INTEGRATED ENVIRONMENTAL STRATEGIES (IES) STUDY FOR CITY OF HYDERABAD, INDIA

Prepared by the Environment Protection Training and Research Institute (EPTRI)

April 2005

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EXECUTIVE SUMMARY

OF THE INTEGRATED ENVIRONMENTAL STRATEGIES (IES)

PROJECT IN HYDERABAD, INDIA:

CO-BENEFITS ANALYSIS OF THE HYDERABAD URBAN DEVELOPMENT AREA[1]

OVERVIEW

In 2002 the United States Environmental Protection Agency (USEPA) and the United States Agency for International Development (USAID) New Delhi Mission initiated the Integrated Environmental Strategies (IES) program in India to help Indian policymakers identify, evaluate, and eventually implement a variety of mitigation opportunities with local and global co-benefits. The Hyderabad-based project aimed to develop analytical tools and an analytical framework for quantifying greenhouse gas (GHG) and particulate matter (PM_{10}) emissions, and assessing the associated public health benefits from reducing local pollutant concentrations through integrated clean energy strategies. In addition to generating a first-ever emissions inventory of all reported combustion sources in the Hyderabad Urban Development Area (HUDA), the team quantified the emissions reductions from several clean-fuel mitigation scenarios. The IES team also:

- Prepared a greenhouse gas inventory of all reported fuel combustion sources in HUDA for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O);

[1] The Hyderabad Urban Development Area includes the Municipal Corporation of Hyderabad, 10 municipalities belonging to Ranga Reddy & Medak Districts, and an industrial growth area.

- Quantified the public health benefits of future mitigation scenarios, as measured by reductions in air pollution-based morbidity and mortality;
- Estimated the value of those human health benefits; and
- Compiled a cost/benefit analysis to estimate the financial implications of the different mitigation measures.

The project's overall goals were to hone in-country analytical skills for co-benefit analyses, conduct a thorough and technically defensible project, and raise awareness with public policy makers, the general public, and industry.

To complete the IES-India project, the team is currently working to raise awareness with the three main stakeholders influencing emissions in Hyderabad (policy makers, private industries, and the general public). The Hyderabad Air Campaign targets the general public, and strives to raise awareness within the Hyderabad citizenry. The Private Sector Outreach Campaign targets the industrial sector for energy efficiency improvements and overall emission reductions. Together, the Hyderabad Air Campaign and the Private Sector Outreach Campaign feed directly into the Policy Maker awareness effort. Additionally, policy makers meetings were held in the summer of 2004 to facilitate dialog between the technical teams and policy makers. The common goal of all three branches of the IES outreach program is to build support within key audiences for the implementation of cost-effective co-beneficial emission reduction measures.

Hyderabad is the fifth largest city in India with a population of 6.3 million in 2001. Hyderabad is also one of the fastest growing and most polluted cities in India. This study was the first IES co-benefits analysis conducted in the Indian sub-continent. The Environmental Protection Training and Research Institute (EPTRI) is the local technical leader for the IES project with the U.S. National Renewable Energy Laboratory (NREL) leading all of the technical and outreach components. NREL serves as USEPA's primary technical contractor for the IES program. With funding from USAID, together EPTRI, NREL, USEPA, and other technical experts prepared a thorough emissions inventory of 558 stationary sources, performed mobile source emissions modeling, conducted air quality and health effects modeling, developed several policy and transportation scenarios aimed to reduce future-year emissions, and evaluated the human health and economical impacts of the scenarios. The mobile and industrial sectors are the largest emission sources in Hyderabad; hence, these two source-categories were the initial focus of the IES project.

Pollutants of concern for this study were particulate matter less than 10 microns (PM_{10}), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The Andhra Pradesh Pollution Control Board (APPCB) supplied the IES technical team with calendar year 2001 industrial fuel-use data for 558 industrial combustion sources located within the Hyderabad Urban Development Area.[2] Unregistered small-scale industrial sources, open burning, re-entrained road dust, and air pollution transport from

[2] Data collected included industry name and address, boiler/ furnace stack height and diameter, control equipment details, boiler configuration and stand-by generator detail, fuel type used and quantity of fuel used for boilers and generators, and any stack test data.

regions outside of Hyderabad were not included in this iteration of the IES study.

Urban growth has brought traffic congestion and severe air quality problems to Hyderabad. With the population expected to grow to 13.6 million in 2020, air quality is expected to continue deteriorating unless mitigation measures are adopted. Historically, public transportation in Hyderabad has been strong, but public transit's predominance has been slipping in recent years due to issues relating to reliability, cost, and travel time. The two available types of public transportation are buses and metro-rail. In addition to buses, there are about 1.2 million registered private vehicles on Hyderabad's roads, with nearly 75% of those being two-wheelers, which are very high emitters of PM_{10} and hydrocarbons. If the current trends continue, there will be further decline in bus ridership, an increase in use of personal vehicles, an increase in traffic congestion, and an increase in emissions from the motor vehicle sector.

The study found that mobile source emissions are currently the largest sector of GHG and air pollutants in Hyderabad - approximately 63% of total emissions in 2001; increasing to 75% by 2021 under Business-as-Usual (BAU). The baseline and projected emissions for the mobile sector were based on population data gathered from the APPCB, vehicle counts, and a stated preference survey. The fleet composition inputs for the International Vehicle Emissions (IVE) model were based on fleet data gathered during a similar study in Pune, India. Emissions were calculated for two-wheelers, auto rickshaws, passenger vehicles, heavy-duty vehicles, and buses. The team calculated emissions by multiplying an estimated Indian-specific emission factor by the number of vehicle kilometers traveled (VKT) in each vehicle class.

Stationary sources also contribute to Hyderabad's greenhouse gas and PM_{10} emissions inventory, but to a much lesser extent. Only four percent of the 558 point sources could be considered major sources (greater than 10 tons per year) for PM_{10} emissions, additionally, all of the large sources are located outside of the city-center, the Municipal Corporation of Hyderabad. There are no power plants located within the boundaries of this study.

EPTRI and their health experts at the Institute for Health Systems (IHS) conducted a health impacts study of air pollution in Hyderabad. PM_{10} was selected as the primary ambient air pollutant for the health effects analysis due to the well documented concentration-response functions. Four main age groups were considered: Children: 0-17 years, Adults: 18-64 years, Elderly: 65 +, and the aggregate of all age groups. Data on all cause-specific deaths, from non-external causes, excluding trauma deaths, for the year 2001 were obtained from the Directorate of Health/ Municipal Health Offices. Morbidity data was collected from individual health care institutions. Hospital and clinical morbidity data was the most difficult to collect due to lack of a centralized database and data availability. Data was collected from 28 out of a total of 68 institutions in Hyderabad and the surrounding area.

The magnitude of health impacts in relation to PM_{10} concentration was calculated using both a health risk assessment approach and percent increase of mortality or morbidity per unit increase of air pollutant concentration. IHS used the Air Pollution Health Effects Benefits Analysis Model (APHEBA) to evaluate the benefits and costs associated with change in atmospheric PM_{10} concentrations, both spatially and temporally. APHEBA is a tool that uses locally derived concentration-response functions to link annual average air pollutant concentrations with a specific health effect. Health effects experts at IHS used APHEBA to analyze the expected air pollution health impacts for different scenarios. The health effects analysis was conducted for BAU years 2001, 2011, and 2021 and for the four PM_{10} mitigation scenarios mentioned below.

Results

The following emission sectors and co-beneficial mitigation measures were analyzed. These mitigation measures were selected based on their environmental and public health merits, economic feasibility, and practicality of implementation. The sectors and scenarios analyzed are:

1. **Transport Sector** – More effective bus transit system including dedicated bus lanes, priority for buses at stoplights and intersections, route rationalization, and a transition to compressed natural gas-fueled (CNG) buses
2. **Industrial Sector** – Use of combined natural gas and biogas as a primary combustion fuel
3. **Industrial Sector –** Install cyclones on small boilers and require baghouses on all industrial boilers that emit greater than 10 tons of PM_{10} per year
4. **Industrial Sector** – Require the use of a fuel additive to improve heavy-oil combustion in oil-fired industrial boilers

Transportation scenario improvements showed the most substantial positive benefits in future morbidity and mortality estimations for Hyderabad residents. While morbidity and mortality would be reduced from PM_{10} concentrations in the other industrial mitigation scenarios, the transportation sector offers the greatest opportunity for human health improvements and greenhouse gas reductions. Implementing reduction measures within the transportation sector would prevent an estimated 2,000 to 20,000 deaths from long-term exposure to PM_{10} concentrations and 1,500 to 7,500 deaths from short-term exposure to PM_{10} concentration in 2011 and 2021 respectively. Hospital admissions are estimated to be reduced by 650 cases in 2011 and over 5,000 cases in 2021. The effective bus transit mitigation measures resulted in a 33% reduction of PM_{10} concentrations compared to BAU levels. The estimated annual monetary value of the health benefits from the avoided mortality of the effective bus/transit mitigation measures range from US $112 million in 2011 to US $1,208 million in 2021. The economic benefits of avoided cardiovascular and respiratory diseases from the effective bus/transit mitigation scenario range from US $10.1 million in 2011 to US $506 million in 2021.

TRANSPORTATION EMISSIONS REDUCTION OVER BAU SCENARIO WITH MORE EFFECTIVE BUS TRANSIT SYSTEM SCENARIO FOR STUDY AREA *(REDUCTION IN TONNES PER DAY)*		
	2011	**2021**
CO	327 (27%)	1410 (46%)
PM_{10}	4 (35%)	18 (55%)
CO_2	688 (13%)	3,792 (34%)
N_2O	-	0.03 (30%)
CH_4	24 (38%)	102 (59%)

***Figures in braces indicate the percentage reduction in emissions from the estimated daily total**

Stationary source emissions benefits are much smaller than the transportation sector due to the large volume of motorized vehicles plying on Hyderabad's roads. However, proper air quality planning requires the careful evaluation of emissions reductions across different sectors. In

Hyderabad, the stationary sources offer two different opportunities for low-cost PM_{10} and GHG emission reductions. The first low-cost opportunity is through implementing the measures identified by the IES analysis, these are cost-effective emission reduction measures that could be implemented with very little overhead expense. Measures would improve boiler combustion efficiency, reduce the absolute emissions rate, and help industries transition to cleaner fossil fuels or even renewable fuel sources (see the diagram below).

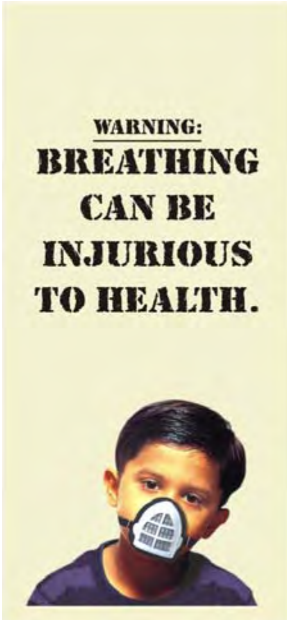
The second opportunity for stationary sources to reduce their emissions is through implementing the energy efficiency measures identified during the Industrial Sector Outreach Campaign energy audits. Implementing plant-wide energy efficiency measures reduces energy demand, which in turn reduces emissions from an on-site or grid-connected power source.

Stationary Source Emission Reduction Scenarios

Scenario	PM_{10} Reduction (tonnes per day) 2011	PM_{10} Reduction (tonnes per day) 2021	GHG Reduction (tonnes eCO_2 per day) 2011	GHG Reduction (tonnes eCO_2 per day) 2021	Cost of Implementation (in Million Rupees)
Fuel Additive	0.74	1.39	50.45	94.47	(43.40)
Control	1.66	3.09	---	----	20.44
Natural Gas	0.66	1.63	91.19	241.65	28.16
Biogas	0.50	1.64	266.47	770.03	Combined with NG

*Figures in red indicate a net financial benefit in implementation over the time-period

Outreach



Building on the technical findings of the IES analysis, outreach programs are being implemented to share the technical finding with industry and the general public.

The Industrial Sector Outreach Campaign is being run by the Confederation of Indian Industries (CII). This campaign has enlisted the voluntary support of approximately 25 businesses in Hyderabad which have undergone third-party energy audits. Each company has vowed to implement several no-cost/low-cost clean energy measures that were recommended during the free energy audit. Energy savings will result in both direct and indirect emission reductions. The most aggressive participants were publicly recognized with an "Energy Management Award 2004" at a ceremony in July 2004.

The general education program is titled the 'Hyderabad Air Campaign' and is being implemented by Winrock International-India. The general education campaign includes the development and distribution of strategic information that identifies the air pollution problem in Hyderabad and empowers the general public to take individual steps to reduce air pollution. Posters, bus backs, and fliers are being advertised and dispersed on all of the primary transportation arteries and bus routes in Hyderabad. Press events and activities that include school children are being held, aiming to improve mass transit ridership and encourage specific individual actions to reduce harmful emissions (see www.HyderabadAir.com for more details).

Future Work

As a result of the IES analysis and policy makers meetings held in June 2004, a number of follow-up steps were recommended, they include:

- Given the likelihood that a CNG infrastructure will develop in Hyderabad over the next decade, the IES team should conduct additional transportation modeling that includes the phasing-in of CNG buses.
- Incorporate additional sources of emissions such as re-entrained road dust, open burning, air pollution transport, etc. into the baseline emissions inventory - providing a more comprehensive picture of emissions.
- Track the results of the general education and private sector outreach efforts to determine social impact and attempt to quantify the benefits of these campaigns (i.e. emission benefits, financial benefits, and social benefits).

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PROJECT OVERVIEW

IES- INDIA PROJECT

HYDERABAD, INDIA.

1.0 IES- INDIA INTRODUCTION

United States Environmental Protection Agency (USEPA) and United States Agency for International Development (USAID) have initiated the Integrated Environmental Strategies (IES) analysis in India with support from Government of India and the State Government of Andhra Pradesh. Technical assistance is being provided by a team of international experts coordinated by the National Renewable Energy Laboratory (NREL). The IES analysis provides Indian policy makers with quantitative analyses and recommendations on how best to improve air quality reduce human health impacts, and reduce greenhouse gas emissions while meeting economic development objectives in the city of Hyderabad. Similar IES studies have been performed in a number of other countries, including Argentina, Brazil, Chile, Mexico, South Korea, China, and the Philippines.

1.1 OBJECTIVES

The objectives of this study are:

- To carry out Ambient Air Quality (AAQ) and Green House Gas (GHG) analysis for Hyderabad Urban Agglomeration (UA) covering major sectors contributing to air pollution, including the transportation and industrial sectors, and to assess the likely reduction in pollution and GHG levels due to various proposed mitigation measures.

- To assess the co-benefits and ancillary benefits of implementing air pollution and GHG mitigation measures.

- To carry out health effects analysis, economic valuation of health effects and cost/benefit analysis based on ambient air quality levels for business-as-usual and mitigation scenarios.

- To demonstrate that the results of the IES studies can enhance policy maker support for measures and technologies to reduce greenhouse gas emissions and improve public health by emissions reductions in conventional air pollutants.

1.2 PROJECT TEAM

Environment Protection Training and Research Institute (EPTRI) is in charge of the overall project coordination within India. The project director is the Director General, EPTRI. Mr. N.S. Vatcha, Senior Scientist, is the technical coordinator and Dr. V. Srinivas, Senior Faculty, performed the air quality modeling tasks. EPTRI is also responsible for the Ambient Air Quality Analysis, basic Greenhouse Gas (GHG) analysis, developing industrial mitigation scenarios as well as preparing the cost/benefit analysis. Health Effects Analysis and Economic Valuation of Health Effects were performed by a team headed by Dr. Satish Kumar of the Institute of Health Systems (IHS), located in Hyderabad. Transportation planning was performed by Rail India Technical Economic Services (RITES), a Government of India Enterprise, established in 1974 and based in New Delhi. Mr. Yash Sachdev is the task leader for the IES transportation study.

2.0 EMISSIONS INVENTORY

The industrial emissions inventory for the IES- India program was compiled for the Hyderabad Urban Development Area (HUDA) which covers the city of Hyderabad and parts of the surrounding districts of Ranga Reddy and Medak, covering approximately 1,850 sq. kms. Fuel usage data to estimate emissions was collected from five regional Andhra Pradesh Pollution Control Board (APPCB) offices with jurisdiction over the study area. The fuel used in the study area consists primarily of fuel oil, diesel, coal, wood and agricultural waste. The base year for this study was calendar year (CY) 2001.

2.1 DATA COLLECTION PROCESS

Data was collected for over 550 small, medium and large-scale combustion sources located within the study area. It should be noted that small-scale industries and area sources not registered with the APPCB were not included in this study. Data was collected from standardized APPCB air quality data forms completed by each industry and submitted to the appropriate PCB regional office for CY 2001. Data collected included industry name and address, boiler/furnace stack height and diameter, control equipment details, boiler heat rating and stand-by generator details (power rating), combustion fuel type and quantity of fuel combusted by boilers and generators, and boiler stack test data (when available). If the quantity of fuel burned by generators was not available this data gap was bridged by assuming that fuel use was the same as quantity combusted by similar sized generators in similar industrial applications. It should be noted that only fuel burning industries were covered by this industrial emissions study. Most often, combustion sources are the largest single emissions sector and contribute the largest volume of particulate matter and greenhouse gases to the atmosphere on a per-industry basis. This is the reason that the IES program initiated the analysis on the fuel combustion sector.

2.2 EMISSIONS ESTIMATION PROCESS

Particulate matter with a diameter equal to or less than ten microns (PM_{10}) was the primary ambient air pollutant of concern for this study. PM_{10} was selected as the pollutant of concern because of the strong correlation between PM_{10} and adverse health effects. Annual emissions of three greenhouse gases (GHGs) were also estimated: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). These three greenhouse gases are the primary anthropogenic contributors to global warming.

The data collected was input into an Excel spreadsheet. All fuel usage data was converted into annual fuel usage. It was assumed that all industries operated 24 hours/day with 10% annual downtime (ie.330 working days/year). Where stack test data was available, annual total suspended particulate matter (TSPM) emissions were calculated from the stack test data, and PM_{10} fractions were used to estimate PM_{10} emissions. When stack test data was not available, emission factors were used to estimate PM_{10} emissions from fuel usage. If control equipment was used, it was taken into account when estimating emissions. Control efficiencies were estimated conservatively due to lack of sufficient data on control equipment maintenance practices by industry in the study area. Transportation and industrial emissions were the only sectors included in this study due to resource limitations. Re-entrained road dust, air pollution transport from the agricultural regions, power plants and other urban areas were not included due to data and resource limitations. The

IES team acknowledges that these sources contribute to Hyderabad's compromised air quality, however, further research is needed in this area.

2.3 RESULTS

Annual PM $_{10}$ and GHG emissions were estimated for operating industries registered with the APPCB in the study area for CY 2001. The results of this study are shown below (refer to Table A below):

Table A: CY 2001 Annual Industrial Emissions Tons (metric)

Criteria Pollutant:	
PM_{10}	1,187 tons
Greenhouse Gases:	
CO_2	768, 816 tons CO_2
N_2O	4, 085 tons eCO_2
CH_4	26,389 tons eCO_2

Please refer to Annex A for detailed explanation of the IES- India Emissions Inventory methodology.

3.0 BASELINE MODELING

The transportation sector is the largest air pollution and greenhouse gas source in the study area with the industrial sector being the second largest. The transportation study for the IES-India program was done by RITES (refer to section 4.0 below). The required line sources data pertaining to vehicular emissions for CY 2001 was collected from the RITES report. The International Vehicle Emissions (IVE) Model developed by "College of Engineering-Center for Environmental Research and Technology (CE-CERT), University of California at Riverside" has been used for estimation of transportation emissions for various scenarios. The methodology for the industrial emissions inventory is described above. There are no large power generation plants within the study area, hence, this sector does not contribute to the total load in any significant way. However, there are small diesel generation sets and limited cogeneration in the study area, contributing to overall emissions.

Once the pollutants are emitted into the atmosphere, the dilution and dispersion of the discharged pollutants are affected by various meteorological parameters like wind speed and direction, ambient temperature, mixing height, etc. The Gaussian plume models are the model of choice for accurately calculating ground-level concentrations due to their simplicity in terms of input parameters and computational requirements. Considering the scarcity of data in Indian conditions, the Gaussian Plume Model (GPM) is recommended for air quality modeling exercise. The Industrial Source Complex (ISC3) model (developed by USEPA) is a steady-state Gaussian plume model, which can be used to assess pollutant concentrations from a wide variety of sources associated within the study area. The ISC3 dispersion model was designed to support the regulatory modeling options. One important feature of the ISC3 model is its ability to hand multiple sources such as point, volume, area, and open pit source types. Line sources may also be modeled as a string of volume sources or as elongated area sources. For the reasons listed above the ISC3 model was selected (by the project team) to carry out the modeling exercise in the study region. The emissions details from different sources such as industrial emissions and vehicular emissions and prevailing micro-meteorological conditions are taken as inputs to run this model.

The modeling output results show that the predicted air pollutant concentrations are not uniform throughout the city, and concentrations vary spatially. It may be observed that air pollution concentrations are high in some pockets of the city. The Air Quality Emissions modeling was performed for the baseline calendar year (CY) 2001, business-as-usual (BAU)-CY 2011 and BAU-CY 2021. The concentrations obtained in BAU-2021, are very high and alarming when compared with the Baseline-2001 and BAU-2011 concentrations. The high concentrations obtained in BAU-2021 are due to contribution of increased transportation emissions. For all three scenarios maximum concentrations are obtained for the Municipal Corporation of Hyderabad (MCH) area, which has a high vehicular population. For BAU-2021, Patancheruvu and Rajendranagar areas would be the most highly polluted areas after MCH, because of their vicinity to the air polluting industries.

Please refer to Annex B for detailed explanation of baseline modeling and thorough discussion of the results.

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4.0 TRANSPORTATION STUDY

4.1 INTRODUCTION

Hyderabad is the fifth largest metropolitan city in India. It is the capital and the largest city of the state of Andhra Pradesh. The city and the surrounding metropolitan area had a population of 6.3 million in 2001. Population is expected to be 13.6 million by the year 2020, i.e., double in 20 years. This growth has also brought with it air quality and traffic congestion problems. Traffic congestion, the predominance of two-stroke vehicles in the traffic mix, and the inability of public (bus) transport to attract significant ridership have all been blamed for the severe air quality problems in Hyderabad, especially the prevalence of respirable particulate matter (RSPM) as well as rapidly growing emissions of greenhouse gases (GHGs).

As part of the IES- India program, the USEPA has undertaken a study in Hyderabad, India, that attempts to investigate the air quality impacts of various specific transport measures. The scope of work for this study has following three components:

(a) Scenario for more effective bus transit service.
(b) Traffic management and measures to improve traffic flow.
(c) Technology/training measures relating to two-stroke vehicles.

The study area has encompassed the HUDA area. However as a part of the study component on "Traffic Management & Measures to Improve Traffic Flow", the following corridors have been considered individually.

(a) Sanathnagar to Nalgonda 'X' road

(b) Panjagutta to Secunderabad Retifile bus station

4.2 EXISTING TRANSPORT SCENARIO IN HYDERABAD

Various primary traffic and travel surveys were carried out to assess the traffic and travel characteristics in the study area as a part of this study. Data collected as a part of the study on Hyderabad Metropolitan Rapid Transit Study (MRTS) was also used. One of the special surveys conducted was Stated Preference (SP) Survey that was designed to gauge potential traveler response to the very characteristics that new systems such as more effective bus systems might introduce. The SP survey results have been used to assess the share of different modes in future for various policy options. The distribution of trips by mode of travel as per the surveys in 2003 is presented in the Table 1 below.

