Pedestrian Routes	0.44	0.66	0.67	0.80
User rating	0.30	0.66	0.54	0.62
Dedicated Bus lane and stations (BRTS)	0.68	0.77	0.82	0.69
Inclusive planning to include disadvantaged and vulnerable groups	0.45	0.50	0.65	0.66
Vehicle Speed	0.67	0.84	0.80	0.52
Convenience efficiency and safety of drivers	0.46	0.63	0.77	0.76

Criteria	Appearance of Pedestrian Routes	User rating	Dedicated Bus lane and stations (BRTS)	Inclusive planning to include disadvantaged and vulnerable groups	Vehicle Speed	Convenience efficiency and safety of drivers
Provision of basic public facilities (school, health care and sport facility)						
Cultural preservation						
Quality of transport facilities and services for disabled, elderly or children						
Affordability - Portion of budget spent on transport by lower income households						
Driver Education and Behaviour						
Community involvement in decision making						
Convenience efficiency and safety of public transport users						
Security against crimes						
Portion of travel to school and other local destinations by walking and cycling						
Road safety, capacity, traffic signal and street lighting						
Convenience efficiency and safety of pedestrains						
Per capita fatalities and injuries						
Quality of transport services and access for non-drivers, non-motorized vehicle paths (walking and cycling path conditions)						
Priorty signal system for the public transportation						
GPS System						
Intelligence Transport System (ITS) Technology (such as tracking exact time of arrival or departure of public transport vehicles)						
Availability of Street Furniture						
Appearance of Pedestrian Routes	1.00					
User rating	0.67	1.00				
Dedicated Bus lane and stations (BRTS)	0.62	0.52	1.00			
Inclusive planning to include disadvantaged and vulnerable groups	0.53	0.65	0.61	1.00		
Vehicle Speed	0.41	0.49	0.82	0.54	1.00	
Convenience efficiency and safety of drivers	0.78	0.73	0.68	0.81	0.59	1.00

C) Correlation Analysis for Environmental Criteria:

Criteria	Provision of Trees and Planters	Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.)	Noise Pollution - Portion of population exposed to high levels of traffic noise	Water Pollution - Per capita vehicle fluid losses	Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions
Provision of Trees and Planters	1.00				
Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.)	0.58	1.00			
Noise Pollution - Portion of population exposed to high levels of traffic noise	0.37	0.65	1.00		
Water Pollution - Per capita vehicle fluid losses	0.39	0.72	0.82	1.00	
Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions	0.53	0.76	0.74	0.76	1.00
Air Pollution - Frequency of air pollution standard violations	-0.64	-0.60	-0.44	-0.42	-0.31
Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilties	0.55	0.84	0.53	0.60	0.72
Alternate use of fuel	0.76	0.62	0.22	0.29	0.49
Habitat protection	0.55	0.73	0.34	0.48	0.49
Habitat fragmentation	0.49	0.72	0.35	0.38	0.38

Criteria	Air Pollution - Frequency of air pollution standard violations	Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilties	Alternate use of fuel	Habitat protection	Habitat fragmentation
Provision of Trees and Planters					
Per capita emissions of air pollutants (CO,VOC,Nox, particulates, etc.)					
Noise Pollution - Portion of population exposed to high levels of traffic noise					
Water Pollution - Per capita vehicle fluid losses					
Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions					
Air Pollution - Frequency of air pollution standard violations	1.00				
Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilties	-0.46	1.00			
Alternate use of fuel	-0.42	0.72	1.00		
Habitat protection	-0.47	0.73	0.65	1.00	
Habitat fragmentation	-0.52	0.63	0.50	0.85	1.00

Annexure –VII **Questionnaire: Part -I: Personal Information**

The following questionnaire is related to PhD research related to sustainable urban transport strategy

1. **NAME :** ……………………………………..
2. **Type of Organization**

   Type of field associated with (mark only one oval)

   ◯ Civil Engineering Department

   ◯ Transport Engineering Department

   ◯ Architecture and Planning Department

   ◯ Development Authority

   ◯ Others

3. **Field of Specialisation** *(Mark only one oval)*

   ◯ Urban planning

   ◯ Transport Engineering and planning

   ◯ Architecture

   ◯ Environment Engineering/Planning

   ◯ Construction

   ◯ Others

4. **Professional Work Experience** (*Mark only one oval)*

   ◯ Fresher

   ◯ Experience 0-5 years

   ◯ Experience 6-10 years

   ◯ > 10 years

5. **Academic Qualification** *(Mark only one oval*)