Table 1: Modal Split - 2003 in HUDA

S.No.	Mode	No of Trips/Day (Millions)	Percentage
1	Walk	2.47	30.2
2	Cycle	0.24	2.9
3	2 Wheeler	2.54	31.0
4	Car	0.18	2.1
5	Auto (3 seater)	0.41	5.0
6	7 Seater	0.06	0.7
7	Bus	2.26	27.6
8	Rail	0.02	0.2
9	Cycle Rickshaw	0.01	0.2
	TOTAL	**8.19**	**100.0**

Public transport usage in Hyderabad has historically been strong, but public transport's predominance has been slipping in recent years. There are about 1.2 million registered private vehicles in the city of Hyderabad, with about 75% of those being (predominantly 2-stroke) two-wheelers. The relatively low mode share of 3-seater and 7-seater auto rickshaws masks larger impacts on the urban system. Auto rickshaws in Hyderabad, like 2-wheelers, are powered by 2-stroke engines, and therefore are very high emitters of hydrocarbons and particulate matter. Moreover, the size, number, and aggressive driving style of auto-rickshaw operators exacerbate congestion and hinder the speed and reliability of other modes, particularly buses.

4.3 TRANSPORT DEMAND MODELING & FORECASTING

The Transportation Study Process consists of development of formulae or models, enabling future travel demand to be forecasted and alternative strategies for handling this demand to be assessed. It is not just one model, but a series of inter-linked and inter-related models of varying levels of complexity, dealing with travel demand. This has been done by developing the formulae to synthesize the present day movement patterns and adjusting the same until these represent observed conditions. Only when the models have been adjusted or calibrated, so that they can adequately predict the present day travel movements, are they used in true predictive mode to determine future conditions. The feedback loop technique has been used to assess the induced demand. Population and land-use distribution as proposed in Hyderabad Master Plan-2020 has been considered to estimate future transport demand using the transport models.

4.4 SCENARIOS FOR MORE EFFECTIVE PUBLIC TRANSIT SERVICE

4.4.1 Business-As-Usual (BAU) Scenario

If the prevailing scenario continues in future as well, it will lead to the following;

(i) Further decline in bus ridership
(ii) Increase in use of personalized vehicles such as motorized two wheelers and IPT modes such as auto rickshaws
(iii) Increase in traffic congestion on roads
(iv) Further decline in speeds of bus system which will lead to high travel time

(v) Higher vehicle kilometers by two wheelers, cars and auto rickshaws
(vi) Increase in emissions from all motor vehicles

The above BAU scenario has been constructed to the year 2021. Transport demand modeling exercise has been carried out to estimate transport demand that would be satisfied by various modes of transport such as motorized two wheelers, cars, auto rickshaws, buses and non-motorized transport to the year 2021 for BAU scenario using the calibrated and validated transport demand models. Mode-wise daily Vehicle Kilometers Traveled (VKT) for BAU scenario for base year (2003) and for horizon years 2011 and 2021 are presented in Table 2.

Table 2: Mode-Wise Daily Vehicle Kilometers for Entire Study Area : BAU Scenario (in thousands)

S. No	Mode	2003	2011	2021
1	Bus	695	942	1223
2	Auto Rickshaw	4500	5941	14799
3	Car	2542	3518	4851
4	2-Wheeler	13556	23273	30387
	Total	21293	33674	51260

4.4.2 Impact of More Effective Bus Transit Services

By providing dedicated bus lanes, properly designed bus stop/bays, priority for buses at signals, bus route rationalization, etc. will have direct impact on speeds of bus, which in turn will increase the reliability of bus and reduce the travel time. Due to this scenario, the bus speed will be higher and travel time in bus transport will decrease. Vehicle kilometers for this scenario have been worked out for the years 2011 and 2021 for the entire study area and are presented in Table 3.

Table 3: Mode-Wise Daily Vehicle Kilometers (More Effective Bus Transit Service Scenario) – Entire Study Area ***(in thousands)***

S No	Mode	2011	2021
1	Bus	1339	2184
2	Auto Rickshaw	2387	3939
3	Car	3380	4587
4	2-Wheeler	19139	25479
	Total	26244	36189

4.4.3 Multi-Modal Transport Service (MMTS) Scenario

Ministry of Railways and Government of Andhra Pradesh are jointly developing multi-modal commuter transport services in the twin cities (Hyderabad and Secunderabad). This is being done by upgrading the existing railway infrastructure along the corridors. Number of passenger trips that will be shifted to MMTS from various modes has been assessed based on transport demand model. The mode-wise vehicle kilometers have then been estimated for 2011 and 2021.

4.4.4 Vehicular Emissions

The vehicular emissions have been estimated by the IVE Model, which was developed by University of California at Riverside. The reduction in quantity over BAU and percentage of pollution reduction due to implementation of two scenarios are shown in following Tables 4 and 5. The table for bus scenario indicates that there are significant reductions in all pollutants. Similar analysis has also been performed for the nine major road corridors[1] in Hyderabad. Substantial reductions in emissions for these corridors are also expected due to 'More Effective Bus Transit Scenario'.

Table 4: Reduction in Emissions Due to More Effective Bus Transit Scenario in Entire Study Area over BAU (in Tons)

YEAR	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2011	327.20 (27)	8.71 (15)	0.15 (17)	4.26 (35)	688.05 (13)	0.00 (0)	23.55 (38)
2021	1410.40 (46)	36.75 (29)	0.82 (39)	17.96 (55)	3792.69 (34)	0.03 (30)	101.75 (59)

Table 5: Reduction in Emissions Due to MMTS Scenario in Entire Study Area over BAU (in Tons)

YEAR	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2011	16.07 (1.33)	1.94 (3.31)	0.01 (1.11)	0.30 (2.46)	110.01 (2.14)	0.00 (-)	1.04 (1.70)
2021	101.51 (3.33)	13.71 (10.70)	0.19 (9.13)	1.50 (4.61)	1147.87 (10.21)	0.03 (30.00)	5.98 (3.49)

(Note: figures in parenthesis indicate the percentage reduction)

Broad cost estimates for implementation of most effective public transit services were prepared based on the unit rates of the items as prevalent in the study area as per 2003 price level. The cost of upgrading facilities for the improved bus services of the entire HUDA area was estimated to be Rs. 760 million. Another Rs. 93 million per annum will need to be spent on maintenance of this additional infrastructure. This excludes the cost of road maintenance, which in any case is being borne by local agencies. This also does not include cost of additional buses that will be required for this scenario.

4.4.5 Traffic Management and Measures to Improve Traffic Flow

The aim of traffic management measures lies in achieving the best use of available transport infrastructure. Various traffic management measures have been proposed for improvement in traffic flow along the identified two corridors. Three scenarios have been developed for the identified corridors as mentioned below:

- Business As Usual Scenario (BAU) as explained above
- Flyover Scenario (for the corridor from Sanathnagar to Nalgonda 'X' Road)
- Good Engineering Practice (GEP) Scenario (Reduction of side friction, provision of foot path and synchronization of signals along with junction improvements)

4.4.6 Flyover Scenario

In Flyover scenario, length of about 12 km has been proposed from Sanathnagar to Nalgonda 'X' Road identified corridor with suitable number of up and down ramps. Accordingly the road network was updated with increased speed of public and private modes due to inclusion of flyover. Hence, Vehicle Kilometers Traveled (VKT) has been estimated. The reduction in emissions over BAU scenario is presented in Table 6. It was observed that VKT increases considerably on the corridor.

Although reduction in emissions is expected to be small in 2011, but there is a reasonable reduction for the year 2021.

Table 6: Reduction in Emissions Flyover from Sanatnagar to Nalgonda 'X' Road Over BAU Scenario

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	0.13 (0.20)	0.13 (3.80)	0.00 (-)	0.07 (8.00)	20.29 (6.50)	0.00 (-)	0.36 (8.00)
2	2021	33.41 (13.60)	1.47 (17.00)	0.04 (22.20)	0.58 (19.10)	175.48 (19.30)	0.00 (-)	2.87 (17.40)

(Note: figures in brackets indicate percentage reduction)

4.4.7 Reduction of Side Friction

The zig-zag parking, on-street parking, encroachments and presence of hawkers significantly reduce the effective carriageway width of roads. These factors directly affect the capacity of road. The reduction in vehicular emissions over BAU and corresponding percentage reductions in this scenario are presented in Tables 7 and 8.

Table 7: Reduction in Emissions- Reduction of Side Friction Over BAU Scenario Sanathnagar to Nalgonda 'X' Road Corridor

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	14.97 (20)	1.03 (30)	0.01 (20)	0.23 (26)	80.99 (26)	0.00 (-)	1.11 (25)
2	2021	125.29 (51)	4.92 (57)	0.10 (56)	1.72 (57)	511.10 (56)	0.00 (-)	9.11 (55)

Note: figures in brackets indicate percentage reduction

Table 8: Reduction In Emissions- Reduction of Side Friction Over BAU Scenario Panjagutta To Secunderabad Corridor

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	0.95 (4)	0.04 (4)	0.00 (-)	0.01 (4)	4.99 (5)	0.00 (-)	0.06 (4)
2	2021	9.68 (19)	0.42 (26)	0.00 (-)	0.14 (25)	38.31 (24)	0.00 (-)	0.75 (24)

Note: figures in brackets indicate percentage reduction

Here it can be seen that emissions are substantially reduced due to traffic management improvements.

4.4.8 Separation of Vulnerable Road Users (Provision of Footpath)

The intermixing of vehicles and pedestrian movements in the absence of footpaths results in reduced speeds and increase in number of accidents. The provision of footpaths and pedestrian crossings and can reduce these conflicts to a great extent and increase the average speed. The reduction in vehicular emissions over BAU and corresponding percentage reductions in this scenario are presented in Tables 9 and 10.

Table 9: Reduction in Emissions from Separation of Vulnerable Road Users Over BAU Scenario : Sanatnagar to Nalgonda 'X' Road

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	14.34 (19)	1.00 (29)	0.01 (20)	0.23 (26)	77.94 (25)	0.00 (-)	1.08 (24)
2	2021	116.70 (47)	4.60 (53)	0.10 (56)	1.61 (53)	475.49 (52)	0.00 (-)	8.51 (52)

Note: figures in brackets indicate percentage reduction

Table 10: Reduction in Emissions from Separation of Vulnerable Road Users Over BAU Scenario : Panjagutta to Secunderabad

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	0.94 (4)	0.05 (5)	0.00 (-)	0.01 (4)	5.01 (50)	0.00 (-)	0.06 (4)
2	2021	8.63 (17)	0.38 (23)	0.00 (-)	0.13 (23)	33.89 (21)	0.00 (-)	0.67 (21)

Note: figures in brackets indicate percentage reduction

The above tables indicate that this low cost traffic improvement measure can bring out substantial reduction in emissions.

4.4.9 Synchronization of Traffic Signals Along With Junction Improvements to Reduce Intersection Delays

In this study, signal coordination exercise has been done by TRANSYT 11 version (Traffic Network Study Tool) developed by TRL, UK. The junction improvements like proper signage, zebra crossings, stop line, removal of encroachment, provision of channelisers for free left traffic movement, etc increase intersection capacity and reduce delays at the intersections. The reduction in vehicular emissions over BAU and corresponding percentage reductions in this scenario is presented in Table 11.

Table 11: Reduction in Emissions Due To Signal Coordination/Junction Improvements over BAU Scenario

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2003	6.94 (15.78)	0.52 (21.22)	0.01 (20.00)	0.07 (15.22)	52.54 (23.26)	0.00 (-)	0.37 (16.44)
2	2011	13.82 (18.00)	0.72 (21.00)	0.01 (20.00)	0.17 (20.00)	71.51 (23.00)	0.00 (-)	0.87 (19.00)
3	2021	50.28 (20.00)	1.88 (22.00)	0.04 (22.00)	0.65 (21.00)	208.92 (23.00)	0.00 (-)	3.51 (21.00)

Note: figures in brackets indicate percentage reduction

Cost of Traffic Management Measures for Sanatnagar to Nalgonda 'x' road corridor and Panjagutta to Secunderabad corridor are Rs. 60 Millions & Rs.40 Millions respectively. The Flyover from Sanathnagar to Nalgonda X road is expected to cost Rs. 2,688 million.

4.4.10 Vehicle Technology/Training Measures Related To Two-Stroke Vehicles

Hyderabad has a large number of 2-wheelers, many of which are powered by 2-stroke engines. All 3-wheelers in Hyderabad are with 2-stroke engines. In addition, the motor fuels are often blended with lesser quality fuels or otherwise adulterated in order to save cost, which further increases emission levels. As a result, 2 stroke two or three wheelers in Hyderabad contribute quite disproportionately to air quality problems. In addition, the drivers of two wheelers and auto rickshaws also add to the air pollution with their inconsistent driving habits.

Emission loads of these 2 stroke vehicles can be reduced by better vehicle maintenance and operations. Better maintenance practices will include better engine tuning, better lubricant etc. Better operations of the vehicle will include improved driving styles such as driving in steady speed instead of driving very fast and very slow by changing gears frequently, switching off engine at signalized junctions, not keeping the foot always on the gear etc. These training programs could be organized by targeting various groups.

Discussions with The Energy Research Institute (TERI) officials regarding the extent of emissions reductions through these measures have revealed that these measures can reduce emission levels by 10% to 30%. However on a conservative side, reduction of emissions by 10% over BAU scenario for 2-stroke vehicles has been assumed in this study. Penetration rate of 5% for 2-stroke two wheeler drivers by 2011 and additional 8% by 2021 for the training programs has been assumed. It may be easier to bring in 3-wheeler drivers to these training programs through their unions/associations. Therefore a penetration rate of about 8% of 2-stroke three wheeler drivers by 2011 and additional 12% by 2021 for these training programs has been assumed. Assuming above reduction in emissions in 2-stroke vehicles and their penetration rates, over all reduction in emissions has been worked out for the year 2011 and 2021.

The reduction in daily emissions due to maintenance and operation (M&O) training programs over BAU is presented in Table 12.

Table 12: Reduction in Daily Emissions due to M & O Training Programs for 2-Stroke Vehicles

YEAR	REDUCTION IN EMISSIONS PER DAY IN TONNES							
	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4	TOTAL
2011	5.98	0.07	0.00	0.06	9.38	0.00	0.37	**15.85**
2021	43.43	0.48	0.02	0.47	70.01	0.00	2.89	**117.30**

Cost of M & O training programs for 2-stroke vehicles operators is estimated as Rs. 2.19 millions by 2011 and Rs. 8.14 millions by 2021.

4.5 RECOMMENDATIONS OF TRANSPORTATION STUDY

- Improved bus transit can attract traffic from modes such as 2 and 3 wheelers and cars and can reduce vehicular emissions significantly. Therefore, more effective bus transit services should be provided in Hyderabad.

- Traffic management and measures such as removal of side friction, segregation of vehicular and pedestrian traffic and synchronization of traffic signals should be implemented on all the corridors wherever they are feasible. These measures do not cost much and are very effective in reducing vehicular emission levels. Although long flyovers with numerous ramps attract higher traffic as compared to BAU scenario, they can still reduce emissions.

- Training programs and publicity for better maintenance of vehicle and proper driving habits for 2-stroke vehicle drivers should be carried out regularly.

Please refer to Annex C for further details of the IES-India transportation analysis.

5.0 MITIGATION OF PM_{10} AND GHG FROM ALTERNATIVE INDUSTRIAL SCENARIOS

Alternative industrial scenarios have been proposed for reduction of particulate matter less than 10 microns in diameter (PM_{10}) and greenhouse gas (GHG) emissions in the Hyderabad Urban Development Area (HUDA). These scenarios have been selected based on relevance and acceptability to study area, as well as having maximum impacts on pollutant reductions. The following is the list of the four alternative industrial mitigation scenarios proposed for the IES- India program.

- Use of additives to improve combustion for heavy fuel oils (furnace oil) in oil fired boilers.
- Particulate controls to be made mandatory for all existing uncontrolled, solid-fuel (coal, wood and agricultural waste) fired boilers. For existing coal, wood and agricultural waste fired boiler with particulate emissions below 10 tons per year (tpy), cyclone controls will be assumed. For existing particulate emissions above 10 tpy, baghouse (fabric filter) controls will be assumed.
- Introducing use of natural gas as primary fuel for industry.
- Use of renewable energy for industry.

These four scenarios were selected because they can be readily implemented and are cost effective solutions to pollution reduction in the Indian context. The Andhra Pradesh Pollution Control Board (APPCB) is currently promoting cleaner production/waste minimization for industries. These mitigation measures could be part of this promotion.

5.1 METHODOLOGY

The industrial database for base year CY 2001 was used as the starting point. It was assumed that the industrial growth rate up to CY 2021 would be 6.5% per annum (source: Confederation of Indian Industry, Hyderabad). It was assumed that industrial fuel use would increase by the same amount. Using this compounded growth rate, the increase in fuel used would be 188% by CY 2011 and 352% by CY 2021. For each scenario, the fuel usage in CY 2001 was multiplied by these percentages to estimate fuel usage in CY 2011 and CY2021, respectively. The PM_{10} and GHGs from the alternative industrial mitigation scenarios were estimated for CY 2011 and 2021 and compared to BAU emissions for CY 2011 and CY 2021, respectively. The tons of PM_{10} and GHG mitigated (reduced) were then estimated for each scenario (results are shown in Table 13 below).

Table 13: PM_{10} and GHG Mitigation for Industrial Mitigation Scenarios

Industrial Mitigation Scenarios	PM_{10} Mitigation (tons PM_{10})		GHG Mitigation (tons eCO_2)	
	(CY2011)	(CY2021)	(CY2011)	(CY2021)
Fuel Additive Scenario	272	509	18,416	34,481
Particulate Control Scenario	605	1128	----	----
Natural Gas (NG) Scenario	241	594	33,283	88,201
Biogas Scenario (BG)	184	598	97,260	281,062
Combined (NG + BG) Scenario	425	1,192	130,543	369,263

It can be seen that there are significant reductions of PM_{10} and GHGs for each mitigation scenario when compared to the BAU scenario. The combined "NG+BG" mitigation scenario gives the largest PM_{10} and GHG reductions. Please refer to Annex D for further details of IES Industrial Mitigation Scenarios.

6.0 Mitigation Scenarios Modeling

The emissions from transport and industrial sectors for base year (CY 2001) are used as the base emissions in the study area. The methodology for the industrial mitigation scenarios is described above.

Air Quality Modeling was carried out for BAU-2011 with the four selected alternative mitigation scenarios (industrial and transportation). The transport emissions estimated with feedback loop methodology are considered for the present study. The same procedure was adopted for

BAU-2021 with alternative mitigation scenarios. The following are the selected four alternative mitigations scenarios.

1) C1-Transport Sector- More Effective Bus Transit System
2) C2-Industrial Sector- Combined natural gas (NG) and biogas (BG) Scenario
3) C3-Industrial Sector- Fuel Additive Scenario
4) C4-Industrial Sector- Particulate Control Scenario

The results of the AQM exercise with mitigation scenarios show that Effective Bus Transit mitigation scenario is the most effective scenario, as compared to the other scenarios, in reducing the particulate (PM_{10}) emissions. With Bus Transit scenario, ambient pollutant concentrations are reduced by about 1/3 of corresponding BAU levels. Industrial mitigation scenarios are not significant in MCH area, but they are significant in reduction of ground-level concentrations (GLCs) in some industrial areas, such as Rajendranagar, Gaddiannaram, Patancheruvu, and Qutbullapur etc. Please refer to table 14 below for modeled PM_{10} concentrations for baseline and mitigation scenarios for each municipality in the study area:

Table 14: PM_{10} Concentrations for Baseline (BAU) and Mitigation Scenarios ($\mu g/m^3$)

Locality	Base			C1 Alternative - Transport -Bus Transit Mitigation Scenario		C2 Combined Industrial (NG+BG) Mitigation Scenario		C3 Industrial (Fuel Additives) Mitigation Scenario		C4 Industrial Control Mitigation Scenario	
	2001	**2011**	**2021**	**2011**	**2021**	**2011**	**2021**	**2011**	**2021**	**2011**	**2021**
HYDERABAD (MCH)	160	420	1010	260	490	420	1009	420	1009	420	1009
RAJENDRANAGAR	30	120	360	50	50	119	219	99	246	109	244
LB NAGAR	70	130	310	70	100	120	260	130	260	120	260
MALKAJGIRI	20	50	60	30	40	40	110	50	110	40	60
ALWAL	60	140	285	70	90	130	285	120	285	130	285
QUTHBULLAPUR	80	220	560	110	180	210	510	210	485	210	510
SERILINGAMPALLY	30	70	210	40	60	70	210	70	210	80	210
GADDIANARAM	70	230	310	100	140	170	310	170	310	180	310
UPPAL KALAN	40	110	260	60	100	100	260	110	260	110	260
KAPRA	20	70	110	30	40	40	110	50	110	40	110
KUKATPALLY	30	70	210	40	60	70	185	70	210	70	210
PATANCHERU	90	190	560	100	180	140	485	190	535	190	535
GHATKESAR	30	50	160	40	50	40	135	40	160	40	160

Please refer to Annex E for details of Mitigation Scenarios Modeling.

7.0 HEALTH BENEFITS STUDY

7.1 INTRODUCTION

Adverse health effects attributable to air pollution are an important public health problem in Hyderabad, India, and throughout the world. Air pollutants such as particulate matter have damaging effects on human health. Estimates of the health damages associated with air pollution, namely particulate matter concentrations, are required to assess the size of the problem and to evaluate the impact of specific pollution control measures.

Worldwide, the World Health Organization (WHO) estimates that as many as 1.4 billion urban residents breathe air exceeding the WHO air guidelines[3]. On a global basis, an estimated 800,000 people die prematurely from illnesses caused by air pollution. Approximately 150,000 of these deaths are estimated to occur in South Asia alone[4]. Air pollution has also been associated with a variety of cardio-pulmonary illnesses. In India, millions of people breathe air with high concentration of pollutants. This leads to a greater incidence of associated health effects in the population manifested in the form of sub-clinical effects, impaired pulmonary functions, increased use of medications, reduced physical performance, frequent medical consultations and hospital admissions.

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[3] World Health Organization (1997). Health and Environment in Sustainable Development: Five years After the Earth summit. Geneva: World Health Organization.

[4] A. Cohen, R. Anderson, B. Ostro, K.D. Pandey, M. Kryzanowski, N. Kunzli, K. Gutschmidt, A. Pope, I. Romieu, J. Samet and K. Smith. (2003). Mortality Impacts of Air Pollution in the Urban Environment. In M. Ezzati, A.D. Lopez, A.D. Rodgers and C.J.L. Murray, ed., Comparative Quantification of Health Risks: Global and Regional Burden of Diseases due to Selected Major Risk Factors. Geneva: World Health Organization.

The health effects analysis for the Integrated Environmental Strategies (IES) Program was carried out in the Hyderabad Urban Development Area (HUDA). The IES health effects study aimed at developing an initial estimation of the health impacts of air pollution in Hyderabad, based on available secondary data and ambient air quality modeling. Since PM_{10} is most strongly associated and documented with respiratory morbidity and premature mortality, it was identified by the IES team as the criteria pollutant for health effects analysis in Hyderabad. The base year for the health effects analysis was Calendar Year (CY) 2001.

The endpoints considered for the studies are as follows: mortality, hospital admissions for respiratory symptoms (RSP), hospital admissions for cardiovascular diseases (CVD), hospital admissions for chronic obstructive pulmonary disease (COPD), and hospital admissions for asthma.

7.2 DATA COLLECTION PROCESS

7.2.1 Population Data

Age-wise and sex-wise population data of the study area were obtained from the Census of India 2001.

7. 2.2 Mortality Data

Data on all cause and cause specific deaths, age and sex-wise for the year 2001 were obtained from the Directorate of Health / Municipal Health Offices falling under the MCH area and 10 municipalities of Ranga Reddy Districts.

7.2.3 Morbidity Data

Cause-specific morbidity data for the selected health endpoints were collected from Health Care Institutions (HCI) selected using APHIDB (Andhra Pradesh Health Institutions Database) an electronic database maintained by IHS. The selection of hospitals was done to be representative of the study area. **Initial survey of all major hospitals and health posts within the study area revealed that record keeping, particularly with respect to retrospective data was very poor.** Hence, data was collected from only 28 hospitals out of total 68 hospitals visited in and around HUDA area, based on availability of medical records. Four age groups were defined for the health effects analysis which are as follows: Children: 0 to 17 yrs; Adults: 18 to 64 yrs; Elder: Greater than 65 yrs.; All: All ages (the whole population).

Table 15 presents the total number of mortality/morbidity cases for all localities for the base and projection years:

Table 15: Total Number of Mortality/Morbidity Cases

End points *	All Population			Elder		
	2001	2011	2021	2001	2011	2021
Mortality	19,702	28,035	49,625	6,006	8,107	12,052
Hosp Adm CVD (ICD 390-429)	6,500	8,676	13,007	1,324	1,742	2,513
Hosp Adm RSP (ICD 460-519)	5,188	6,691	9,957	670	973	1,518
Hosp Adm COPD (ICD 490-496)	2,128	2,745	4,072	134	170	229

* Refer to Annex F for details of End Points.

7.3 CONCENTRATION-RESPONSE FUNCTIONS

Concentration-Response (C-R) functions are one of the most critical areas. Unfortunately, there are very few air pollution C-R studies conducted in India. However, a recent meta-analysis has been conducted on Asian studies[5]. The results of the meta-analysis give a beta of 0.0004 and a standard deviation of 0.00008 for all cause mortality. These were used in the IES health effects analysis. For the other endpoints, C-R functions were used with the following relative risks (refer to Table 16 below):

Table 16: Concentration – Response Functions

Endpoints *	All	Children	Adult	Elder
Mortality (long-term exp)	3.40%	-	-	-
Mortality All	0.40%	4.00%	-	-
Hosp Adm CVD (ICD 390-429)	2.30%	-	-	1.20%
Hosp Adm RSP (ICD 460-519)	0.02%	-	-	1.70%
Hosp Adm COPD (ID 490-496)	-	-	-	2.6%

*Refer to Annex F for details of End Points.

7.4 HEALTH EFFECTS QUANTIFICATIONS

The magnitude of health impacts in relation to PM_{10} exposure was calculated using both a health risk assessment approach and percent increase of mortality or morbidity per unit increase of air pollutant concentration.

Since most of the epidemiological studies linking air pollution and health endpoints are based on a relative risk model in the form of Poisson regression, the number of health effects at a given concentration C, is given by the following equation:

[5] HEI International Scientific Oversight Committee (2004). Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Boston, MA, Health Effects Institute. Available at http://www.healtheffects.org/Pubs/SpecialReport15.pdf

$$\text{Effects (C)} = \exp(\beta \times (C - C_0)) \times R_0 \times \text{Pop}$$

In the above Equation, β is the slope of the CR function, C and C_0 are concentrations of the air pollutants in one specific scenario and baseline scenario respectively, R_0 refers to the base rate of effects at concentration C_0, and *Pop* is the exposed population.

7.4.1 APHEBA Model

The Air Pollution Health Effects Benefits Analysis (APHEBA) Model was selected for the health effect analysis component of the IES - India Project. The APHEBA model is an integrated assessment model designed to evaluate the benefits or costs associated with changes in atmospheric pollutant concentrations in a given location and time period. It allows comparison of a base case and study case for a selected pollutant. It is an object oriented health effects modeling language developed by Dr. Luis Cifuentes of P. Catholic University of Chile. It incorporates uncertainty propagation and analysis through Monte Carlo Simulation. APHEBA makes it possible to manage complex multidimensional objects as simple objects. The Model also enables easy visualization of results by scenarios, using different metrics. Progressive refinement of the model is possible by defining interconnecting models.

The health effects analysis was conducted for Business as Usual (BAU) years: 2001, 2011, 2021 and four identified alternative mitigation scenarios. The scenarios considered are given in table 17 below:

Table 17: Alternative Mitigation Scenarios

Scenario		Definition
Base	Base Case	BAU for years 2001, 2011, 2021
C1	Control 1	Alternative – Transport – Bus Transit Mitigation Scenario
C2	Control 2	Combined Industrial (NG+BG) Mitigation Scenario
C3	Control 3	Industrial (Fuel Additives) Mitigation Scenario
C4	Control 4	Industrial Control Mitigation Scenario

7.5 RESULTS

7.5.1 Change in Health Effects

The change in health effects is computed using the formula based on the Poisson C-R functions. The excess cases in each scenario with respect base case scenario are computed based on the change of population exposure levels to PM_{10} under each scenario, C-R functions, and baseline rates for the health outcomes.

The change in health effects by scenarios is presented in table 18:

Table 18: Change in Health Effects by Scenarios

(a) All Population								
End point	**2011**				**2021**			
	C1	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure)	3,699	90	49	65	21,552	847	845	780
Mortality (short - term exposure)	1,469	34	19	25	7,544	284	314	271
Hosp Adm CVD (ICD 390-429)	2,320	304	196	173	17,401	821	683	582
Hosp Adm RSP (ICD 460-519)	56	13	9	8	181	20	14	16
Hosp Adm COPD (ICD 490-496)	0	0	0	0	0	0	0	0
(b) Elder Population								
End point	**2011**				**2021**			
	C1	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure	771	28	17	20	4052	179	161	163
Mortality (short - term exposure	0	0	0	0	0	0	0	0
Hosp Adm CVD (ICD 390-429)	301	27	14	13	1922	90	77	68
Hosp Adm RSP (ICD 460-519)	278	43	39	28	2553	471	360	357
Hosp Adm COPD (ICD 490-496)	70	15	7	6	667	46	24	22

The transportation sector is the largest contributor to air emissions (approx. 70% of the total load) in Hyderabad. The **C1** Scenario (i.e., Alternative-Transport-Bus Transit-Mitigation Scenario) resulted in, $1/3^{rd}$ reduction of PM_{10} concentrations compared to BAU levels, and the most significant decreases in mortality and occurrence of CVD and other respiratory diseases. Implementation of effective bus transit mitigation measure in Hyderabad would prevent **3,699** long-term deaths, **1,469** short-term deaths, **2,320** cardiovascular hospital admissions in 2011 and **21,552** long-term deaths, **7,544** short-term deaths, and **17,401** cardiovascular hospital admissions in 2021.

7.5.2 Benefits Calculations

Valuation of health effects is a crucial component in assessing the social costs of air pollution, because valuation allows the performance of cost-benefit analysis of pollution control measures and provides a basis for setting priorities for actions. In order to perform the economic valuation of health effects of air pollution, the unit cost of valuation to translate health impacts into economic values should be known. Benefits were computed using values derived from local data and values transferred from the USA.

Human Capital Approach (HCA) was followed for mortality valuation. Premature deaths were valued using the value of a statistical life (VSL), which is estimated as the discounted value of expected future income at the average age. The VSL was computed using a life expectancy at birth of 62.5 years, and an average age of the population of 27.5 years. The average annual wage considered was US$357.55 using an annual discount rate of 5%. The VSL for Hyderabad was estimated at US$ 6, 212. There are no Indian studies of Willingness to Pay (WTP) to reduce risks of death. Therefore, the US values were transferred to India. The current value used in the US is US$5.5M. The annual per capita income for USA is US$ 35,060. For India the per capita income (PCI) is US$ 480, while expressed in purchase power parity (PPP) it is US$2570[6]. Although the value computed for India is US$357, the World Bank figure was used, since it is consistent with the figure for the US. The following table shows the VSL values (US $ per case) transferred from USA to India for the present analysis (refer to Table 19).

Table 19: VSL Values (US $)

Income Type	USA	India	Eta = 0	Eta = 0.4	Eta = 1.0
PPP	35,060	2,570	5,500,000	1,933,798	403,166
PCI	35,060	357	5,500,000	878,562	56,090
Eta = Income Elasticity					

The Cost of Illness (COI) Approach was used for valuing morbidity. The unit values for morbidity endpoints derived locally for Hyderabad for the base year 2001(US$ per case) is given below (see Table 20):

Table 20: Unit Value for Morbidity Endpoints (US $)

Endpoint	Age Group	Type of value	
		Medical Costs	Lost Productivity
Hosp Adm COPD	All	122.23	14.30
Hosp Adm CVD (ICD 390-429)	All	119.22	11.44
Hosp Adm RSP (ICD 460-519)	All	74.76	12.87
Hosp Adm Asthma (ICD 493)	All	87.31	10.01
OP Visits IM	All	8.26	1.43

[6] World Development Report, 2002. Building Institutions for Markets. The World Bank. Washington, D.C. www.worldbank.org

7.5.3 Benefits estimation

Tables 21 presents the total benefits by endpoint in Millions of US$ per year, for two transfer scenarios: using PPP and Elasticity (Eta)=0.4, and using PCI and Eta = 1.0. These two scenarios are the upper and lower bound values of benefits. The values shown are the total values, i.e. COI and WTP (refer to Table 21).

Table 21 Total Benefits by Endpoint, COI plus WTP (Millions of US$ per year)

(a) PCI and 1.0								
End point	**2011**				**2021**			
Mortality (long-term exposure)	**C1**	**C2**	**C2**	**C4**	**C1**	**C2**	**C3**	**C4**
	207.46	5.02	2.77	3.66	1,208.9	47.53	47.40	43.73
Mortality (short – term exposure)	82.41	1.92	1.06	1.407	423.15	15.94	17.62	15.21
Hosp Adm CVD (ICD 390-429)	0.303	0.04	0.026	0.023	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.042	0.006	0.006	0.004	0.378	0.079	0.062	0.061
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.001	0.0009	0.0911	0.0063	0.0033	0.003

(b) PPP and 0.4								
End point	**2011**				**2021**			
	C1	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure)	7,152.3	173.1	95.5	126.2	41,678	1,639	1,634	1,508
Mortality (short term exposure)	2,841.0	66.2	36.4	48.2	14,589	550	608	524
Hosp Adm CVD (ICD 390-429)	0.3032	0.0397	0.0256	0.0230	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.0420	0.006	0.0061	0.0044	0.3776	0.079	0.0619	0.0613
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.0010	0.0009	0.0911	0.0063	0.0033	0.0030

The estimated annual health benefits from changes in air pollution in terms of deaths (long-term mortality) avoided from effective bus transit mitigation measures (C1 Scenario), range from US$ 207 million in 2011 to US$ 1209 million in 2021. The economic benefits of the cardiovascular and other respiratory diseases avoided from the C1 Scenario ranges from US$ 0.0096 million in 2011 to US$ 2.27 million in 2021. The transportation sector was recognized as an area where significant air quality and health benefits could be realized through the IES-India analysis.

Please refer to Annex F for further details of IES-India Health Benefits Study.

8.0 Cost Benefit Analysis

For the Cost-Benefit Analyses (CBA), the bus transit scenario and the three industrial scenarios were considered. The bus transit scenario (C1) is expected to make bus travel faster on selected corridors, and will induce/shift passengers from other less public modes of transport to that of bus travel. The expected cost of constructing a more effective bus transit system has been estimated to be Rs. 698 Million (US$ 15 Million). Health and ancillary benefits of implementing the proposed system are quite substantial. Total expected benefits including that from reduced GHGs, range from Rs 548.24 Million (US$ 11.64 Million) to Rs. 338,076 Million (US$ 7,177.83 Million) in 2011, and from Rs.2,847.2 Million (US$ 60.41 Million) to Rs. 1,969,949.96 Million (US$ 41,824.8 Million) in 2021.

For the combined natural gas and biogas mitigation scenario (C2), the expected net economic cost for 2011 is Rs. 28.16 Million (US$ 0.60 Million), while for 2021, it is - Rs. 33.82 Million (US$ 0.72 Million). (Note that negative cost implies savings to industry; economic gains to industry are higher than costs of implementation of mitigation measures). Total expected benefits including that from reduced GHGs, range from Rs 42.86 Million (US$ 0.91 Million) to Rs. 8,212.83 Million (US$ 174.37 Million) in 2011, and from Rs. 179.45 Million (US$ 3.81 million) to Rs. 77,528.96 Million (US$ 1,646.05 Million) in 2021.

The second industrial scenario (C3) involves addition of chemical catalysts to fuel oil. After taking into consideration the value of fuel oil saved, the cost of implementation is negative. In other words, this scenario also offers economic gains to industry that are higher than the cost of implementation of this mitigation scenario. Net-costs have been worked out to – Rs 43.40 Million (US $0.92 Million) in 2011 and – Rs 81.55 Million (US $ 1.73 Million) in 2021. Health and ancillary benefits as well as expected benefits from reduced GHGs, range from Rs. 11.30 Million (US$ 0.24 Million) to Rs. 4,519.72 Million (US$ 95.86 Million) in 2011, and from Rs. 107.39 Million (US$ 2.28 Million) to Rs. 77,228.46 Million (US$ 1,639.67 Million) in 2021.

For the third industrial mitigation scenario (C4), particulate controls are assumed to be made mandatory for all uncontrolled solid fuel fired boilers (using coal, wood or agricultural waste as fuel). Total cost for implementation of this scenario is Rs. 20.44 Million (US$ 0.43 Million). Expected benefits of implementing this scenario range from Rs. 8.48 Million (US$ 0.18 Million) to Rs. 5,964.27 Million (US$ 126.63 Million) in 2011, and from Rs. 86.19 Million (US$ 1.83 Million) to Rs. 71,238.75 Million (US$ 1,512.5 Million) in 2021.

Table 22 below summarizes the cost-benefit analysis results described above:

Table 22: Results of Cost – Benefit Analysis (in million of Rs.)

Scenarios	2011			2021		
	Net Costs (Rs. Million)	**Health Benefits from Air Pollution changes (Rs. Million)**		**Net Costs**	**Health Benefits from Air Pollution changes (Rs. Million)**	
		Lower Bound	**Upper Bound**		**Lower Bound**	**Upper Bound**
C1	698.00	548.24	338,075.79	698	2,847.20	1,969,949.96
C2	28.16	42.86	8,212.83	-33.82	179.45	77,528.96
C3	-43.40	11.30	4,519.72	-81.55	107.39	77,228.46
C4	20.44	8.48	5,964.27	20.44	86.19	71,238.75

Please refer to Annex G for further details of IES- India Cost Benefit Analysis.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The entire IES- India study for the Hyderabad area is briefly summarized above. The emissions inventory and air quality modeling clearly show that PM_{10} emissions emanate primarily from transportation sources for the HUDA area. For calendar year 2001, transportation emissions are approximately 62.5% of total emissions for the HUDA area, increasing to 66.5% in CY 2011 and almost 75% in CY 2021. It can be seen from the modeling studies that the concentration of PM_{10} is highest in the MCH area due to high vehicle density in this region. A few industrial regions also show high PM_{10} concentrations due to industrial clusters, but the concentrations are not as high as found in the MCH area.

Of the four mitigation scenarios considered (one transportation and three industrial), it is obvious that the bus transit mitigation scenario shows greatest potential for reductions in PM_{10} and greenhouse gases (GHGs). Particulate concentrations are reduced by more than a third for the bus transit scenario. Of the industrial scenarios, the natural gas/biogas combination scenario shows greatest reduction in GHGs, as well as greatest reduction in PM_{10} emissions in the long term.

The health effects study shows greatest reduction in mortality and morbidity for the transportation (bus transit) mitigation scenario for CY 2011 and 2021. The three industrial mitigation scenarios also show reduction in mortality and morbidity, but these reductions are small when compared to the bus transit mitigation scenario.

The cost-benefit analysis shows that all four mitigation scenarios have positive benefits (i.e., the health benefits from reductions in PM and cost savings from each scenario usually exceeds the implementation costs of the scenario). Again, the bus transit mitigation scenario showed greatest cost benefits, followed by the combined (natural gas + biogas) scenario, fuel additive scenario and industrial control scenario. It should be noted that the combined NG + BG scenario (for 2021) and the fuel additive scenarios have positive net costs benefits even before considering health benefits (i.e., the net cost savings of these scenarios exceeds the implementation costs of these scenarios).

Some limitations of this study include the uncertainty around the percentage of major source emissions that were included (only transportation and industrial sectors were considered), lack of emission factors dedicated to local Hyderabad conditions, and use of secondary data. Also, for the bus transit mitigation scenario, some important costs such as fuel savings, costs of additional buses, increased passenger capacity were not considered due to limited data availability. For the health benefits study, no Indian studies are available to estimate willingness to pay (WTP) to reduce risks of death. Therefore, values used in the US were transferred to India based on per capita income. Benefits were computed using values derived from local data and values transferred from the US. Also, for the health benefits study, PPP and PCI values were not adjusted for growth in per capita income.

The following recommendations are suggested for improving and enhancing the IES-India study:

- Include all significant emissions sources, including re-entrained road dust particulates, open burning, commercial and residential emissions, etc.

- Include primary data for emissions inventory, if possible.

- Incorporate air quality monitoring data and assess air pollution transport.

- Use emission factors dedicated to local conditions, if available.

- Include more transportation mitigation scenarios for modeling and health studies (eg., natural gas scenario for heavy vehicles).Further refine cost/benefit analysis with improved cost approximations.

ANNEX – A

INDUSTRIAL EMISSIONS INVENTORY FOR THE IES – INDIA PROJECT

ANNEX - A

INDUSTRIAL EMISSIONS INVENTORY FOR THE IES-INDIA PROJECT

1.0 INTRODUCTION

The industrial emissions inventory for the IES- India program was completed for the Hyderabad Urban Development Area (HUDA) which covers the city of Hyderabad and parts of the surrounding districts of Ranga Reddy and Medak in Central Andhra Pradesh, covering approximately 1,850 sq. kilometers (km) (refer to Figure: 1). Hyderabad and the surrounding urban area has a population of approximately 6.9 million people. Industrial fuel usage data to estimate emissions was collected from five regional Andhra Pradesh Pollution Control Board (APPCB) offices with jurisdiction over the study area. The fuel used in the study area consisted primarily of fuel oil, diesel, coal, wood and agricultural waste. The base year for this study was Calendar Year (CY) 2001.

2.0 DATA COLLECTION PROCESS

Data was collected for- approximately 560 small, medium and large-scale combustion sources at industries located in the study area. It should be noted that small-scale industries not registered with the APPCB were not included in this study. Combustion fuel-use data was collected from standardized APPCB air quality data forms completed by each industry and submitted to the appropriate PCB regional office for CY 2001. Data collected included industry name and address, boiler/furnace stack height and diameter, control equipment details, boiler heat rating and stand-by generator details (power rating), fuel type used and quantity of fuel used for boilers and generators, and boiler stack test data (when available). If the quantity of fuel used by generators was not available, fuel quantity was assumed to be same as quantity used by similar sized generators in similar industries. It should be noted that only fuel burning industries were covered by this industrial emissions study.

3.0 EMISSIONS ESTIMATION PROCESS

Particulate matter with a diameter equal to or less than ten microns (PM_{10}) was the primary ambient air pollutant of concern for this study. PM_{10} was selected as the pollutant of concern because of the strong correlation between PM_{10} and adverse health effects. Annual emissions of three green- house gases (GHGs) were also estimated: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). These three gases are the primary contributors to the global warming phenomenon. The data collected was input into an Excel spreadsheet. All fuel usage data was converted into annual fuel usage. It was assumed that all industries operated 24 hours/day with 10% annual downtime (i.e., 330 working days/year) (refer to the assumptions listed below).

Where stack test data was available, annual total suspended particulate matter (TSPM) emissions were calculated from the stack test data, and the PM_{10} fractions were used to estimate PM_{10} emissions. When stack test data was not available, emission factors were used to estimate PM_{10} emissions from fuel usage (refer to Table **1** for emission factors used). If control equipment was used, it was taken into account when estimating emissions (refer to Table **2** for control equipment efficiencies). Control efficiencies were conservatively estimated due to lack of sufficient data on control equipment maintenance practices by industry.

4.0 EMISSIONS CALCULATIONS

1) When stack test data was available, TSPM emissions were calculated by using the following equation:

TSPM emissions (kg) = [concentration (mg/m^3) x flow rate (m^3/hr) x 24 hrs/day x 330 days/year]/ 10E06 mg/kg

PM_{10} emissions were calculated by using PM_{10} fractions of TSPM obtained from various sources (refer to Table **3**).

2) When boiler control equipment was used (and no stack test data available), PM_{10} emissions were estimated using the following equation:

   PM_{10} emissions (kg) = Fuel Used (tons or liters) x Emission Factor (kg/ton or kg/liter) x (1- CE)/100

   Where: CE= control efficiency of equipment (refer to Table **2** for control efficiencies).

3) When no control equipment (and no stack test data available) was used, PM_{10} emissions were estimated using the following equation:

PM_{10} emissions (kg) = Fuel Used (tons or liters) x Emission Factor (kg/ton or kg/liter).

5.0 ASSUMPTIONS

The following assumptions were made during preparation of the emissions inventory:

1. If fuel usage was not available for diesel generators, usage was assumed to be the same as similar sized generators used in similar industries.
2. It was assumed that industry boiler availability was 90%, or 330 working days per year (Source: National Productivity Council and APPCB). 10% downtime was used for boiler maintenance. Though a few large industries operate around the year with back-up boilers, most industries in the study area are medium scale, so 90% boiler availability (330 working days/year) was assumed throughout).
3. Diesel generators were assumed to be operating throughout the year, assuming 8hrs/week usage
   (Source: National Productivity Council).
4. All industrial boilers are well below 100 MMBtu/hr (small/medium size).
5. Vast majority of the coal boilers in the study area are hand fed units (Source: Boiler Inspectorate).
   Well over 90% of boilers use sub-bituminous coal; however, a few industries use bituminous coal (Source: Singareni Collieries).
6. Most industries in the study area operate 3 shifts (24 hours/day), while some smaller units operate 2 shifts/day (Source: National Productivity Council); however, continuous 24 hour
   production was conservatively assumed for this study for all industries (for boiler emissions).
7. Most oil-fired boilers use Heavy Fuel Oil (Furnace Oil). (Source: BPCL Corp.).
   TSPM was estimated only when stack test data was available. PM_{10} fractions were used to estimate PM_{10} emissions from TSPM. When no stack test data was available, emission factors were used to estimate PM_{10}.