   ◯ Graduate

   ◯ Post Graduate

- Pursuing PhD
- PhD

6. **Designation** *(Mark only one oval)*
   - Student
   - Research Scholar
   - Asst./Asso. Professor
   - Architect
   - Town planner
   - Others

7. **Awareness on Sustainability***(Mark only one oval)*
   - Knowledge of various dimension of sustainability
   - Involvement in research related to sustainability
   - Experience in sustainability research project
   - No Knowledge

8. **Experience of using indicator related to sustainability of project**
   Yes No

9. **Location**

10. **Contact**

ANNEXURE – VIII

QUESTIONNAIRE-2 EVALUATION OF SUSTAINABLE TRANSPORT STRATEGY

Alternative Strategy- Enhancement of Public Transport

The following are the sub criteria for assessing the sustainability of alternate strategy in Dehradun city. Kindly rate the importance of following indicators with respect to each other according to your perception.

Name:

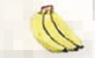
METHOD OF FILLING FORMS

Analytical Hierarchy Process (AHP)

AHP is the technique been used for the filling of questionnaire which is explained as follows along with the method to answer the questionnaire:

Example:Suppose there are 2 fruits and we have to decide which fruit is better than other and by how much.

Method : let us make a relative scale how the fruit on the left(apple) compared to the fruit on the right(banana).if you like apple better than banana kindly mark it 1,3,5,7,9 on left side.whe you favour banana more than apple the you mark on right side.

Apple 	If you think apple is better than banana than mark on left on 9 point scale while if you think banana is better than apple then mark on right side on 9 point.	Banana 

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremel y Preferred

Following represents the rating scale

Importance	Definition	Explanation
1	Equal importance	The two criteria are being compared are of equal importance to choosing a sustainable urban transport.
3	Moderate importance	Experience and judgments slightly favor one criterion over another.
5	Strong importance	Experience and judgments strongly favor one criterion over another
7	Very strong importance	A criteria is favored strongly over another
9	Overwhelmingly more important	The evidence favoring one criteria over another is the highest possible order of affirmation.
2,4,6,8	Intermediate values to represent the shades of judgments between the five basic assessment above	There may be times when experience and judgement may not render one criteria comparable to another in accordance with the five scale above instead a middle value between two scales may be more appropriate.

Apple

If you strongly preferred banana in comparison with apple the indicate as below

Banana

9	7	5	3	1	3	●	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Apple

If you Extremely preferred banana in comparison with apple the indicate as below

Banana

9	7	5	3	1	3	5	7	●
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Apple

If you equally preferred booth banana and apple then mark in the middle

Banana

9	7	5	3	●	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

IMPORTANCE OF CORE CRITERIA WITH RESPECT TO ALTERNATE STRATEGY

Economical effectiveness	Social sustainability	Environmental sustainability	Risk to sustainability

Rate the core criteria importance with respect to strategy

Economical effectiveness **Social sustainability**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Economical effectiveness **Environmental sustainability**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Economical effectiveness

Risk to sustainability

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Social sustainability **Environmental sustainability**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Social sustainability **Risk to sustainability**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Environmental sustainability **Risk to sustainability**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

ECONOMIC DESIGN SUB-CRITERIA

Eco 1	Eco 2	Eco 3	Eco 4	Eco 5
People's mobility and accessibility to efficient transportation modes	Affordability of transport systems for businesses	Quality of transport facilities and services	Transport incentives for taxpayers	Land use planning or Integrated transport systems planning for economic development of region

People's mobility and accessibility to efficient transportation modes

Affordability of transport systems for businesses

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

People's mobility and accessibility to efficient transportation modes

Quality of transport facilities and services

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

People's mobility and accessibility to efficient transportation modes

Affordability of transport systems for businesses

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

People's mobility and accessibility to efficient transportation modes	Land use planning or Integrated transport systems planning for economic development of region

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Affordability of transport systems for businesses	Quality of transport facilities and services

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Affordability of transport systems for businesses	Transport incentives for taxpayers

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Affordability of transport systems for businesses	Land use planning or Integrated transport systems planning for economic development of region