9. For process emissions, PM_{10} fractions were not available, therefore it was assumed that PM_{10}= TSPM.

6.0 RESULTS

Annual PM_{10} and GHG emissions were estimated for operating industries registered with the APPCB in the study area (for CY 2001). The results of this study are shown below:

CY 2001 Annual Industrial Emissions **Tons (metric)**

Criteria Pollutant: PM_{10}	1,187 tons
Greenhouse Gases: CO_2 N_2O CH_4	768, 816 tons CO_2 4, 085 tons eCO_2 26,389 tons eCO_2

7.0 NEXT STEPS

This industrial emissions inventory is the first step in the IES- India program. The industrial emissions will be combined with transportation emissions to obtain total emissions. The total emissions will be entered into the ISC-3 model to obtain PM_{10} concentrations. Health effects will then be estimated based on the air quality modeling study results. Mitigation scenarios for industry and transportation will also be modeled, and health effects of mitigation scenarios compared to the business as usual (BAU) scenario. A cost/benefit analysis will also be performed for the mitigation and BAU scenarios. All results will be disseminated to steering committee members, policy makers and the public. For detailed explanations and results of these procedures, please refer to Annexes B-G.

Figure 1: Study Area Map for Integrated Environmental Strategies

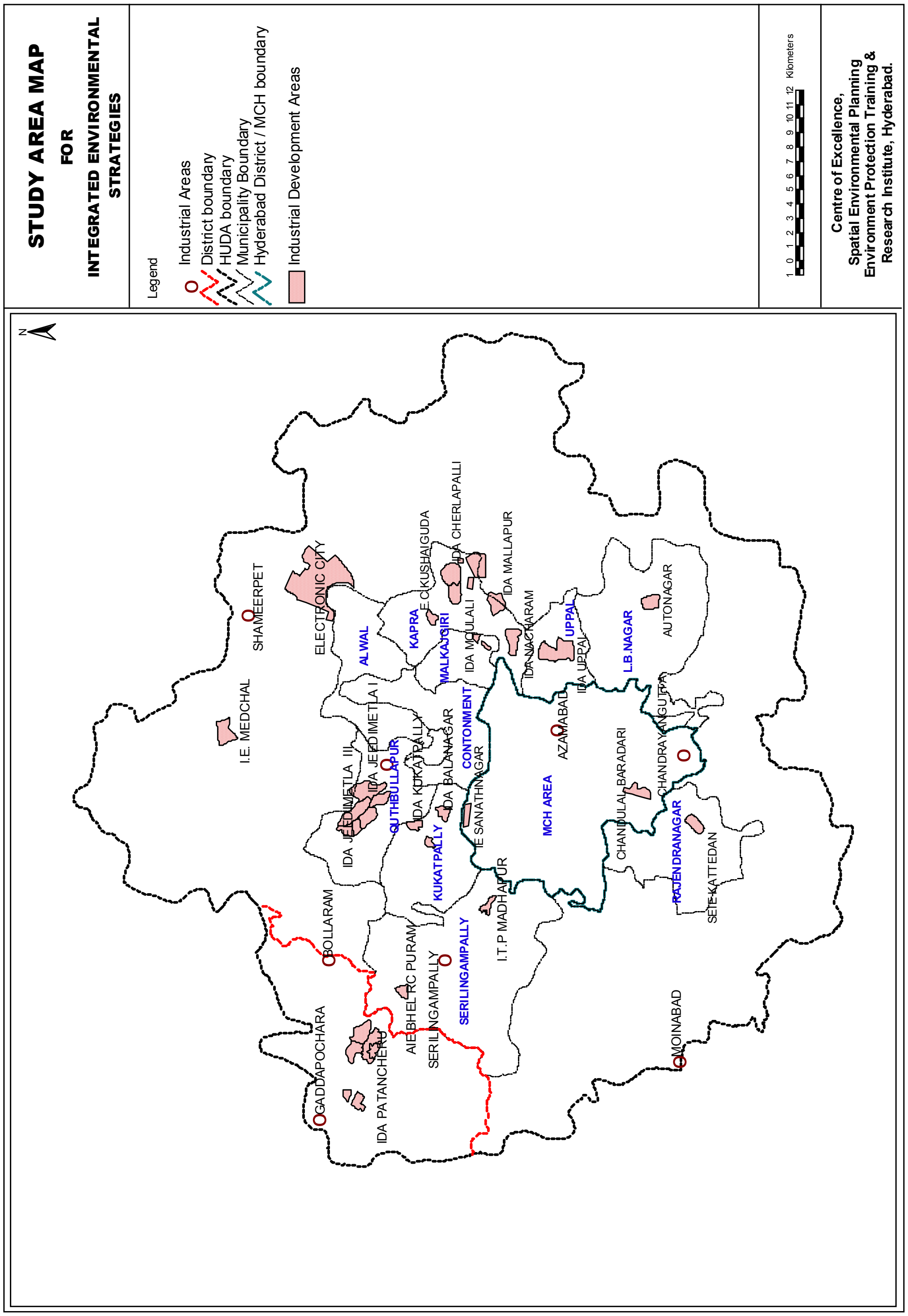


Table 1: Emission Factor Table for PM_{10} (used when stack test data not available) (for Boilers)

Source	Fuel Type	Emission Factor	Units	% of Sulfur
WBS	Fuel Oil	**0.0108**	Kg/Lt.	3.7
WBS	Light Diesel Oil	**0.0057**	Kg/Lt.	1.8
WBS	High Speed Diesel	**0.0015**	Kg/Lt.	0.25
WBS	Low Sulfur Heavy Stock	**0.0035**	Kg/Lt.	1
AP-42	Coal	**3.1**	Kg/ton	0.69
AP-42	Wood	**2.88**	Kg/ton	-
WHO	LPG	**0.06**	Kg/ton	-
WHO	CNG	**0.061**	Kg/ton	-
AP-42	Agricultural Waste	**7.8**	Kg/ton	-
% of Sulfur obtained from Fuel Oil Companies (HPCL, BPCL & IOC) and SCCL				

Emission Factor Table for PM_{10} (for Emergency Generators)

Source	Fuel Type	Emission Factor	Units
WBS	Diesel	0.01024	Kg/Lt.

Note: WBS= World Bank Study: (Environmental Costs of Fossil Fuels: A Rapid Assessment Method With Application to Six Cities, October 2000).

WHO= World Health Organization (Rapid Inventory Techniques in Environmental Pollution).

AP-42= USEPA AP-42 document.

Table 2: Control Equipment Efficiency

Control Equipment Efficiency		Source
Single Cyclone (also Cyclone Dust Collector	60%	1
Multi Cyclone Dust Collector	80%	1
Scrubber	95%	1
Electro Static respirator	95%	1
Bag filter or Bag house	98%	1
Two Bag filters	99%	2
Wet Scrubber with Bag filter	99%	2
Multi Cyclone with Bag filter	99%	2
Wet Scrubber and Dust Collector	99%	2
Cyclone & Scrubber	99%	2
Cyclone with Heat Recovery	60%	2

Source:
1. Air Pollution Engineering Manual (AWMA)
2. EPTRI & NREL Engineering Judgment

Table 3: PM_{10} fraction of TSPM (used when stack test data available)

Source	Fuel Type	PM_{10} fraction
AP-42	Fuel Oil	50% of TSPM
AP-42	Coal	41% of TSPM
AP-42	Wood	86% of TSPM
AP-42	LPG	100% of TSPM
AP-42	CNG	100% of TSPM
Not Available	Agricultural Waste	100% of TSPM

ANNEX B

BASELINE AIR QUALITY MODELING STUDIES FOR IES-INDIA PROJECT

ANNEX B

BASELINE AIR QUALITY MODELING STUDIES FOR IES-INDIA PROJECT

1.0 INTRODUCTION

In India, the Ministry of Environment and Forests (MoEF), is the nodal agency in the administrative structure of the Central Government. The Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) were set up under the Water Act of 1974 for controlling and monitoring environmental degradation in the country and they function under MoEF. To tackle the challenges posed by air pollution, Indian Parliament enacted Air (Prevention and Control of Pollution) Act in 1981 and entrusted the implementation of this law to the State Pollution Control Boards (SPCBs) and the Central Pollution Control Board (CPCB). Under Environment Protection (EP) Act-1986, making environmental clearance mandatory for expansion or modernization of any activity or for setting up new projects listed in Schedule I. CPCB has laid down the ambient air quality standards for different areas and SPCBs have fixed emission standards for different industries. The SPCBs are also responsible for industrial emissions compliance with National Ambient Air Quality Standards (NAAQS).

The Air Quality Modeling (AQM) study under the IES-India project was carried out for the Hyderabad Urban Development Area (HUDA), covering approximately 1,850 sq. kms. The primary pollutant of concern, particulate matter less than 10 microns in diameter (PM_{10}), is being considered for air quality modeling because it has a major impact on the health of the exposed population and PM_{10} also exceeds the air quality standards in most locations within the study area.

Many major air pollution sources in the study area were considered under the present study, including industrial point sources, industrial area sources, and transportation. Due to time and resource limitations, the study was not able to consider the PM_{10} fraction transported into the Hyderabad area from surrounding agricultural and open burning sources nor was the PM_{10} fraction from re-entrained road dust considered during this iteration of the IES India study. The base year for the IES project and this AQM study was calendar year (CY) 2001.

2.0 AIR QUALITY MODEL STUDIES

Once the pollutants are emitted into the atmosphere, the dilution and dispersion of the pollutants are controlled by various meteorological parameters like wind speed and direction, ambient temperature, mixing height, etc. In most dispersion models the relevant atmospheric layer is that nearest the ground, varying in thickness from several hundred to a few thousand meters. Variations in both thermal and mechanical turbulence and in wind velocity are greatest in the layer in contact with the surface. The atmospheric dispersion modeling and the prediction of ground level pollutant concentrations has great relevance in the following activities:

- Estimation of the probable impact of multiple sources like point sources, line sources, and area sources on the surrounding environment.

- Zoning and planning of an urban area.

- Estimation of impact of expansion of an existing industry or setting up of new industry or cluster of industries on surrounding environment.

- ❖ Estimation of maximum ground level concentration and its location in the study area.

- ❖ Locating ambient air quality monitoring stations to collect representative samples of the surrounding activities.

The Gaussian plume models are most practical for such exercises because of their relative simplicity in terms of input parameters and computational requirements. Considering the scarcity of data in Indian conditions, the Gaussian Plume Model (GPM) is recommended for air quality modeling exercise. The concentration of any pollutant released into the atmosphere from a single continuous point source at the X, Y, and Z co-ordinates of a location may be calculated using "Gaussian equation". Because of a multitude of scientific and technical limitations, the diffusion computation method discussed may provide best estimates only, but not infallible predictions. The predictions and estimates are based on the some following assumptions:

- ❖ The emissions from the source are continuous and the emission time is equal to or greater than the travel time of the pollutants over the distance considered under the study. If the emissions are not continuous and emission time is less than the travel time of the pollutants in the study area, then the pollutants may not propagate or disperse up to the boundary of the study area.

- ❖ The diffusion in the direction of transport of the pollution is negligible as the direction of transport of pollution depends on the wind vector.

- ❖ None of the material from the plume is removed as it moves down wind and there is complete reflection at the ground. It is assumed that there is no stack tip down wash.

- ❖ The mean wind direction specifies the X-axis and a mean wind speed representative of the diffusing layer chosen.

- ❖ The plume constituents are distributed normally in both the crosswind and vertical directions.

2.1 Selection and key features of Industrial Source Complex (ISC3) model

The ISC3 model is a steady-state Gaussian plume model, which can be used to assess pollutant concentrations from a wide variety of sources associated with in the study area. The ISC3 dispersion model was designed to support the regulatory modeling options. An important feature of the ISC3 model is its ability to handle multiple sources such as point, volume, area, and open pit source types. Line sources may also be modeled as a string of volume sources or as elongated area sources. The inputs and options required/available for this model are:

- ❖ Control options
- ❖ Sources data
- ❖ Meteorological data
- ❖ Receptors information

After close observation of the study area and our past experience in this area, we have chosen the ISC3 model in order to predict ambient air concentrations for the IES-India study.

2.2 Data Collection Procedure

This section, specifically, deals with the procedure that must be followed in obtaining values of the required parameters for carrying out the air quality modeling. The transportation sector is the largest source of air pollution in the study area and the industrial sector is the second largest source of air pollution in the study area. The required line source data pertaining to vehicular emissions and travel patterns was collected from the RITES- IES Transportation Report. RITES (Rail India Technical Economic Services - a Government of India Enterprise) was established in 1974. RITES has carried out "Transportation study for Hyderabad Urban Development Authority (HUDA) area" (refer to Annex C of details of this report). The main components of the transportation study are a) Transport demand modeling and forecasting b) Development of a more effective bus transit system, and c) Traffic system management measures. As part of the study, vehicular emissions were estimated for the entire HUDA area, including nine major corridors within the HUDA area for the years 2001, 2003, 2011 and 2021.

While estimating the emissions, all home-based trips (work, education and other purposes) along with inter-city trips were assigned to the base year network through Capacity Restrained Assignment procedure. Passenger trips obtained from assignment were converted into vehicular trips by using average vehicle occupancy factors as observed in traffic studies. The mode-wise (bus, auto, car and two-wheeler) daily vehicle kilometers traveled for the HUDA area have been estimated for the 2003 base year and the horizon years 2011 and 2021. Similarly, mode-wise vehicle kilometers traveled have been assessed for 9 major corridors. The IVE (International Vehicle Emissions) Model developed by "College of Engineering-Center for Environmental Research and Technology (CE-CERT), at the University of California, Riverside" has been used to estimate the emissions for various scenarios (refer to Annex C for details of IVEM model).

The RITES study also recommends the following air pollution mitigation scenarios: a) More effective bus transit system scenario b) Fly- over scenario and c) Technology transfer/training scenarios. Based on the reduction in emissions, more effective bus transit mitigation scenario has been selected for the AQM study; the other scenarios do not generate sufficient emissions reductions to demonstrate mitigation benefits using the ISC3 Model.

As part of Emission Inventory module of IES program, Environment Protection Training and Research Institute (EPTRI) collected air emissions and fuel-use details from potential air polluting industries, which are registered under APPCB in the study area. Emissions pertaining to the CY-2001 were considered for the present study. Data collected included:

- industry name and address,
- boiler/furnace stack height and diameter,
- control equipment details,
- boiler heat rating and stand-by generator details (power rating),
- fuel type used and quantity of fuel used for boilers and generators, and
- boiler stack test data etc. (refer to Annex A for further details).

It should be noted that only fuel burning industries were covered by this study. If stack-test data was available, pollutant loads were estimated based on pollutant concentrations and flow rate of the flue gas. Otherwise, emissions were estimated based on the annual fuel consumption, fuel type and appropriate emissions factor. Type of control equipment and its efficiency were also considered while estimating pollutant loads. The details of the emission factors are discussed in detail in the Emissions Inventory section of this report (please refer to Annex A).

Data was collected for approximately 560 small, medium and large-scale combustion sources at industries located in the study area. It should be noted that small-scale industries not registered with the APPCB were not included in this study. Emissions information pertaining to 23 industries that had emissions of 10 tons per year (tpy) or greater in 2001 were selected as point sources and the pollution loads from the remaining industries were considered as area sources. It is assumed that all the area sources are located at the center of the sub-study areas (MCH area, neighboring municipalities, and out-growths). Most of the large air polluting industries (10 point-sources in number) are located in Jeedimetla Area. Only one major point-source was located in the MCH area. This is probably due to the closing or relocation of industries located in the city (MCH area).

There are no large power generation plants within the study area, but there are several small diesel generation sets and limited cogeneration operations. Therefore, cogenerators do not contribute significantly to the total PM_{10} emissions load in Hyderabad. The domestic (household energy) fuel consumption and its emission load has been considered to be insignificant when compared to the industrial or vehicular PM_{10} emissions, as the primary domestic fuel for household operations is liquid petroleum gas (LPG) and/or kerosene. It should be noted that any small-scale industries, which were not registered with APPCB and have less air pollution potential, were not included in this study.

2.3 AIR QUALITY MODELING EXERCISE

The Industrial Source Complex (ISC) Model was selected to carry out the modeling exercise in this IES study region. The emissions details from different sources such as industrial emissions and vehicular emissions along with the prevailing micro-meteorological conditions are taken as model inputs required to run these models. A cup anemometer and wind vane or vane with a propeller speed sensor mounted in front can be the primary data-gathering device for obtaining information on the basic wind system. Micro-meteorological information for this study area was taken from the Indian Meteorological Department.

A uniform Cartesian grid system was used to locate/fix sources and receptors in the study area. The south-west point in the system is considered as 'origin' and north-east point in the system is 'the point' of maximum x and y values. The maximum Ground Level Concentrations (GLC) of the selected pollutant (PM_{10}) are presented in the table below. The table presents a maximum of fifty ground-level concentrations along with time of occurrence and location in the coordinate system. For each modeling scenario, a set of a maximum of 50 concentrations were obtained along with corresponding coordinates and contour map. Table 1 given below is one such example, which provides information on the Baseline Scenario of the study area. The PM_{10} concentrations in the table are representative for predicted peak values in the study area for the year 2001. The average annual PM_{10} concentrations are presented area wise in the Table 2.

Table 1: PREDICTED GROUND LEVEL CONCENTRATIONS OF PM_{10} FOR HUDA REGION

(Peak values in the study area for CY 2001)

** CONC OF PM10-96 IN MICROGRAMS/M**3 **

RANK	CONC (YYMMDDHH) AT	RECEPTOR (XR,YR) OF TYPE	RANK	CONC (YYMMDDHH) AT	RECEPTOR (XR,YR) OF TYPE
1.	316.50510 (00101524) AT	(27000.00, 19000.00) GC	26.	227.06000 (00100224) AT	(32000.00, 43000.00) GC
2.	300.94379 (00100224) AT	(27000.00, 19000.00) GC	27.	226.20323 (00101524) AT	(22000.00, 43000.00) GC
3.	290.56027 (00100124) AT	(27000.00, 19000.00) GC	28.	226.11499 (00100224) AT	(31000.00, 43000.00) GC
4.	268.17108 (00100424) AT	(27000.00, 19000.00) GC	29.	225.49922 (00101524) AT	(23000.00, 23000.00) GC
5.	267.22238 (00100524) AT	(27000.00, 18000.00) GC	30.	224.98451 (00100224) AT	(30000.00, 43000.00) GC
6.	262.81158 (00100524) AT	(27000.00, 19000.00) GC	31.	224.84258 (00101524) AT	(21000.00, 43000.00) GC
7.	260.55072 (00101224) AT	(26000.00, 19000.00) GC	32.	223.84380 (00100224) AT	(29000.00, 43000.00) GC
8.	260.52377 (00101224) AT	(27000.00, 19000.00) GC	33.	223.72058 (00100224) AT	(26000.00, 19000.00) GC
9.	250.70178 (00101124) AT	(26000.00, 19000.00) GC	34.	223.58110 (00101124) AT	(26000.00, 20000.00) GC
10.	248.29021 (00101324) AT	(27000.00, 19000.00) GC	35.	223.23407 (00101524) AT	(20000.00, 43000.00) GC
11.	241.28687 (00100324) AT	(27000.00, 19000.00) GC	36.	222.69768 (00100224) AT	(28000.00, 43000.00) GC
12.	239.53090 (00101524) AT	(33000.00, 43000.00) GC	37.	221.97240 (00100124) AT	(33000.00, 43000.00) GC
13.	238.64589 (00101424) AT	(27000.00, 19000.00) GC	38.	221.53764 (00100224) AT	(27000.00, 43000.00) GC
14.	238.32082 (00101524) AT	(32000.00, 43000.00) GC	39.	220.87733 (00100124) AT	(32000.00, 43000.00) GC
15.	237.32347 (00101524) AT	(31000.00, 43000.00) GC	40.	220.36684 (00100224) AT	(26000.00, 43000.00) GC
16.	236.13240 (00101524) AT	(30000.00, 43000.00) GC	41.	219.98358 (00100124) AT	(31000.00, 43000.00) GC
17.	235.26715 (00101524) AT	(26000.00, 19000.00) GC	42.	219.17535 (00101524) AT	(19000.00, 43000.00) GC
18.	234.93034 (00101524) AT	(29000.00, 43000.00) GC	43.	219.11012 (00100224) AT	(25000.00, 43000.00) GC
19.	233.72258 (00101524) AT	(28000.00, 43000.00) GC	44.	218.90544 (00100124) AT	(30000.00, 43000.00) GC
20.	232.50018 (00101524) AT	(27000.00, 43000.00) GC	45.	218.04817 (00100224) AT	(24000.00, 43000.00) GC
21.	231.26654 (00101524) AT	(26000.00, 43000.00) GC	46.	217.81816 (00100124) AT	(29000.00, 43000.00) GC
22.	229.94270 (00101524) AT	(25000.00, 43000.00) GC	47.	217.80693 (00101224) AT	(23000.00, 23000.00) GC
23.	228.82265 (00101524) AT	(24000.00, 43000.00) GC	48.	217.07483 (00101324) AT	(33000.00, 43000.00) GC
24.	228.20839 (00100224) AT	(33000.00, 43000.00) GC	49.	216.80473 (00100224) AT	(23000.00, 43000.00) GC
25.	227.51280 (00101524) AT	(23000.00, 43000.00) GC	50.	216.72581 (00100124) AT	(28000.00, 43000.00) GC

Reference point is westside end point of HUDA region: (0,35000)

****
*** ISCST3 Finishes Successfully ***
****

From the predicted Ground-Level Concentrations (GLCs) for Baseline Scenario, listed in Table 1 above, it can be seen that the contribution of PM_{10} load in the study area is significant. Maximum ground level concentration of PM_{10} for the baseline scenario is 316.5 ug/m3, which occurred at the coordinates (27000, 19000), which falls in MCH area. These Ground Level Concentrations (GLCs) exceed the Ambient Air Quality Standards of Central Pollution Control Board (CPCB). The CPCB prescribed standards for PM_{10} pollutant (for residential and commercial areas), is 100 ug/m3 (24 hours average concentration) and 60 ug/m3 (annual average concentrations). From the concentrations in Table 1, it can be observed that the predicted air pollutant concentrations are not uniform throughout the city. The PM_{10} concentrations vary spatially. It can be observed that air pollution concentrations are high in some pockets in the city. The spatial distribution of GLCs of PM_{10} can be seen in the figure given below. The air quality modeling was carried out in similar manner for air emissions in the Business-as-Usual (BAU) scenarios for 2011 and 2021 (BAU-2011 and BAU-2021). The following Table-2, Figure-A and Figure-B give GLC trends of PM_{10} for Baseline-2001, BAU-2011 and BAU-2021. The concentrations obtained in BAU-2021 are very high and quite alarming when compared with the Baseline-2001 and BAU-2011 concentrations. The high concentrations obtained in BAU-2021 are probably due to contribution of increased transport emissions. For all three scenarios, maximum concentrations are obtained in the MCH area, which is due to the high vehicular population. For BAU-2021, Patancheru and Rajendranagar are the next most adversely impacted areas (after MCH), because of their proximity to the air polluting industries.

Table 2: Predicted Ground Level Concentrations of PM_{10} for HUDA area- Base line, BAU-2011 and BAU-2021

(Annual Avg. Concentrations)

S. No.	Locality	Baseline-2001	BAU-2011	BAU-2021
		PM_{10} ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
1	MCH Area	160	420	1010
2	Rajendranagar	30	120	360
3	L B Nagar	70	130	310
4	Uppal	40	110	260
5	Kapra	20	70	110
6	Malkajgiri	20	50	60
7	Alwal	60	140	285
8	Qutbullapur	80	220	560
9	Kukatpally	30	70	210
10	Serlingampally	30	70	210
11	Patancheru	90	190	560
12	Ghatkesar	30	50	160
13	Gaddiannaram	70	230	310

Figure A: Predicted GLCs of PM_{10}

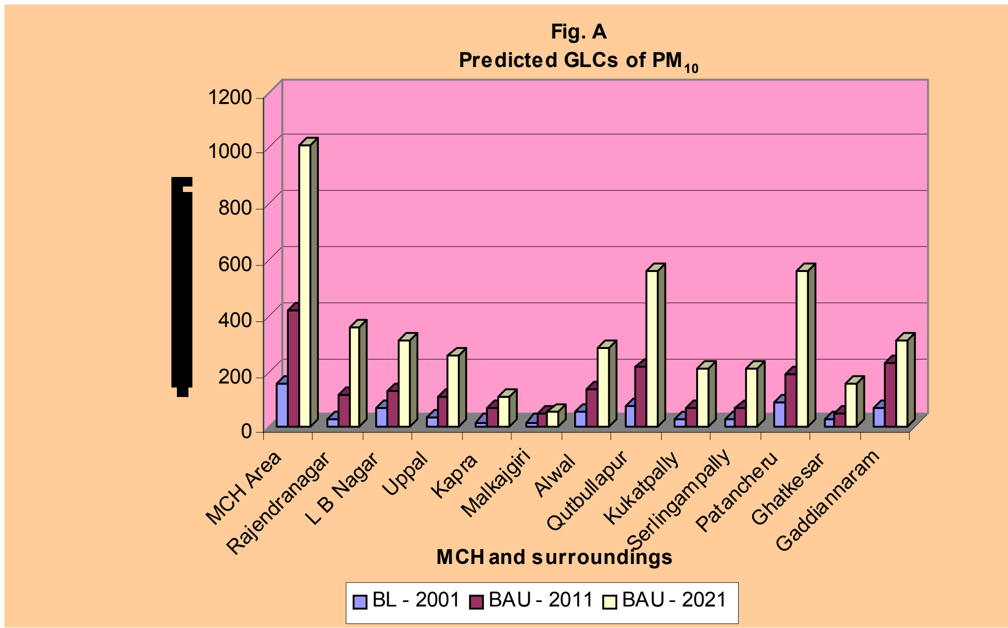
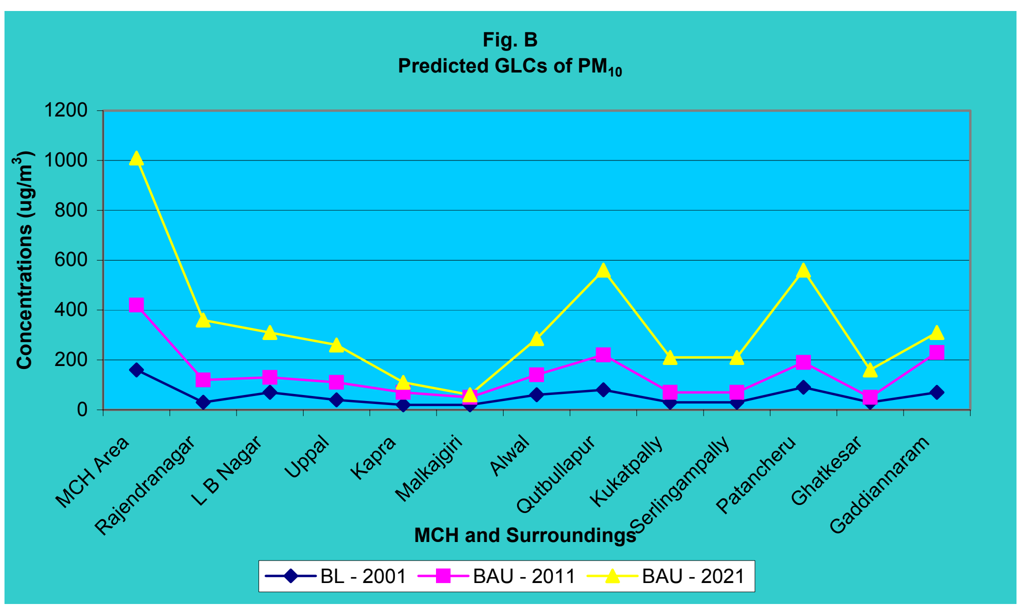


Figure B: Predicted GLCs of PM_{10}



ANNEX C

TRANSPORT MEASURES TO REDUCE EMISSIONS IN HYDERABAD FOR IES - INDIA PROJECT

ANNEX C

TRANSPORT MEASURES TO REDUCE EMISSIONS IN HYDERABAD FOR IES - INDIA PROJECT

1.0 INTRODUCTION

1.1 OBJECTIVE AND SCOPE OF THE STUDY

1.1.1 Hyderabad is one of the fastest growing centers of urban development in India. This growth has also brought with it air quality and congestion problems. For a number of reasons, motorized two wheelers, auto rickshaws and private passenger cars, have displaced trip making, which has been more traditionally accomplished by public transport and bicycle.

1.1.2 Traffic congestion, the predominance of two-stroke vehicles in the traffic mix and inability of public (bus) transport to attract significant ridership have all been blamed for the severe air quality problems in Hyderabad especially the prevalence of Respirable Particulate Matter (PM_{10}) as well as rapidly growing emissions of Greenhouse Gases (GHGs). The objective of this study is to carryout an analysis of policies to address these important areas of concern in Hyderabad's transport sector. The scope of work for this study has the following three components:

(d) Scenario for more effective bus transit service.
(e) Traffic management and measures to improve traffic flow.
(f) Technology/Training measures relating to two-stroke vehicles.

1.1.3 However RITES has identified 3 more corridors in addition to the GEP Corridor (ESI Hospital to Khairatabad Junction, Length=4.6km) as a part of the study component on "Traffic Management & Measures to Improve Traffic Flow" (please refer to Figure 3.1 for details of study area). The corridors are:

(i) Erragadda junction to ESI Hospital (NH-9), L=0.9km.

(ii) Khairatabad junction to Nalgonda 'X' roads (NH-9) via Nampally Public Garden and MJ Market, L=7.1km.

(iii) Panjagutta junction to Secunderabad Retifile bus station via Green lands and Begumpet road, L=8.05km

1.1.4 However, the above (i) and (ii) corridors are extensions of the GEP Corridor. Hence, the total selected corridors effectively are two. i.e.,

(a) Erragadda to Nalgonda 'X' road

(c) Panjagutta to Secunderabad Retifile bus station

1.1.5 These analyses have been done as a part of the Integrated Environment Strategies (IES) program being carried out by the Environment Protection Training & Research Institute (EPTRI) of Hyderabad with funding from USAID and USEPA.

1.1.6 USEPA has commissioned ICF Consulting for carrying out this analysis, which in turn engaged the services of RITES Ltd. to accomplish these tasks.

2.0 STUDY METHODOLOGY

2.1 METHODOLOGY

2.1.1 Methodology adopted for the study is presented in **Figure 2.1.** Broadly, the identified methodology comprises the following stages:

i) Collection and Preparation of Database for the Study
ii) Transport Demand Modeling
iii) Transport Demand Forecasting
iv) Business-as-Usual Scenario
v) Formulation of Policy Scenario
vi) Estimation of Vehicular Emissions
vii) Block Cost Estimates
viii) Evaluation of Policy Scenarios

2.1.2 The above stages are described briefly in the following paragraphs. More details are given in the following Chapters.

2.2 COLLECTIONS AND PREPARATION OF DATABASE FOR THE STUDY

2.2.1 As a part of the study, various previous data/reports/maps were collected from various agencies and reviewed to assess the existing traffic scenario in Hyderabad. Secondary data such as population, employment, road network map, vehicle registration details, school enrollment and land use details were collected from various agencies viz., Census Department, Labor Office, Bureau of Economics and Statistics, HUDA, MCH, Department of School and College Education, Commercial Tax office and Industrial Department.

2.2.2 Following Primary Traffic and Travel surveys were also carried out to assess the traffic and travel characteristics of the commuter traffic in study area.

(a) Turning Movement Traffic Volume Count Survey along with Vehicle Survey Occupancy at major junctions (29 locations)
(b) Road Network Inventory Survey
(c) Speed and Delay Survey
(d) Traffic Signal Time Survey
(e) Parking Survey
(f) Pedestrian Survey
(g) Passenger's Opinion Survey (Public and Private modes)
(h) Driving Habits of Two wheeler & Auto Rickshaw drivers
(i) Household Travel Survey (Activity Diary & Stated Preference)

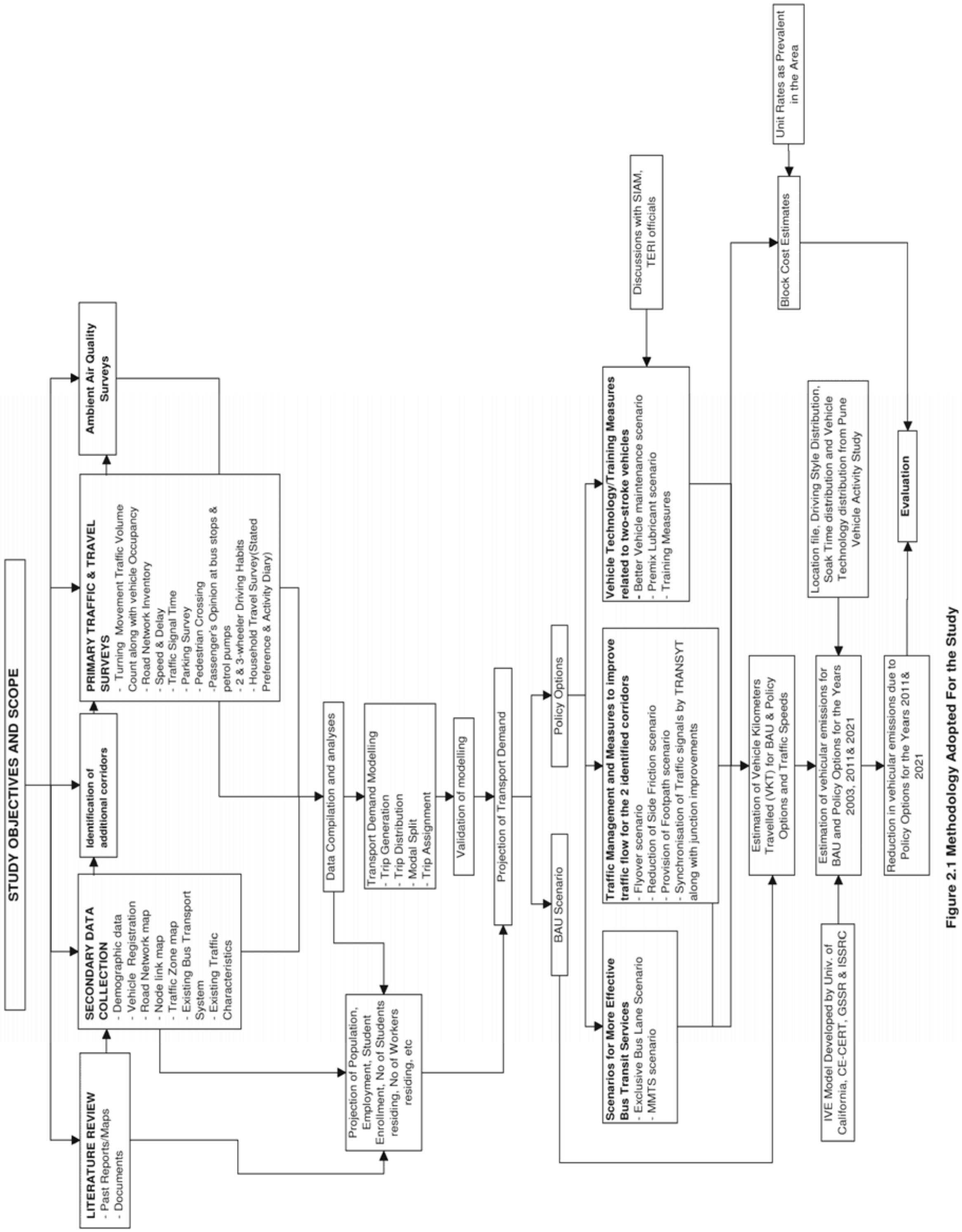


Figure 2.1: Study Methodology Adopted for the Study

2.2.3 A special survey carried out as a part of this study was Stated Preference survey of household travelers. The objective of this survey were to assess trade-offs among time, cost and reliability by commuters, develop performance goals to improve the existing bus transport system, and assess individual's willingness to pay towards newer transport services.

2.2.4 Here it may be mentioned that the data collected from Household Travel Surveys and other surveys conducted as a part of project "Hyderabad Mass Rapid Transit System" has also been used to supplement the data collection exercise as a part of this study. The data collected was then analyzed to give traffic and travel characteristics for the year 2003.

2.3 TRANSPORT DEMAND MODELING

2.3.1 In the present study, we have used in-house developed transport demand modeling software. The 4-Step Transportation Study Process consists of development of formulae or models, enabling future travel demand to be forecasted and alternative strategies for handling this demand. In the present study, an attempt has been made to develop operational models. The normal and easily available planning variables at zonal levels such as population, employment, number of workers residing, number of students residing and student enrollment, etc. collected as a part of household survey and secondary data collected have been made use of in transport analysis. The study area has been divided into 129 Traffic Analysis Zones for the purpose.

2.3.2 **Trip Generation:** The first of the sub-models in the conventional study process is that which predicts the number of trips starting and finishing in each zone. For the present study the regression analysis technique has been adopted for the development of trip generation sub models for home based one-way trips for various purposes. Attempts have been made to develop simple equations using normally available variables, which can be forecasted with reasonable degree of accuracy.

As part of this stage about 25 trip production models were developed for various purposes (work, education, others and total trips) with independent variables such as population, number (no.) of workers residing, no. of students residing, no. of cars, no. of 2 wheelers, average monthly income, accessibility rating (represented by no. of bus routes connecting a zone to other parts of the study area with assigned ratings of, 1(least connected), 2(medium connected) and 3(highly connected)), zone- wise no. of households, average household size and distance from CBD. Among the models developed it was found that zone wise no. of workers residing and no. of cars & no. of 2 wheelers are the most significant in estimating one-way work trips produced from each zone. For the models developed for one-way education trips produced from each zone, highly significant variable was no. of students residing in each zone. The one-way other purpose trips produced from each zone are most significantly related to zonal population and distance from CBD. 13 trip attraction models were developed for work, education and other purposes by relating the purpose wise trips attracted to zone with independent variables such as zone wise employment, student enrollment, distance from CBD, accessibility rating and population. One-way work trips attracted to a zone were found to be statistically most significant to the zone wise employment. Zone wise student enrollment is significant in estimating one-way education trips attracted to a zone. Employment and accessibility rating were found to be most significant in estimating one-way other purpose trips attracted to each zone.

Accordingly the most significant trip production and attraction models were used along with projected values of the selected independent variables for 2011 and 2021 for estimating future zone-wise trip productions and attractions.

2.3.3 **Trip Distribution:** Trip distribution or inter-zonal transfers, is that part of transportation planning process which relates a given number of travel origins for every zone of the study area, to a given number of travel destinations located within the other zones of the study area. The gravity model with negative exponential deterrence function has been used in this study. The Gravity model has been validated by comparing the simulated and observed trip length frequency distributions for various trip purposes. The model thus developed has then been used to work out trip distribution for the years 2011 and 2021 for work, education and other trips with inputs of future zone-wise trip productions and attractions.

2.3.4 **Modal Split:** A total of 27000 choice set data points were collected as a part of Stated Preference (SP) household survey and separate models were developed for respondents who had no access to any individual vehicle, those who had access to 2-Wheelers and those had access to cars. A multinomial logit model was developed to examine empirically how travelers trade-off among the attributes of price, time and reliability. The results from SP survey data analysis indicate that travelers are relatively more sensitive to time and reliability, and relatively less sensitive to cost. For all the groups reliability is relatively more important criteria than time. Among all groups, buses suffer from an image problem in Hyderabad and vehicle owners showed inherent preferences for their own vehicle over buses.

In Business-as-Usual scenario it has been worked out that there will be substantial reduction in modal shares of bus and private vehicles, where as modal share of auto rickshaws would increase quite significantly. Based on the results obtained from modal split model, the modal shares for horizon years were derived for BAU and policy options.

2.3.5 **Trip Assignment:** Trip assignment is the process of allocating a given set of trip interchanges to a specific transportation system and is generally used to estimate the volume of travel on various links of the system to simulate present conditions and to use the same for horizon years. Capacity Restraint Assignment Technique has been followed in this study.

The models developed were calibrated to synthesize the present day travel pattern and also validated by checking the assigned flows on various links with the ground counts after applying correction factors to account for additional trips that have not been taken care of in transport demand forecast exercise.

2.4 TRANSPORT DEMAND FORECASTING

2.4.1 For estimating the transport demand for the horizon years 2011 & 2021, various model parameters (viz., Population, Employment, No. of workers residing, No. of Students Residing, Student Enrollment, etc) were projected for the year 2011 &

2021 and were inputted in the developed models as explained above to estimate the travel demand for future.

2.4.2 Zone wise population and employment were projected as per the Master Plan for Hyderabad for 2020. The zone wise total no of vehicles were estimated based upon the income levels of households in each zone as estimated from household surveys. These households were classified into different vehicle owning groups. From this, zone wise total no of vehicles were derived. Income level of household was projected based on the Net State Domestic Product growth rates upto the years 2011 & 2021.

2.4.3 After forecasting the independent variables, zone wise future trip productions and attractions were obtained by using the selected models for various purposes. Then the future trip production and attractions were distributed by using the trip distribution model developed. The modal split and trip assignment for BAU & policy options are explained in the following paragraphs.

2.5 BUSINESS-AS-USUAL (BAU) SCENARIO

2.5.1 The data collected from APSRTC and RTO office, indicates that there is decline in the no. of passengers carried per bus and there is very heavy increase in the registration of 2-wheelers, cars and auto rickshaws. Heavy traffic of 2-wheelers, cars and auto rickshaws will reduce the bus speeds and further deteriorate the reliability of the bus. If such trend continues there will be increase in traffic congestion, which will lead to higher travel times. As the usage of private vehicles and Auto rickshaws increases, there will be increase in the vehicle kilometers traveled, which in turn will increase the vehicular emissions.

2.5.2 Under such a situation there will be increase in the headway for the buses. As the no. of 2-wheelers and cars usage increases in future, there will not be enough supply for parking of the vehicles, which will result in increased parking cost and parking time. By considering these conditions, modal split for the years 2011 & 2021 were obtained from the modal split model developed. These trips were assigned on to future road network as given in Master Plan for Hyderabad - 2020 to derive the mode wise VKTs for the years 2011 & 2021 for BAU scenario. Average hourly volume and traffic speeds for private and public modes were estimated for the years 2011& 2021. With these speeds the assignment procedure was repeated again till the speeds on the road network were stabilized. After 5 such iterations, speeds on the road network were stabilized. Trip Distribution process was repeated by using the stabilized speeds to obtain the modified OD matrices. By applying the Modal Split model results, mode wise OD matrices were derived. These matrices were then assigned on to their respective networks to derive the VKT. This process has been carried out for the years 2011 & 2021.

2.6 FORMULATION OF POLICY OPTIONS

2.6.1 In Business-as-Usual (BAU) situation the vehicle kilometers traveled will grow heavily, which will increase the pollution levels enormously. In order to address this problem 3 policy options were formulated. They are as follows:

a) Scenario for more effective public transit service.

b) Traffic management and measures to improve traffic flow.

c) Vehicle Technology/Training Measures related to two-stroke vehicles.

2.6.2 **Scenario for More Effective Public Transit Service:** In this scenario following two options were tested

i) More Effective Bus Transit Scenario

ii) Multi Modal Commuter Transit System (MMTS)

i) More Effective Bus Transit Scenario

This scenario was considered for the total study area i.e., HUDA and Nine major corridors including the two identified corridors for Traffic Management Scenario for the horizon years 2011&2021.

By providing dedicated bus lanes, properly designed bus stop/bays, priority for buses at signals, bus route rationalization, etc will have direct impact on speeds of bus, which in turn will increase the reliability of bus & reduce the travel time. The modified purpose wise OD matrices derived in BAU scenario were used to obtain the mode wise OD matrices by using the modal split model results. The modal split for the years 2011&2021 was worked out using the developed Multinomial Logit Model. After this, the mode wise trips obtained were assigned on to future road network to determine the Vehicle Kilometers Traveled by all modes for the year 2011&2021. Average hourly volume and traffic speeds for private and public modes were estimated for the years 2011&2021.

ii) MMTS Scenario

Ministry of Railways, Government of India and Government of Andhra Pradesh are jointly developing Multi-Modal Commuter Transport Services in the twin cities of Hyderabad and Secunderabad for facilitating suburban commuter transportation. This is being done by upgrading the existing railway infrastructure along the two railway corridors. In this scenario, number of passenger trips that will shift to MMTS from various modes as against BAU scenario were assessed based on transport demand model by including the rail corridors in the transport network. When full MMTS is operational, the number of vehicle kilometers of other modes would be reduced. The mode wise vehicle kilometers were then estimated for 2003, 2011 and 2021.

2.6.3 **Traffic Management and Measures to Improve Traffic Flow:** Various Traffic Management measures have been proposed for improvement in traffic flow along the two identified corridors viz., Sanathnagar to Nalgonda X Roads and Punjagutta to Secunderabad. A total of two scenarios have been developed for the these corridors as mentioned below:

i) Flyover Scenario
ii) GEP Scenario

i) Flyover Scenario

A flyover of length about 12km is proposed on the first corridor from Sanathnagar to Nalgonda 'X' road with suitable number of up & down ramps. Accordingly road network with stabilized speeds was updated by adding flyover network. With this updated network, by using trip distribution model purpose-wise, OD matrices were derived and then mode wise OD matrices were obtained by applying the modal split model results. Then the traffic was assigned on to the updated network. Mode wise vehicle kilometers traveled (VKT) and traffic speeds were estimated for the flyover corridor for the years 2011 & 2021. This then has been compared with BAU scenario for the years 2011 & 2021.

ii) GEP Scenario

In GEP Scenario the following measures have been considered for the two identified corridors:

- ❖ Reduction of Side friction
- ❖ Provision of Foot path
- ❖ Synchronization of Traffic Signals along with junction improvements to reduce intersection delays

2.6.4 **Reduction of Side Friction:** The zig-zag parking, on-street parking, encroachments and presence of hawkers significantly reduce the effective carriageway width of roads. The provision of Guardrails, Signboards, and carriageway edge lines would result in increased road capacity as well as average speed. Speed-flow relationship was developed for base year for speeds on links with parameters such as traffic flow, side friction and link length for roads of various widths. By using this relationship, the traffic speeds in improved situation were calculated.

2.6.5 **Provision of Footpath:** The intermixing of vehicles and pedestrian movements in the absence of footpaths results in reduced speeds and increase in number of accidents. The provision of footpaths and pedestrian crossings and traffic enforcement can reduce these conflicts to a great extent and increase the average speed of road traffic.