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

SOCIAL DESIGN SUB-CRITERIA

Soc 1	Soc 2	Soc 3	Soc 4	Soc 5
Provision of basic accessibilities(healthcare / education) and community involvement in decision making	Convenience efficiency for transport users by utilizing new technologies. i.e. ITS	Availability of diverse range of transportation modes(Walking/Cycling/ Ride sharing/Public Transportation etc.)	Safety and security of transport users	Inclusive planning to include disadvantaged and vulnerable groups

Soc 1	**Soc 2**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 1 **Soc 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 1 **Soc 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 1 **Soc 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 2 **Soc 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 2 **Soc 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 2 **Soc 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 3 **Soc 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 3 **Soc 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Soc 4 **Soc 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

ENVIRONMENTAL DESIGN SUB-CRITERIA

Env 1	Env 2	Env 3	Env 4	Env 5
Reduction of per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions such ass green house gases	Environment protection and control on account of transportation including air, water and land pollution	Resource efficiency - Non-renewable resource consumption in the production and use of vehicles and transport facilities	Use of alternative sources of energy to design sustainable transport systems	Preservation of natural habitat

Env 1 **Env 2**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 1 **Env 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 1 **Env 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 1 **Env 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 2 **Env 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 2 **Env 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 2 **Env 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 3 **Env 4**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 3 **Env 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Env 4 **Env 5**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

RISK DESIGN SUB-CRITERIA

Risk 1	Risk 2	Risk 3
Risks associated with the design & evaluation of sustainable transport systems	Risks associated with the implementation of sustainable solutions for the urban transport	Risks associated with the transport operational services

Risk 1 **Risk 2**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Risk 1 **Risk 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extreme y Preferre

Risk 2 **Risk 3**

9	7	5	3	1	3	5	7	9
Extremely Preferred	Very strongly preferred	Strongly Preferred	Moderately preferred	Equally Preferred	Moderately preferred	Strongly Preferred	Very strongly preferred	Extremely Preferred

Annexure IX : FUEL STATION SURVEY QUESTIONNAIRE

Date	:
Location	:

Questions		Responses	Remarks
Do you use this vehicle for private use or for commercial purposes (eg. as a taxi)?	(1) Private		
	(2) Commercial		
Vehicle Type	Type		
(Whether a; Car / Scooter (2 or 4stroke) / Motor-cycle (2 or 4stroke) / Moped	(2 or 4stroke) /		
Passenger Auto (2 or 4 stroke) / Vikram / Mini-bus / Big Bus / State Bus /			
What make is your engine of? (For eg. Ashok Leyland, Tata, Maruti etc.)			
In which year was your vehicle registered? (Registration year)			
Which fuel do you use in your vehicle?		*Petrol/ Diesel*	
How much mileage does your vehicle give (in Kms/Liter)?			
What is the maximum capacity of your vehicle?			
How many people normally travel in your vehicle?			
Fuel Consumption (within the city):	In Litres per month		
Fuel bill per month			
Total Number of Kms travelled per day (within the city limits)			

Annexure –X **USER PREFERENCE SURVEY QUESTIONNAIRE**

1. Mode of Travel Presently Used-

2W ☐ **3W-Auto** ☐ **3Wvikram** ☐ **Mini bus** ☐ **large bus** ☐ **Car** ☐

For the research a small stretch has beed selected to estimate the carbon emission reduction in various scenario.4 Scenario are been created to enhance the public transport in the city.

Scenario :1 Enhancement of public transport Buses

In this scenario public transport system is assumed to be enhanced in terms of its mobility comfort, convenience and frequency. The fare would be same for the transport.

Would you like to shift to proposed scenario?

Yes ☐ No ☐

Scenario :2 Introduction of CNG Buses

In this scenario Cleaner fuel CNG would be introduced for buses .it is more comfortable, safe and secure, reduces waiting and travel time. It reduces the air and noise pollution too.

Would you like to shift to proposed scenario?

Yes No

Scenario-3 Electric Auto Rickshaw and CNG 3 Wheeler (Vikram)

In this scenario 50% of battery operated E-rickshaw would be introduced on behalf of Auto and CNG would be introduce as alternative fuel for 3W(vikram).they are more environment friendly. And having good appearance.

Would you like to shift to proposed scenario?

Yes No

Scenario-4: introduction of PRT (Personal Rapid Transit)

PRT is an electric operated system ,is introduced at guided lanes from point to point destination.as it is on demand service so it is more safe secure and congestion free .Reduce travel time waiting time and pollution too.there would be no intermediate stops

Would you like to shift to proposed scenario?

Yes

No