Speed-flow relationship was developed with availability or non-availability of footpath for the base year. This relationship was then used in estimating the speeds in improved situation.

2.6.6 **Synchronization of Traffic Signals along with Junction Improvements to reduce Intersection delays:** Signal coordination is one of the important measures in traffic management system. In this study, signal coordination exercise has been done by using TRANSYT 11 developed by TRL, UK. Signal coordination has positive impact on improving the traffic speeds. The junction improvements like signal coordination along with proper signages, zebra crossings, stop lines, removal of encroachments, provision of channelisers for free left traffic movement etc.. increases intersection capacity and reduces delays at the intersections. A total of 2 sections, comprising four junctions in each section of Sanathnagar to Nalgonda X Road Corridor were coordinated. The corridor from Punjagutta to Secunderabad was excluded in this scenario because of presence of many flyovers, rotaries and non-signalized intersections. The analysis shows that there can be significant reduction in delays on the Sanathnagar to Nalgonda X road corridor due to signal coordination when compared with BAU scenario. Expected traffic speeds were then worked out on this corridor with this scenario.

2.6.7 **Vehicle Technology/Training Measures related to two-stroke vehicles:** In Hyderabad most of motorized auto rickshaws and 2-wheelers are powered by 2-stroke engines. These engines operate at relatively low compression ratios, do not burn fuels completely and burn a mix of gasoline and lubricating oil. These result in high CO_2, hydrocarbon, CO and high particulate matter emissions. Poor maintenance levels of these vehicles leads to higher emissions. In order to reduce operation costs some of the operators adulterate the fuels, which exacerbate the emissions and engines degradation.

Emission levels of the 2-stroke vehicles can be reduced by better vehicle maintenance and operations. Consultants have held meeting with officials of The Energy Research Institute (TERI), New Delhi to discuss about vehicle maintenance/training measures. During the discussions it was revealed that there could be better results by training the 2-wheeler and auto-rickshaw operators in good maintenance and operations practices. The discussions with these officials also revealed that due to better vehicle maintenance /training, emissions can be reduced by 10% to 20%. In our study, we have assumed that a conservative reduction of 10% in emissions due to better vehicle maintenance/training for car and 2-wheelers.

The penetration rate of the training is assumed to be 5% of 2-wheelers by 2011 and 8% by 2021. Similarly, a conservative estimates of penetration rates of 8% by 2011 and 15% by 2021 of 3-wheeler for the training programmes has been assumed.

2.7 ESTIMATION OF VEHICULAR EMISSIONS

2.7.1 The IVE (International Vehicle Emissions) Model developed jointly by University of California, Riverside, College of Engineering – center for Environmental Research and Technology (CE-CERT), Global Sustainable Systems Research

(GSSR) and the International Sustainable Systems Research Center (ISSRC) has been used for estimation of emissions for BAU and policy options scenarios. The input data for running IVE model are mode wise vehicle kilometers traveled, vehicle startups, average speeds, altitude, humidity, temperature, mode wise driving style distribution, soak time distribution, fuel characteristics, etc. Mode wise driving style distribution, soak time distributions and mode wise vehicle technology distribution were taken to be the same as the Pune Vehicle Activity Study (India) carried out by CE-CERT.

2.7.2 IVE model was then run for BAU, More Effective Public Transit scenario and Traffic Management and Measures to Improve Traffic Flow scenarios as discussed above to estimate the vehicular emissions for the years 2003, 2011 & 2021.

2.7.3 For vehicle/technology training measures, overall reduction in emissions has been worked at assuming a certain level of reduction in existing in 2-stroke vehicles and their penetration rates for the years 2011 and 2021.

2.8 BLOCK COST ESTIMATES

Considering the proposed improvement measures for the various options, quantities have been estimated. Then the corridor wise preliminary cost estimates for the proposed improvement schemes have been worked out on the basis of the unit rates as prevalent in the region for such works. Similarly, assuming training cost per participant for the training programmes and target groups, cost of these training programmes has been worked out.

3.0 EXISTING TRANSPORT SYSTEM IN HYDERABAD

3.1 STUDY AREA

3.1.1 The study area is under jurisdiction of Hyderabad Urban Development Authority (HUDA) and Secundrabad Cantonment Board. The total jurisdiction of HUDA is 1864.87 sq.km. The study area is shown in **Figure 3.1.** The Hyderabad Urban Development Area (HUDA) includes the Hyderabad District (excluding its parts falling in Secunderabad Cantonment Board area), substantial parts of Ranga Reddy District and a small portion of Medak District. The components of different districts in terms of area are as shown in **Table 3.1.**

Table 3.1: Components of Different Districts in HUDA Area

District	Total Area of Dist. in sq.km	Approx. area in HUDA jurisdiction in sq.km	Approx. % of area of total district
Hyderabad	217	173	80
Ranga Reddy	7493	1526	20
Medak	9699	166	2
Total		**1865**	**100**

Source: Draft Master Plan for Hyderabad Metropolitan Area-2020

3.1.2 The Jurisdiction of HUDA may also be considered as the Hyderabad Metropolitan Area (HMA) if we add the small but significant Secunderabad Cantonment Area which is not part of HUDA area. The Secunderabad Cantonment Board is another 40.17 sq. km, making the Hyderabad Metro Area nearly 1905.04 sq. km.

3.1.3 The main components of HUDA area are shown in Table. 3.2.

Table 3.2: Components of HUDA Area

S.No	Components	Area in sq. km/Percentage	Population-2001
1.	MCH	172.6(9%)	3632586
2.	10 Municipalities	418.58(22%)	1717617
3.	Secunderabad Cantonment. Board (SCAB) NOT PART OF HUDA	40.17(2%)	207258
4.	Osmania University (OU), 13 Outgrowths (OG) & 4 Census Towns (CT) in HUA	146.82(8%)	194319
	Sub Total for Hyderabad Urban Agglomeration (HUA)	778.17(41%)	5751780
5.	Other Parts of HUDA area namely Ghatkesar, Medchal and various rural areas not falling in HUA	1126.87(59%)	600000
	Total HUDA area (taking in to account the SCB area)	1905.4	6383033
	Total HUDA area (excluding the SCB area)	1864.87	6150000

Note: Secunderabad Cantonment Board is not part of HUDA area.

Source: Draft Master Plan for Hyderabad Metropolitan Area-2020

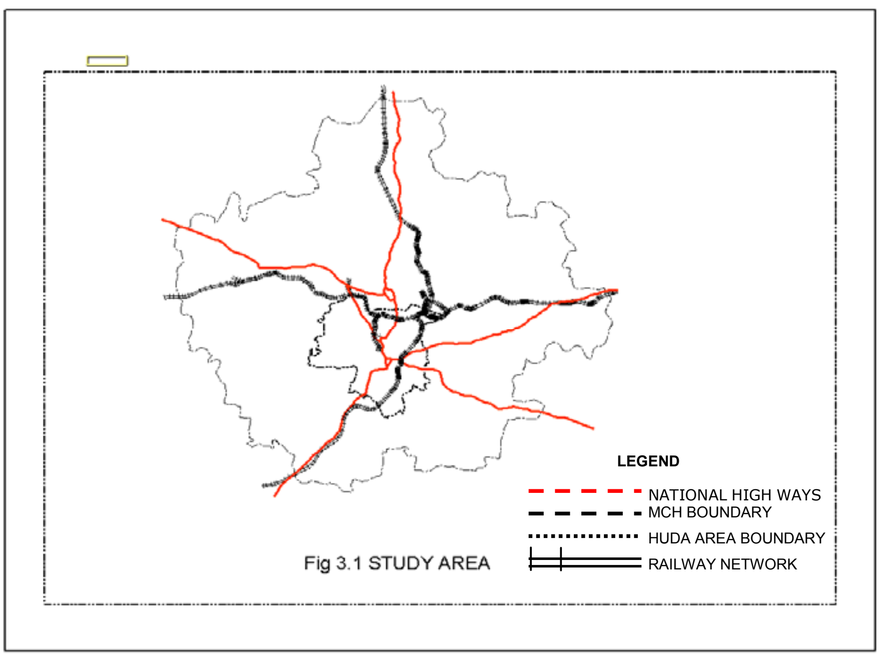


Fig 3.1: Study Area

3.1.4 The Hyderabad city population growth trend is shown in **Table 3.3.** During the past 30 years, Hyderabad Metropolitan Area population has increased at about 4% p.a. It is expected to grow at the same rate for the next 20 years. As per Master Plan, the population for HUDA is expected to be 13.64 million in 2021.

Table 3.3: Hyderabad Population Growth

S. No.	**Year**	**Population (in '000)**	
		Urban Agglomeration	**HMA**
1.	1971	1796	2093
2.	1981	2546	2994
3.	1991	4344	4667
4.	2001	5752	6383
5	2011*	N/A	9055
6.	2021*	N/A	13644

**Projected figures*

Source: Draft Master Plan for Hyderabad Metropolitan Area-2020

3.1.5 The total number of vehicles registered/on Road in HUDA area up to March, 2002 is given in **Table 3.4.**

Table 3.4: Total Number of Vehicles Registered/on road in HUDA

S. No	**Type of Vehicle**	**Hyderabad Dist.**	**Ranga Reddy Dist (RR)**	**Medak Dist.**	**Total HUDA Area=HYD+75 %RR+25%MEDAK**
1	Private Stage Carriages	56	7	6	63
2	Goods Vehicles including TTs	40112	9809	3292	48292
3	Contract Carriages	876	200	314	1105
4	Taxi Cabs	4334	1486	331	5531
5	Auto Rickshaws	68493	2402	3098	71069
6	Private Service Vehicles	1125	379	66	1426
7	School Buses	590	248	47	788
8	Omni Buses	9014	1702	576	10435

S. No	Type of Vehicle	Hyderabad Dist.	Ranga Reddy Dist (RR)	Medak Dist.	Total HUDA Area=HYD+75 %RR+25%MEDAK
9	Car & Jeeps	165764	24415	2559	184715
10	Two Wheelers	929768	242199	52364	1124508
	Total	1220132	282847	62653	1447932

Source: Draft Master Plan for Hyderabad Metropolitan Area-2020

3.1.6 The percentage share and growth of vehicles in HUDA between 1993 & 2002 are given in **Table 3.5.**

Table 3.5: Growth of Vehicles between 1993 and 2002 in HUDA

S. No	Categories	1993	2002	1993-2002 increase (%)
1	Buses	3836(0.66)	12391(0.86)	223.02
2	Auto rickshaws	23874(4.08)	71069(4.91)	197.68
3	Cars & Jeeps	66793(11.41)	184715(12.76)	176.55
4	Two Wheeler	467225(79.78)	1124508(77.06)	140.68
5	Goods Vehicles	16473(2.81)	48292(3.34)	193.16
6	Taxi Cabs	5333(0.91)	5531(0.38)	3.71
7	Pvt. Service Vehicles	2110(0.36)	1426(0.10)	-32.42
	Total	585644(100)	1447932(100)	147.24

Source: Draft Master Plan for Hyderabad Metropolitan Area-2020

3.1.7 The percentage of two-wheelers in total number of motor vehicles in Hyderabad is one of the highest in the country. It may be seen that almost all vehicles have increased significantly in the period 1993-2002. However, increase in buses is largely in inter-city or chartered bus operations. The growth of city buses has been minimal. But the high growth in personalized modes of transport and auto rickshaws has very much increased traffic on roads of Hyderabad.

3.2 PRIMARY TRAFFIC & TRAVEL SURVEYS

3.2.1 The following Primary Traffic and Travel surveys were carried out to assess the traffic and travel characteristics of the commuter traffic in study area as a part of this study and the Hyderabad MRTS study:

a) Turning Movement Traffic Volume Count Survey along with Vehicle Survey Occupancy at major junctions (29 locations)
b) Road Network Inventory Survey
c) Speed and Delay Survey
d) Traffic Signal Time Survey
e) Parking Survey
f) Pedestrian Survey
g) Passenger's Opinion Survey (Public and Private modes)
h) Driver Habits of Two wheeler & Auto Rickshaw drivers
i) Household Travel Survey (Activity Diary & Stated Preference)

3.2.2 The data collected through the above field surveys has been analyzed to assess the present traffic and travel characteristics of the commuters in the study area. The detailed analyses of the surveys have been presented in the following paragraphs.

3.3 TRAFFIC & TRAVEL CHARACTERISTICS

3.3.1 Junction Approach Traffic Volume: Turning Movement Traffic Volume Count Survey along with vehicle occupancy was carried out at total 29 major junctions, during peak period i.e., 8-12AM and 4-8PM on a typical weekday. The traffic data collected at each location was analyzed to assess the traffic flow characteristics. The survey locations are shown in **Figure 3.2.** The approach peak hour volume of traffic at survey locations is given in **Table 3.6.**

Table 3.6: Peak Hour Approach Volume

S. No	JUNCTION NAME	Morning Peak		Evening Peak	
		Vehicles	PCUs	Vehicles	PCUs
1	Erragadda Junction	11736	8799	8856	7294
2	**ESI JUNCTION**	9523	7864	8999	7390
3	S.R.Nagar Junction	11399	8771	11124	8548
4	Maitrivanam Junction	10696	8207	11833	9109
5	Ameerpet Junction	9389	8330	12603	10249
6	Panjagutta Junction	16745	12751	17529	13072
7	Saifabad New Police Station Junction	14966	11598	14393	11978
8	Ravindra Bharathi Junction	15261	12519	14888	12017
9	Police Control Room Junction	17140	14090	16880	13094
10	L.B.Stadium Junction	12085	10635	12016	10420
11	A-1 Junction	14050	11861	16350	13395
12	Lata Talkies Junction	14365	11417	15632	12276
13	Goshamahal Junction	11982	9015	15717	12068
14	M.J.Market Junction	17860	13536	18915	14384
15	Putli Bowli Junction	7933	6631	10083	8066
16	Ranga Mahal Junction	11388	8819	10652	8743
17	Chadarghat Junction	23220	17820	25408	24565
18	Naigara Junction	12917	8980	13366	10345
19	Nalgonda 'X' Road Junction	13470	11013	11927	11233
20	Secunderabad Retifile Junction	8068	6430	6952	5909
21	Sangeet Cinema Junction	6946	5269	5822	4877
22	East Marradepally Junction	6819	5044	5986	4553
23	YMCA Junction	7284	6340	7797	6652
24	Hari Hara Kala Bhawan Junction	5591	4813	3617	3027

S. No	JUNCTION NAME	Morning Peak		Evening Peak	
		Vehicles	PCUs	Vehicles	PCUs
25	Plaza Junction	14565	11431	14397	11798
26	Parade Grounds Junction	8852	6265	8113	6435
27	NTR Junction	14275	10573	11714	9886
28	Green Lands Junction	18784	13548	21502	16028
29	Rajeev Gandhi Statue Junction	13005	9525	12847	9704

Source: RITES Primary Survey, 2003

It can be observed from above table that the maximum traffic is observed at Chaderghat junction with peak hour approach volume of 25408 vehicles (24565 PCUs).

3.3.2 **Road Network Inventory Survey:** The Road Network Inventory survey was carried out along all arterial and sub-arterials roads in the study area as a part of Detailed Project Report (DPR) for Hyderabad MRTS Study in April 2003. The data collected as part of this survey included cross-sectional details such as Carriageway Width, ROW, footpath, median etc. The network comprised a total length of about 419 km.

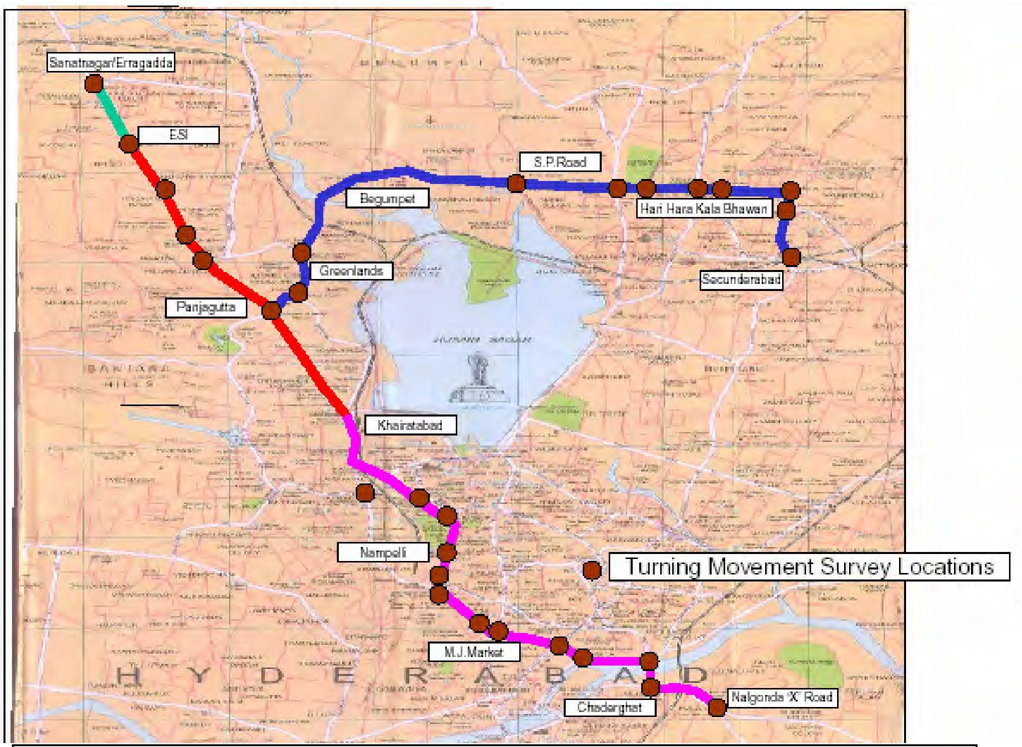


Figure 3.2: Turning Movement Count Survey Locations

3.3.2.1 The distribution of Road Network as per ROW is presented in **Table 3.7.** It can be observed that that about 99% of road length has ROW less than 40m, which indicates that roads cannot be widened significantly to accommodate the growing traffic of personalized and IPT modes.

Table 3.7: Distribution of Major Road Network as per ROW

ROW (M)	Length (KM)	Percentage
<20	174.50	41.66
20-30	240.80	57.48
30-40	0.00	0.00
>40	3.60	0.86
TOTAL	**418.90**	**100.00**

3.3.2.2 The distribution of the road network as per carriageway width is presented in Table 3.8. It can be observed that about 40%

roads are between 2-4 lanes and 60% roads are more than 4 lanes.

Table 3.8: Distribution of Major Road Network as per Carriageway Width

Carriage way width (m)	Length (KM)	Percentage
>=2 and <4 lanes	171.20	40.87
>=4 & <= 6 lane	244.94	58.47
> 6 lane	2.76	0.66
TOTAL	**418.90**	**100.00**

3.3.3 Speed & Delay Survey: Speed & Delay Survey was conducted in a study area as a part of Detailed Project Report (DPR) for Hyderabad MRTS Study in April 2003 using the Moving Car/ Test Car method during peak period. The results of the surveys with respect to the journey speeds are presented in the Table 3.9. It can be observed that more than half of the road length has speed below 20kmph. Average peak hour traffic speed is observed to be about 21kmph.

Table 3.9: Distribution of Road Length by Peak Period Journey Speed

S.No	Journey Speed (Km/hr)	Traffic Stream	
		Road Length (Km.)	**Percentage (%)**
1	< 10	1.48	0.35
2	10 – 20	221.56	52.89
3	20 – 30	151.28	36.11
4	30 – 40	37.76	9.01
6	>40	6.82	1.63
	Total	**418.90**	**100.00**

3.3.4 **Traffic Signal Time Survey:** Traffic Signal Time survey was carried out at 25 major junctions of the two identified corridors of the study area for traffic management scenario. The survey was carried out during peak period on a typical weekday. Delays at these junctions were also noted down. The survey locations haven been shown in **Figure 3.3.** The peak hour cycle times for junctions are shown in **Table 3.10.**

Table 3.10: Peak hour Traffic Signal Time

S.No	NAME OF THE JUNCTION	Peak Hour Cycle Time (Sec)
1	Erragadda Junction	75
2	E.S.I. Junction	80
3	S.R.Nagar Junction	127
4	Maitrivanam Junction	109
5	Ameerpet Junction	113
6	Panjagutta Junction	72
7	Khairatabad Junction	122
8	Saifabad New Police Station	88
9	Ravindra Bharathi	94
10	Control Room	104
11	L.B.Stadium	Un Signalized
12	A - 1 Junction	76
13	Lata Talkies	78
14	Goshamahal	59
15	M.J.Market	130
16	Putti Bowli Junction	59
17	Rangamahal	78
18	Chadharghat Junction	116
19	Niagara Junction	Un Signalized
20	Nalgonda X Roads	65
21	Secunderabad Retifile	Signals are not functioning
22	Sangeet Junction	100
23	East Marredpally	Un Signalized
24	Y.M.C.A	Un Signalized
25	Hari Hara Kala Bhavan	127
26	Plaza Junction	Un Signalized
27	Parade Grounds Junction	127
28	N.T.R.Junction	123
29	Green Lands Junction	57
30	Rajeev Gandhi Statue	Un Signalized

3.3.5 **Parking Accumulation Survey:** Parking Accumulation survey was carried out on the two identified corridors of study area for traffic management scenario. The survey was carried out for 12 hours on a typical weekday (10 am to 10 pm). The survey locations are shown in **Figure 3.4.** In the analysis, section wise parking accumulation has been established. The peak hour parking accumulation on major stretches are shown in **Table 3.11.** It is observed that most of the road stretches have high parking of two-wheelers, cars and auto-rickshaws.

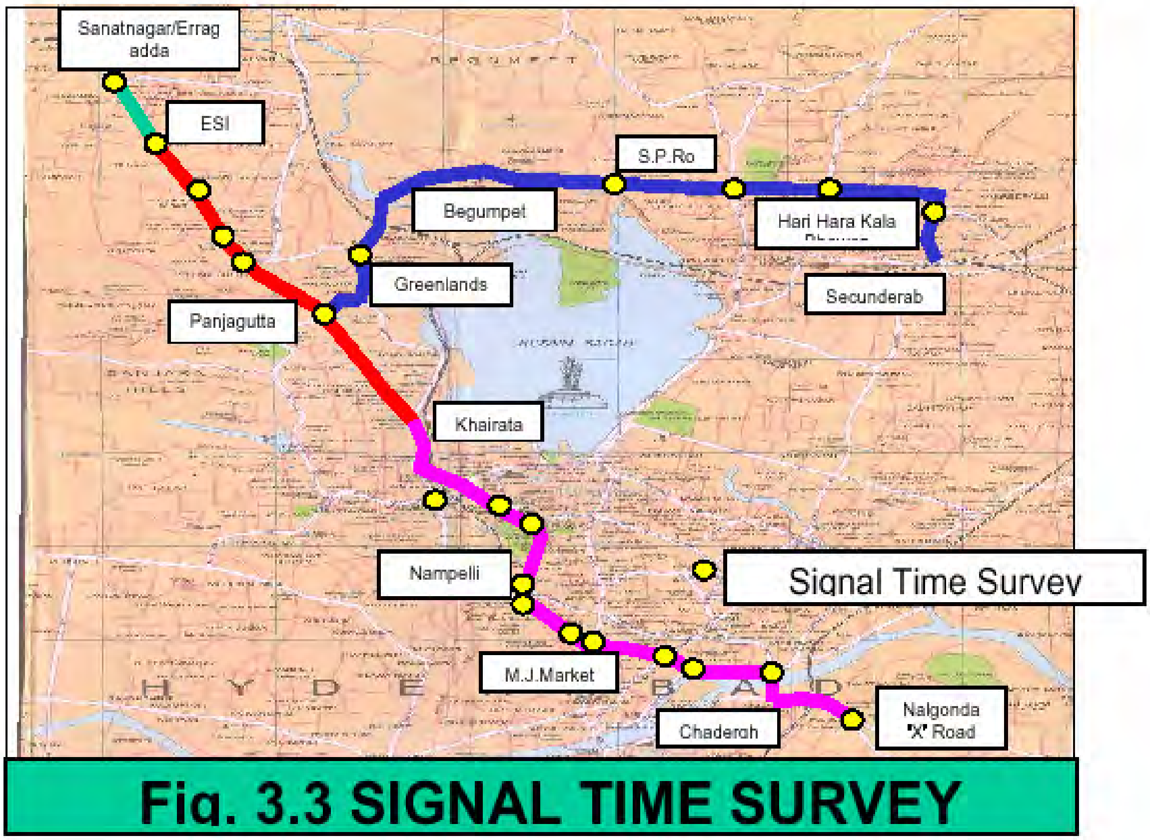


Figure 3.3: Signal Time Survey

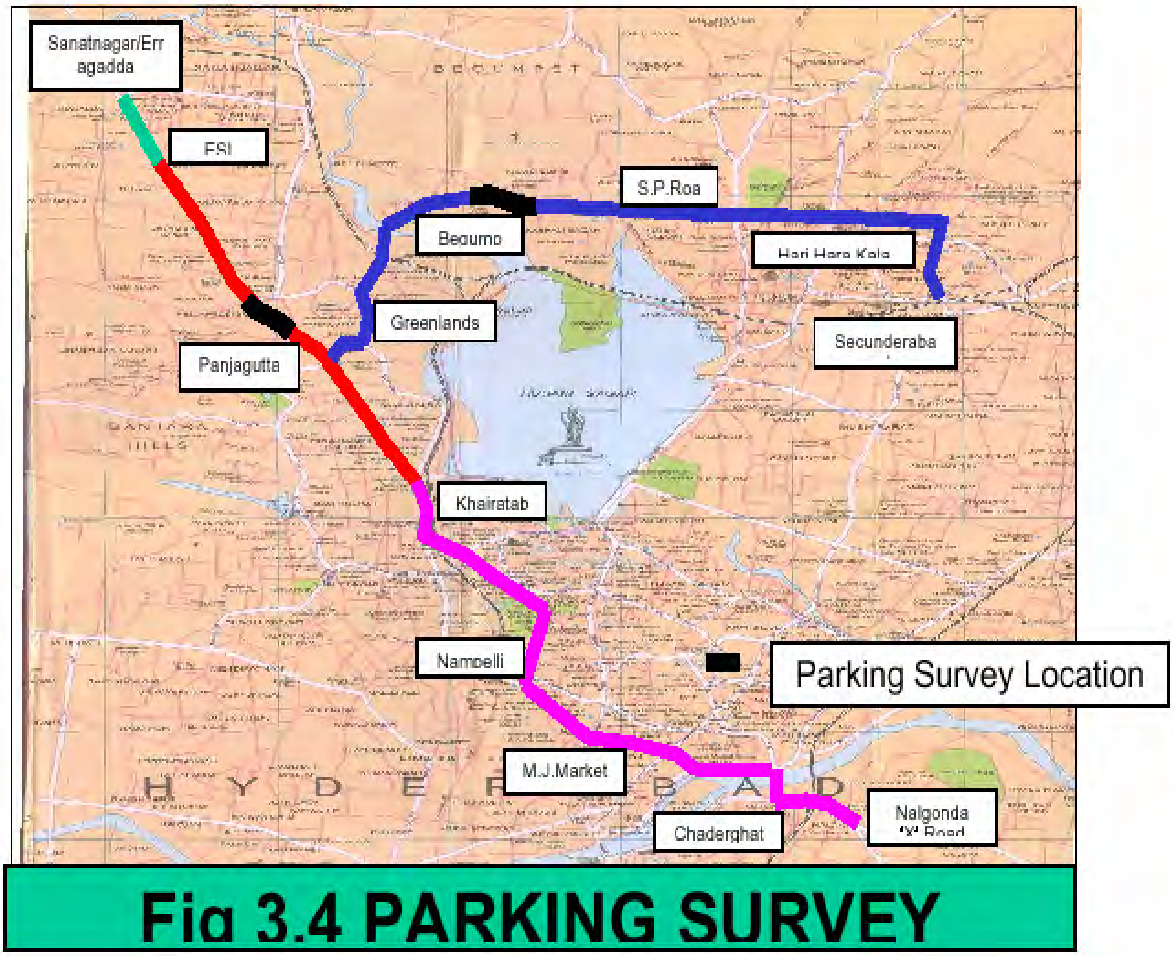


Figure 3.4: Parking Survey

Table 3.11: Peak Hour Parking Accumulation

S. No	Location Direction	Name of Section	Parking Accumulation				
			2w	Car	Auto Rick.	Cycle	Total ECS
1	Ameerpet to Shalimar	Fantoosh to R.S. Fashion	39	5	4	7	**20**
		R.S.Fashion to Hotel Abhilasha	25	16	14	14	**39**
		Hotel Abhilasha to Shalimar	70	16	19	12	**55**
2	Shalimar to Ameerpet	Swadesi Khadi Bhandar to Gopi Photo Studio	48	24	4	13	**43**
		Gopi Studio to Chandana Bros	97	24	38	18	**90**
		Chandana Bros to Shalimar	25	14	16	8	**38**
3	Mayur Marg to Begumpet Air Port	Mayuri Marg to Begumpet Airport	20	10	6	16	**24**
		Begumpet Airport to Mayuri Marg	42	22	14	12	**49**

3.3.6 **Pedestrian Count Survey:** Pedestrian Count survey was carried out at 6 locations on demo corridors of the study area. The survey was carried out for 12 hours on a typical weekday (8 am to 8 pm). The survey locations have been shown in Figure 3.5. The daily and peak hour pedestrian volumes at the survey locations are presented in Table 3.12. The analysis indicates quite high pedestrian traffic at these locations. The Peak Hour cross pedestrian traffic is highest at the Panjagutta Junction and M.J. Market Junction.

Table 3.12: Pedestrian Volume

S.No	Location	Daily Pedestrian Volume		Peak Hour Pedestrian Volume	
		Along	Across	Along	Across
1	Erragadda Junction	5524	5948	706	725
2	S.R.Nagar Junction	5160	7367	597	895
3	Ameerpet Junction	7969	8341	937	939
4	Panjagutta Junction	6283	7609	962	1125
5	M.J.Market Junction	8412	7350	1091	956
6	Khairatabad Junction	8648	5910	1402	908

3.3.7 Household Travel Survey - Hyderabad MRTS & Activity Diary Surveys

3.3.7.1 **Zoning:** The objective of the survey was to collect the socio-economic characteristics of the Households and individual trip information and Activity Diary of the individuals from the household survey. The study area was divided into 129 zones. These 129 zones consist of MCH area, 10 Municipalities and remaining area of Hyderabad Urban Development Authority (HUDA) area. The division of the zones was carried out to obtain the zones with homogenous population. The traffic analysis zone map is shown in **Figure 3.6.** The list of traffic zones is presented in **Annexure 3.1.** The zone- wise land use parameters (population & employment) for base year 2003 and horizon years 2011 and 2021 have been estimated based on HUDA master plan and presented in **Annexures 3.2 & 3.3.**

Figure 3.5: Pedestrian Survey Locations

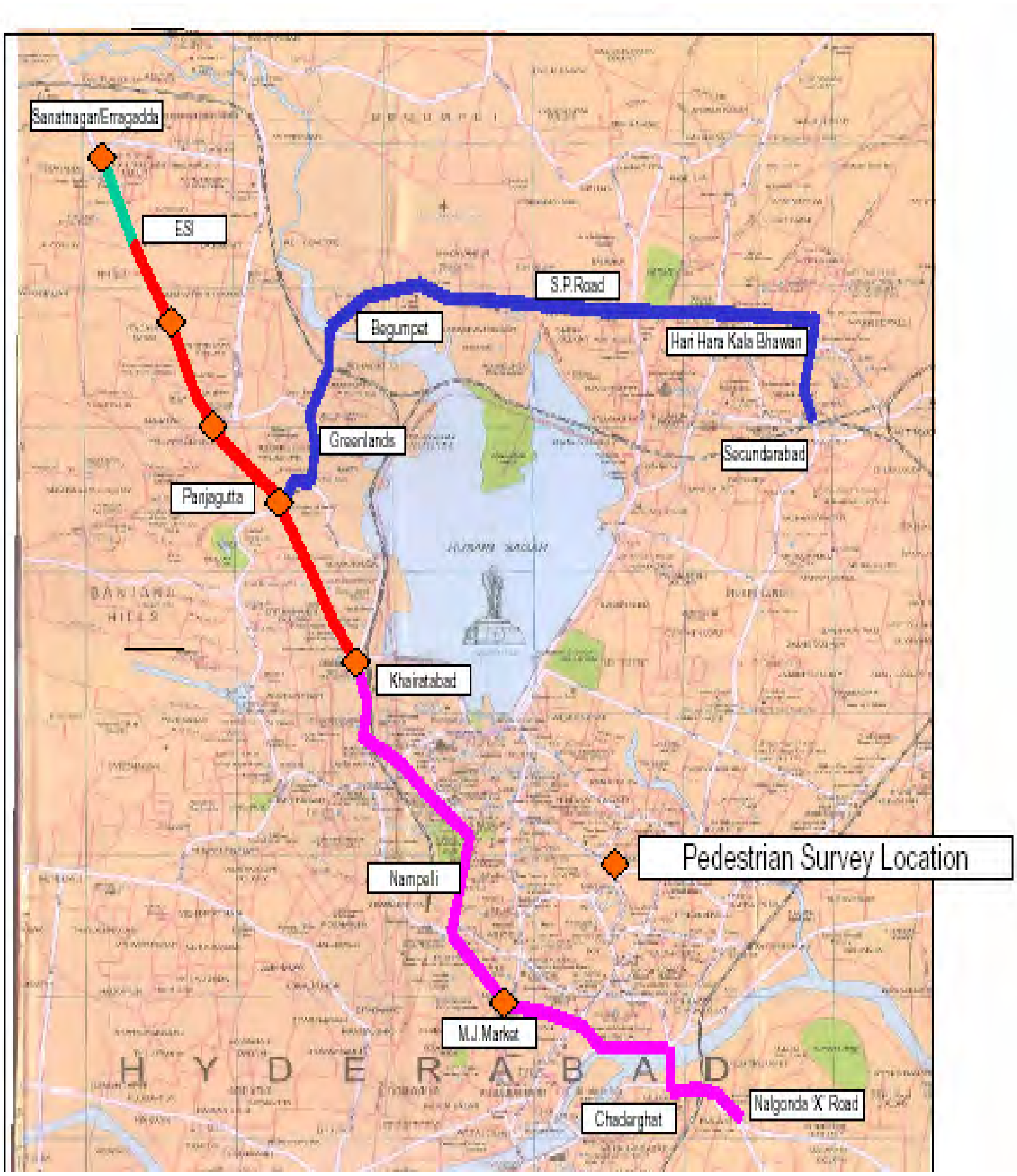


Fig. 3.6 ZONAL MAP OF HUDA

Figure 3.6: Zonal Map of HUDA

3.3.7.2 **Sample Size:** A household travel survey for 5500 household samples was collected as a part of Detailed Project Report (DPR) study for Hyderabad MRTS in April-May 2003. In addition to this about 1500 household surveys were carried out to get the information of Activity Diary of the individuals in the study area. 5500 samples of MRTS study have also been used for the analyses. Thus a total sample of about 7000 households has been made use of from all the traffic zones by random sampling basis. Stratification of the sample was done to cover various income groups. The zone wise distribution of sample size is given in **Annexure 3.4.**

3.3.7.3 **Survey Format:** The survey format covered the socio-economic profile of the household providing details like Household size, Education Levels, Income, Vehicle Ownership, the individual trip information of the members of the household, which provides the details of all the trips performed on the previous day, by the household members and their complete activities performed. The survey format of Activity Diary survey is enclosed in **Annexure 3.5.**

3.3.7.4 **Training Of Enumerators:** The enumerators with minimum graduate qualification were selected and were trained in-house by ICF and RITES experts to carryout the survey. Pilot survey was then carried out to obtain the response from the households and minor modifications were later incorporated in the proforma, based on the pilot survey. The pilot survey also helped in the training of the enumerators.

3.3.7.5 **Field Survey:** The survey was carried out after 6 PM on weekdays and during daytime on weekends so that the head of the household and other members were available.

3.3.7.6 **Output/Results:** The following outputs are derived from the analysis of the Household and Activity Diary surveys: zone wise distribution of the Households according to Household size, Household income and Vehicle Ownership, zone wise distribution of the individuals by their occupation, education and expenditure on transport, distribution of trips by mode and purpose, trip length frequency distribution by time.

Distribution Of Household By Size

Distribution of households according to its family size is presented in **Table. 3.13.** The table indicates that only 2.08% of the households have 1 or 2 members. Majority of households (86%) have 3 to 6 persons per households. The average household size is 4.8.

Table 3.13: Distribution of Households According to Size

S. No.	Household by Size	Number of HH	Percentage
1	Up to 2	144	2.08
2	3 – 4	3374	48.78
3	5 – 6	2572	37.18
4	7 – 8	732	10.58
5	>8	95	1.37
	Total	**6917**	**100.00**

Distribution of Household by Vehicle Ownership

Distribution of households owning motorized vehicles is presented in **Tables 3.14 to 3.16. Table 3.14** indicates that 61% of households own two wheelers, 2% own car, and 10% households having both car and two wheelers, whereas 27% households have no motorized vehicle. **Table 3.15** indicates in that only about 10% households have 1 car or more. However, **Table 3.16** indicates that about 71% of households have one or more scooters/motor cycles.

Table 3.14: Number of Vehicle Owning Households by Type

S No	Type of Vehicle	Number of Household Owning Vehicle	Percentage
1	Car	144	2.08
2	Scooter/Motor Cycle	4227	61.11
3	Car & Scooter/Motor Cycle	687	9.93
4	No Vehicles	1859	26.88
	Total	**6917**	**100.00**

Table 3.15: Distribution of Households by Number of Cars Owned

S. No.	No of Cars Owned	Number of Sampled HH	Percentage
1	No Car	6243	90.26
2	1	622	8.99
3	2	40	0.58
4	3+	12	0.17
	Total	**6917**	**100.00**

Table 3.16: Distribution of Households by Number of Scooters/Motor Cycles Owned

S. No.	No. of Scooters/ M. Cycles Owned	Number of Sampled HH	Percentage
1	0	2022	29.23
2	1	3935	56.89
3	2	791	11.44
4	3	133	1.92
5	4+	36	0.52
	Total	**6917**	**100.0**

Distribution of Individuals by Occupation

Distribution of individuals of sampled households according to their occupation is presented in **Table 3.17**. It is observed that a little over 32% of individuals are engaged in Government Service, Private Service & Business. Interestingly the number of students is also accounted for by similar percentages.

Table 3.17: Distribution of Individuals by Occupation

S. No.	Occupation	Number of Individuals in Sampled Households	Percentage
1	Govt. Service	2146	6.49
2	Pvt. Service	4759	14.39
3	Business	3937	11.90
4	Student	10376	31.37
5	House Wife	8421	25.46
6	Retired	1112	3.36
7	Unemployed	878	2.65
8	Others	1452	4.39
	Total	**33081**	**100.00**

Distribution of Individuals by Education

Distribution of individuals of sampled households according to their education is presented in **Table 3.18.** Graduates and post-graduates account for nearly 28% of the individuals. About 7% are illiterates.

Table 3.18: Distribution of Individuals by Education

S. No.	Education	Number of Individuals in Sampled Households	Percentage
1	Below 10 th. Class	9612	29.06
2	10 th. Class	6503	19.66
3	Intermediate	5335	16.13
4	Graduate	7740	23.40
5	Post Graduate	1567	4.74
6	Illiterate	2149	6.50
7	Others	175	0.53
	Total	**33081**	**100.00**

Distribution of Households by Monthly Household Income

Distribution of Households according to monthly Income ranges is presented in **Table 3.19**. It is observed that about 44% of households have monthly income less that Rs. 5000 and another 34% have income between Rs. 5000-10,000 per month. The percentage of households having monthly income more than Rs. 20,000 is only 4%. Average household income per month in the study area has been observed to be Rs. 7300.

Table 3.19: Distribution of Households According to Monthly Household Income

S. No.	Income Group	Number of Sampled Households	Percentage
1	< Rs. 5000	3039	43.94
2	Rs. 5000 – 10000	2337	33.79
3	Rs. 10000 - 15000	892	12.90
4	Rs. 15000 - 20000	335	4.84
5	> Rs. 20000	314	4.54
	Total	**6917**	**100.00**

Distribution of Households by Monthly Expenditure on Transport

Table 3.20 gives the distribution of the Households according to monthly expenditure on Transport. The table indicates that about 38% of Households spend less than Rs. 500 per month on transport and over 34% have monthly expenditure on transport ranging between Rs. 500-1000. Only 5% of Households are having more than Rs. 2000 expenditure per month on transport. Average monthly expenditure on transport per household is Rs. 835, which is more than 11% of the average household income.

Table 3.20: Distribution of Households According to Monthly Expenditure on Transport

S. No.	Expenditure on Transport	Number of Sampled Households	Percentage
1	Up to Rs. 500	2654	38.37
2	Rs. 500 - 750	932	13.47
3	Rs. 750 - 1000	1401	20.25
4	Rs. 1000 - 1250	530	7.66
5	Rs. 1250 - 1500	602	8.70
6	Rs. 1500 - 2000	409	5.91
7	> Rs. 2000	389	5.62
	Total	**6917**	**100.00**

Distribution of Trips by Mode of Travel

Distribution of trips according to mode of travel is given in **Tables 3.21 to 3.23.** It is observed that 30% of the trips are walk trips. 31% the trips are performed by 2 Wheelers and 28% performed by bus. Trips performed by rail and cycle rickshaw are only 0.4%, where as trips performed by auto rickshaws, shared Auto and 7-Seaters are nearly 6%. Per capita trip rate for the base year 2003 is observed to be 1.203

including walk trips. If walk trips are excluded, share of two-wheelers in total demand goes upto 44% while the share of bus system becomes 40%. Per capita trip rate is observed to be 0.840 excluding walk trips.

Table 3.21: Modal Split - 2003 (Including Walk)

S.No.	Mode	No. Of Trips	Percentage
1	Walk	2473970	30.21
2	Cycle	241003	2.94
3	2 Wheeler	2541161	31.03
4	Car	176605	2.16
5	Auto (3 seater)	412181	5.03
6	7 Seater	54578	0.67
7	Bus	2257244	27.57
8	Rail	18000	0.22
9	Cycle Rickshaw	13569	0.17
	TOTAL	**8188311**	**100.00**

Table 3.22: Modal Split - 2003 (Excluding Walk)

S.No.	Mode	No. Of Trips	Percentage
1	Cycle	241003	4.22
2	2 Wheeler	2541161	44.47
3	Car	176605	3.09
4	Auto (3 seater)	412181	7.21
5	7 Seater	54578	0.96
6	Bus	2257244	39.50
7	Rail	18000	0.31
8	Cycle Rickshaw	13569	0.24
	TOTAL	**5714341**	**100**

Table 3.23: Modal Split - 2003 (Motorized Trips)

S.No.	Mode	No. Of Trips	Percentage
1	2 Wheeler	2541161	46.54
2	Car	176605	3.23
3	Auto (3 seater)	412181	7.55
4	7 Seater	54578	1.00
5	Bus	2257244	41.34
6	Rail	18000	0.33
	TOTAL	**5459769**	**100**

Purpose-wise Distribution of Trips

Table 3.24 gives the purpose wise distribution of the trips. It is observed from the table that about 26% of the trips are performed for work and business purpose together, where as 19% trips are education and 7% for other purpose trips which includes shopping, social, health and recreation. 49% of total trips are return trips.

Table 3.24: Purpose-wise Distribution of Trips – 2003

S. No.	Purpose	No. Of Trips	Percentage
1	Work	2091356	25.54
2	Education	1541409	18.82
3	Others	547615	6.69
4	Return	4007931	48.95
	TOTAL	8188311	100.00

Distribution of Trips by Total Travel Time

Distribution of trips according to Total Travel Time is given in **Table 3.25**. It is observed that about 65% trips are having travel time less than 30 min, however 27% of the trips are having travel time between 30 min-60 min, where as 8% of the trips are having travel time more than 60 min.

Table 3.25: Distribution of Trips by Total Travel Time

S. No.	Travel Time (min)	No.of Trips (Sampled)	Percentage
1	0 – 15	14118	35.80
2	15 – 30	11638	29.51
3	30 – 45	6754	17.12
4	45 – 60	4036	10.23
5	60 – 75	1599	4.05

S. No.	Travel Time (min)	No.of Trips (Sampled)	Percentage
6	75 – 90	861	2.18
7	90 – 105	229	0.58
8	105 – 120	163	0.41
9	> 120	43	0.11
	Total	39441	100.00

Other Household Characteristics

As a part of Activity Survey, other household characteristics were also collected and the results are given in **Annexure 3.6.**

3.3.8 HOUSEHOLD TRAVEL SURVEY-STATED PREFERENCE SURVEY

Stated Preference (SP) survey was carried out to know the modal preferences of respondents. About 3500 household surveys were carried out to get the inherent modal preferences of the individual spread over the study area. The total 3500 samples were drawn from all the traffic zones by random sampling basis. Stratification of the sample was done to cover various income groups. The survey format covered the socio-economic profile of the household providing details like Household size, Education Levels, Income, Vehicle Ownership, the trip information of Head of the Household or regular trip Maker of the household and also SP survey choice sets (10 choices sets each) with improved modes and existing modes. The survey format of SP survey is enclosed in Annexure 3.7. The SP survey results have been used to assess the share of different modes in future for various policy options. The results are presented in later chapters of this report.

3.4 VEHICLE EMISSION SURVEYS AND CHARACTERISTICS

3.4.1 The present study has attempted to generate air quality data for a few pollutants viz., Respirable Particulate Matter (RSPM or PM_{10}), Total Suspended Particulate Matter (TSPM), Sulphur dioxide (SO_2), Oxides of Nitrogen (NO_x), Carbon monoxide (CO), and Hydrocarbons (HC) along with atmospheric temperature and wind velocity along the two identified corridors of the study area for Traffic Management scenario.

3.4.2 Vehicular Emission Surveys

3.4.2.1 The vehicular emissions survey was carried out in the following demo corridors:

a) Sanathnagar/Erragada junction to Nalgonda X-Road (NH-9).
b) Panjagutta junction to Secunderabad Retifile bus station via Green Lands road, Begumpet road, S.P. Road, Hari Hara Kala Bhavan.

3.4.2.2 The vehicular emissions monitoring was carried out in following locations (5 Junctions & 6 Mid Blocks) during typical working day continuously from 6 am to next day 6 am (24 hours) along with atmospheric temperature and wind speed measurements. In mid blocks sections, survey was carried out at one side/median of the road depending upon the site conditions. The ambient air quality monitoring stations are shown in **Figure 3.7.** The sampling locations along with the sampling date are shown in **Table 3.26.**

Table 3.26: Sampling Locations along with the Sampling Date

Station Code	Sampling Location	Sampling Date
A	Ravindra Bharathi Junction	03.03.03-04.03.2003
B	Ameerpet Junction	03.03.03-04.03.2003
C	Rajeev Gandhi Junction	04.03.03-05.03.2003
D	NTR/Rasoolpura Junction	04.03.03-05.03.2003
E	Sangeet Theatre Junction	05.03.03-06.03.2003
F	Nalgonda X Roads Junction	05.03.03-06.03.2003
G	Mid point of Hari Hara Kala Bhavan and Parade Ground Fly Over	06.03.03-07.03.2003
H	Chaderghat (Mid point)	06.03.03-07.03.2003
I	Erragada near Gokul Theatre (Mid point)	07.03.03-08.03.2003
J	Panjagutta near NIMS Hospital (Mid point)	07.03.03-08.03.2003
K	MJ Market near Care Hospital (Mid point)	07.03.03-08.03.2003

3.4.3 AIR QUALITY MONITORING

3.4.3.1 Respirable Dust Samplers (ENVIROTECH-APM 460) were used for monitoring. Monitoring was carried out on 24 hourly basis. RSPM was collected on Glass Fiber Filter Paper (Whatman) on 8 hourly intervals, while gaseous sampling (APM 411) was carried out for every 4 hours by drawing air at a flow rate of 0.5-0.6 LPM. CO was monitored with CO analyzer (NEOTOX-XL) and Hydrocarbons were monitored using portable GC analyzer (FOX BORO – OVA 128) at 1-hour interval. Temperature and Wind Speed were recorded using thermometer and anemometer respectively on hourly basis.

3.4.3.2 Particulate matter was determined gravimetrically. SO2 was determined by West and Geake method and NO_x was determined by Jacob-Hoccheiser method. TSPM, RSPM, SO_2

and NO_x were reported in µg/m^3 at normalized temperature and pressure. CO and HC are reported in PPM.

3.4.4 AIR QUALITY EXPOSURE INDEX (AQEI)

3.4.4.1 For assessing the ambient air quality (AAQ) status, Air Quality Exposure Index (AQEI) concept has been used. Among the various air quality indices, Oak Ridge- Air Quality Index (ORAQI) is found most useful in depicting ambient air quality parameters (SPM, SO_2 and NO_x) into a single value, as it clearly defines the AAQ status and also meets the criteria of uniform AQI, suggested by Thom and Off (1975). QRAQI is calculated using the equation:

$$ORAQI = (a \sum Ci/Si)^b$$

Where a and b are constants, Ci is monitored/predicted concentration of pollutant 'i' and S is National Air Quality Standard for pollutant "i".

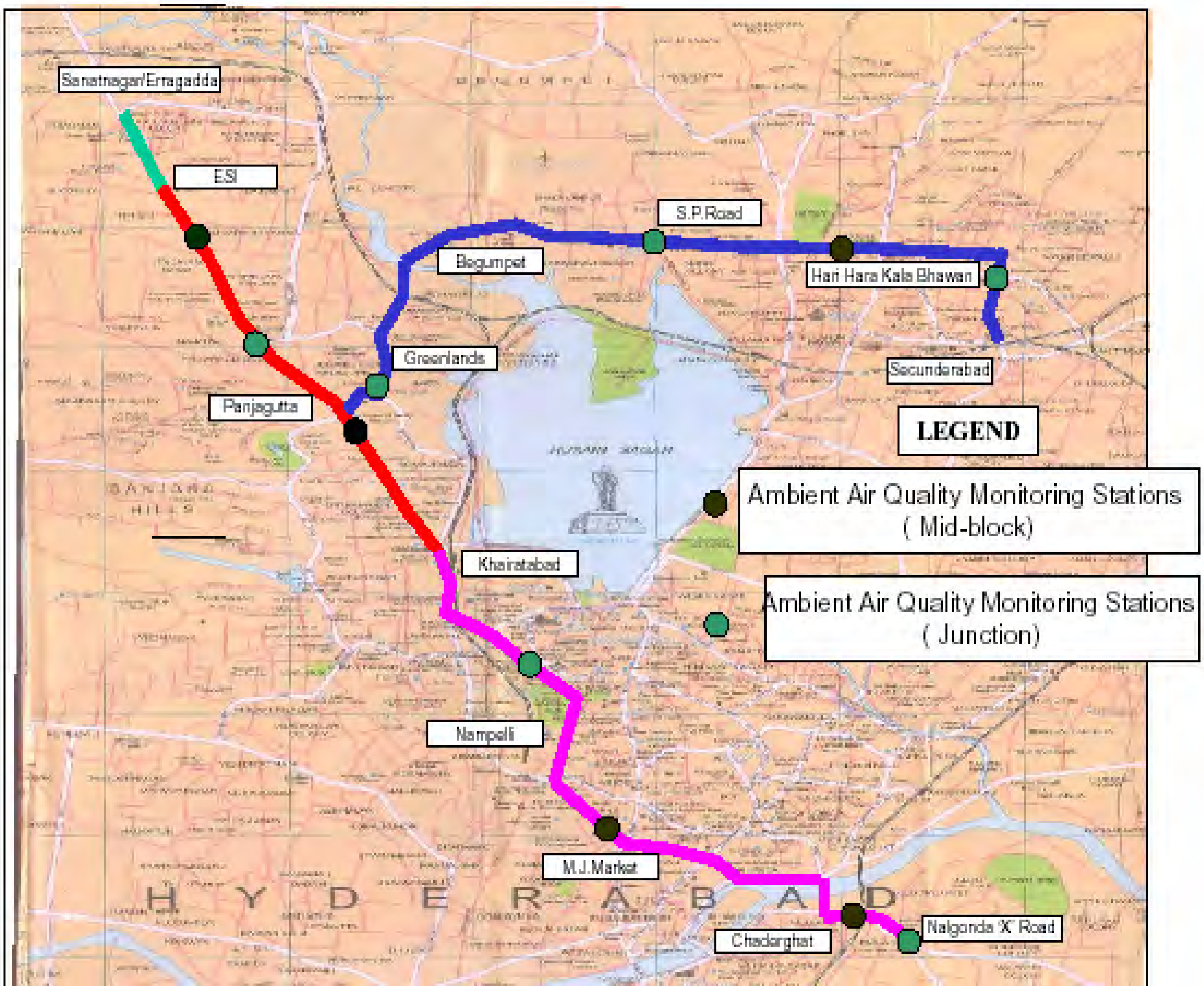


Figure 3.7: Ambient Air Quality Monitoring Stations

The constants a and b are estimated as a = 39.02 and b = 0.967, with the assumption that AQI 10 corresponds to back ground concentration levels of SPM, SO_2 and NO_x and AQI 100 corresponds to the pollutant concentration equal to the permissible standards. The above equation for three pollutants is

$$ORAQI = (39.02 \sum Ci/Si)^{0.967}$$

The descriptor category are given below:

ORAQI	Category
<20	Excellent
20-39	Good
40-59	Fair
60-79	Poor
80-99	Bad
>100	Dangerous

3.4.5 AMBIENT AIR QUALITY

3.4.5.1 **Temperature and Wind Speed:** The hourly recorded atmospheric and wind speed during the study period at various locations is given in **Annexure 3.8** respectively. The temperatures were in the range between 20.6 ^{0}C and 36.1 ^{0}C and the wind speed values were between 0.3kmph and 9.6kmph. The values recorded at different locations are more or less in the same range.

3.4.5.2 **Particulate Matter:** The 8 hourly observed TSPM and RPM values in the study area at different monitoring stations are shown in **Table 3.27.** Maximum and minimum values of TSPM are 1061 µg/m^3 and 344 µg/m^3. Maximum values were observed at Sangeet Cinema Hall junction during 6-14 hrs, and minimum value at Chaderghat during 22-6 hrs. The maximum and minimum concentrations of RPM were 665 µg/m^3 and 54 µg/m^3, maximum value was observed at MJ market during 6-14 hrs and minimum value at Rajeev Gandhi junction during 22-6 hrs.

Table 3.27: RSPM and TSPM (μg/m³) Concentrations in the Study Area

Sample Code	Sampling Station	RSPM (μg/m³)			TSPM (μg/m³)		
		Time					
		6-14	14-22	22-6	6-14	14-22	22-6
	Ravindra Bharati Junction	167	119	279	396	417	636
	Ameerpet Junction	242	143	152	445	293	403
	Rajeev Gandhi Junction	123	123	54	381	768	190
	NTR/Rasoolpura Junction	178	169	189	469	404	468
	Sangeet Theatre Junction	329	368	183	1061	871	444
	Nalgonda X Roads	112	268	225	558	646	754
	Hari Hara Kala Bhavan	169	235	224	463	550	372
	Chaderghat RUB	335	193	101	945	634	344
	Erragadda Junction	211	358	232	372	1057	369
	Punjagutta Junction	307	229	109	1126	759	785
	MJ Market Junction	665	387	594	1027	533	767

The variations in the average concentrations of SPM and RSPM for different locations are depicted in **Annexure 3.9.** The concentrations were observed to be high when compared to National Ambient Air Quality (NAAQ) Standards of TSPM 200 μg/m³ and RSPM 100 μg/m³ for commercial area respectively. Observed high levels reflect the base line conditions of surrounding area activities of study area.

3.4.5.3 **Gaseous Pollutants:** The 4 hourly values of SO_2 and NO_x are given in **Tables 3.28 to 3.29** respectively. The SO_2 concentrations were in the range of 9.6 μg/m³ to 69.5 μg/m³, while NO_x values are found to be in the range between 19.5 μg/m³ and 216.3 μg/m³. Maximum values of SO_2 and NO_x were observed at Chaderghat during 10-14 hrs, while minimum values of SO_2 and NO_x were observed at Ameerpet and MJ market during 22-2 hrs respectively.

The average Values of SO_2 and NO_x are shown in **Annexure 3.10** respectively. The average values of SO_2 and NO_x are well below the prescribed standards of 80 μg/m^3 for commercial area except at Chaderghat where the NO_x value has exceeded the standard.

Table 3.28: SO_2 (μg/m^3) Concentrations in the Study Area

Station Code	*Sampling Station*	Time					
		6-10	**10-14**	**14-18**	**18-22**	**22-2**	**2-6**
A	Ravindra Bharati Junction	26.0	44.7	35.0	22.5	13.6	17.0
B	Ameerpet Junction	44.1	45.3	25.1	30.9	9.6	11.3
C	Rajeev Gandhi Junction	14.8	38.9	48.7	28.6	14.8	15.9
D	NTR/Rasoolpura Junction	18.8	26.8	32.0	25.7	9.6	15.9
E	Sangeet Theatre Junction	18.2	24.0	21.1	18.8	13.6	21.7
F	Nalgonda X Roads	36.6	21.1	22.8	38.9	12.5	18.2
G	Hari Hara Kala Bhavan	21.7	14.2	29.2	18.8	11.3	31.5
H	Chaderghat Rub	33.8	69.5	40.7	36.6	18.8	22.8
I	Erragadda Junction	14.8	49.4	36.8	12.3	24.9	29.3
J	Punjagutta Junction	44.1	11.9	25.1	22.8	13.0	14.8
K	MJ Market Junction	21.1	11.3	13.6	18.8	13.0	18.2

Table 3.29: NO_x ($\mu g/m^3$) Concentrations in the Study Area

Station Code	*Sampling Station*	Time					
		6-10	10-14	14-18	18-22	22-2	2-6
A	Ravindra Bharati Junction	62.2	124.1	97.6	50.1	35.0	34.3
B	Ameerpet Junction	81.4	91.7	60.1	98.3	30.5	26.1
C	Rajeev Gandhi Junction	53.9	71.1	81.4	59.1	29.1	31.2
D	NTR/Rasoolpura Junction	52.2	75.2	95.5	94.2	29.1	35.0
E	Sangeet Theatre Junction	51.5	49.8	39.5	58.4	24.7	56.3
F	Nalgonda X Roads	125.1	57.7	79.0	65.3	20.2	45.7
G	Hari Hara Kala Bhavan	43.6	23.0	79.0	64.2	29.1	74.2
H	Chaderghat Rub	105.5	216.3	114.5	116.5	34.3	48.4
I	Erragadda Junction	21.3	159.6	89.4	34.3	69.4	76.1
J	Punjagutta Junction	104.8	23.6	59.4	60.8	29.1	25.7
K	MJ Market Junction	40.2	21.2	35.1	39.5	19.5	34.3

The hourly CO and HC values are given in **Tables 3.30 & 3.31** respectively. The CO values were in the range between 1.0 ppm and 17.7 ppm. Maximum values are observed at Ravindra Bharathi junction during 17:00 hrs and also at Rajeev Gandhi junction during 18:00 hrs. Minimum values are observed at NTR junction at 1:00 hr. The maximum hourly values of CO are observed to be higher than compared to the standard of 3.5 ppm (on 1 hourly basis).

Table 3.30: Hourly CO (ppm) Concentrations in the Study Area

Station Code/Time	A	B	C	D	E	F	G	H	I	J	K
6.00	6.0	2.0	3.5	1.5	3.2	3.2	1.5	4.0	2.0	2.6	3.3
7.00	4.3	2.8	5.2	2.2	2.7	3.8	2.7	8.2	2.8	2.3	5.7
8.00	8.2	3.5	6.3	5.5	7.0	4.0	3.0	13.7	3.5	3.8	9.3
9.00	11.5	7.0	10.3	11.8	12.3	8.8	13.0	15.0	7.0	12.2	9.2
10.00	14.7	3.5	10.7	16.5	14.5	11.0	14.0	17.2	3.5	13.2	10.0
11.00	13.8	3.7	12.7	15.5	13.3	10.3	13.7	15.8	3.7	14.0	10.3
12.00	12.8	4.8	13.0	8.2	15.0	15.8	13.5	11.7	4.8	12.3	6.0
13.00	11.5	4.0	13.7	2.8	5.7	11.3	7.8	9.5	4.0	3.7	2.8
14.00	10.7	2.8	12.7	4.8	3.0	9.2	3.5	12.5	2.8	2.3	3.2
15.00	13.0	2.3	13.0	4.0	4.5	7.8	3.2	14.2	2.3	4.2	4.2
16.00	12.2	3.3	13.0	4.7	6.7	7.5	9.8	12.0	3.3	6.8	4.0
17.00	17.7	7.2	18.3	14.0	13.8	13.0	15.0	12.8	7.2	12.7	6.3
18.00	19.5	5.8	17.7	13.0	16.2	11.0	13.8	20.2	5.8	13.2	8.8
19.00	20.5	6.7	20.0	13.5	15.2	14.3	11.7	23.5	6.7	12.8	9.8
20.00	16.8	3.8	15.3	12.3	15.3	14.7	4.7	17.3	3.8	13.3	9.8
21.00	8.0	4.7	11.0	7.3	6.0	15.7	4.2	13.2	4.7	7.8	5.8
22.00	3.2	1.8	9.0	3.2	2.7	11.8	3.3	9.7	1.8	2.6	3.7
23.00	2.8	2.2	3.2	1.7	2.5	14.2	4.0	7.2	2.2	2.3	3.5
24.00	2.5	2.2	2.3	1.2	2.2	13.3	3.8	4.7	2.2	2.3	2.3
1.00	3.2	1.3	2.7	1.0	1.5	6.7	4.7	3.7	1.3	1.3	2.2
2.00	3.3	1.3	2.0	1.6	1.2	3.0	3.0	2.7	1.3	1.8	1.0
3.00	1.5	1.5	2.7	1.6	1.2	1.5	2.8	2.8	1.5	2.0	1.0
4.00	2.0	1.3	3.8	1.6	1.5	3.1	1.3	2.8	1.3	2.5	1.2
5.00	3.0	2.3	2.6	1.7	3.3	3.6	2.0	4.0	2.3	2.4	3.9

Table 3.31: Hourly HC (ppm) Concentrations in the Study Area

Station Code/Time	A	B	C	D	E	F	G	H	I	J	K
6.00	4.2	6.0	1.5	4.0	4.5	4.0	1.7	3.5	2.7	4.0	2.5
7.00	2.2	11.7	2.5	5.3	11.0	6.0	6.0	3.3	2.7	4.7	3.7
8.00	3.7	12.3	2.5	7.2	11.8	10.3	5.7	4.3	3.5	4.5	6.3
9.00	12.7	13.0	5.7	14.2	13.2	16.7	10.2	14.5	7.0	9.7	12.5
10.00	10.2	14.0	8.7	12.3	13.0	22.3	13.0	10.8	5.3	12.0	11.0
11.00	13.7	14.7	13.7	14.0	12.0	13.0	13.8	14.0	6.0	14.2	5.2
12.00	11.8	16.2	16.0	7.5	12.3	12.0	11.0	9.0	3.0	8.2	3.8
13.00	3.7	17.2	17.7	4.0	11.7	13.3	10.3	7.7	4.2	2.3	2.5
14.00	3.5	17.0	13.3	6.5	9.7	20.7	7.5	6.2	5.0	1.3	2.5
15.00	2.3	17.3	17.7	17.7	14.3	18.0	13.5	13.7	1.3	2.5	3.7
16.00	8.0	16.2	15.0	14.5	15.0	15.7	19.0	16.5	2.5	6.0	7.0
17.00	13.2	19.3	13.0	11.8	13.0	21.0	20.3	14.2	8.5	12.2	15.2
18.00	13.5	20.0	10.3	8.8	13.5	20.3	15.8	14.2	6.5	12.8	11.5

Station Code/Time	A	B	C	D	E	F	G	H	I	J	K
19.00	15.7	19.3	13.0	13.8	14.2	20.7	9.5	11.0	4.8	12.2	13.5
20.00	9.5	12.3	16.0	7.5	12.0	15.7	3.7	6.7	4.3	9.2	8.2
21.00	7.3	8.5	17.3	3.5	14.3	13.5	3.5	6.5	4.3	3.0	3.5
22.00	4.2	4.0	3.2	2.8	4.3	6.8	5.0	5.5	4.2	3.3	3.3
23.00	1.7	3.5	2.5	2.2	2.8	3.8	3.7	4.3	2.3	3.2	1.8
24.00	2.0	3.3	1.3	3.0	1.3	2.5	3.7	4.7	5.0	2.3	1.5
1.00	1.5	2.0	1.3	1.5	1.5	4.2	4.0	2.5	3.2	1.5	1.3
2.00	1.5	1.3	1.5	1.5	1.7	3.0	6.0	2.0	2.5	1.5	1.5
3.00	1.7	1.8	2.2	1.7	1.5	2.2	3.8	1.7	2.2	1.5	1.7
4.00	1.8	2.2	2.2	1.7	1.5	4.7	1.5	1.8	1.7	2.8	1.3
5.00	3.6	3.3	1.7	2.6	4.3	4.1	2.6	1.7	3.0	3.6	3.3

The HC concentrations were in the range between 1.3 ppm and 22.3 ppm with maximum value observed at Nalgonda X Roads junction during 10:00 hrs and with minimum value at Rajeev Gandhi junction during 24: 00 hrs to 1:00 hr. There are no prescribed standards for HC in the Indian context. The average values of CO and HC are shown in **Annexure 3.11.**

3.4.5.4 **Ambient Air Quality Indices:** There is a need to provide accurate, timely and understandable information about air quality status in the region. Awareness of the daily level of air pollution is often important to those who suffer from illness, which are aggravated or caused by air pollution, as well as to the general public. A typical air pollution index is an interpretive technique, which transforms complex data on measured atmospheric pollutant concentrations into a single number or set of numbers in order to make the data more understandable.

An air quality standard predicts the maximum permissible limit for a particular pollutant to be present in the air so as not to cause any severe health and other damages. When two or more pollutants are present in air in significant amounts, the cumulative effect is observed. The AQEI gives an over all picture of air quality. The AQEI for TSPM, SO_2, and NO_x with respect to commercial standards of Central Pollution Control Board (CPCB) for all the 11 sampling locations are presented in **Table 3.32**.

Table 3.32: Air Quality Exposure Index (AQEI) and Air Quality Categories in the Study Area

Station Code	Sampling Station	24 hourly Avg. Conc. (µg/m³)			AQEI	*Category*
		TSPM	SO_2	NO_x		
A	Ravindra Bharati Junction	295	27	67	103	Dangerous
B	Ameerpet Junction	201	28	129	112	Dangerous
C	Rajeev Gandhi Junction	346	27	54	104	Dangerous
D	NTR/Rasoolpura Junction	268	22	64	91	Bad
E	Sangeet Theatre Junction	499	20	47	125	Dangerous
F	Nalgonda X Roads	451	25	66	127	Dangerous
G	Hari Hara Kala Bhavan	253	21	52	83	Bad
H	Chaderghat RUB	431	37	89	139	Dangerous
I	Erragadda Junction	332	35	75	101	Dangerous
J	Punjagutta Junction	675	30	51	159	Dangerous
K	MJ Market Junction	227	16	32	66	Poor

MJ market junction was observed to be having poor air quality while Hari Hara Kala Bhavan and NTR junction fall under bad air quality category and rest of the sampling locations were observed to be highly polluted and fall under dangerous category. The high air quality indices in the sampling locations reflect that the population residing in these areas are exposed to higher pollution levels which are bound to escalate in near future due to ever expanding population growth and related activities such as transport and growing commerce.

Hence, it is clear that most of the localities in Hyderabad are experiencing the air pollution stress and the trend is likely to worsen in near future if proper control measures are not implemented.

The National Ambient Air Quality (NAAQ) standards are presented in **Annexure 3.12.**

3.5 EXISTING BUS TRANSPORT

3.5.1 INTRODUCTION

3.5.1.1 APSRTC (Andhra Pradesh State Road Transport Corporation) is the largest bus transport corporation in India. APSRTC finds its place in Guinness Book of World Records as the largest transport undertaking in the world with about 20,000 buses and 1.20 lakh employees. APSRTC bus services carrying large number of commuters both at urban and moffusil levels.

3.5.1.2 The existing public transport in Hyderabad mainly comprises bus system. The bus services are being exclusively operated by the State run APSRTC. The modal share by the bus transit system in Hyderabad at present is about 40% of total vehicular transport demand. Ideally modal share should be more in favor of public transport for the city of size of Hyderabad. This shows that a large proportion of demand is being met by personalized and intermediate modes of transport, which is resulting in increased road congestion and higher emissions. The total bus fleet size in Hyderabad was 2605 in the year 2001-02 with 874 bus routes.

3.5.1.3 The total number of bus stops in Hyderabad City Region are about 1850. The number of bus depots in Hyderabad City

Region are 21 viz., Barkatpura, Faluknama, HCU, Mehdipatnam, Musheerabad, Rajendranagar, Diksukhnagar, Hayatnagar, Ibrahimpatnam, Midhani, Uppal, Contonment, Hakimpet, Kushiguda, Ranigunj-I, Ranigunj-II, BHEL, Jeedimetla, Kutkatpally, Medchal and Miyapur Depots.

3.5.2 Hyderabad City Region Bus Operating Characteristics

3.5.2.1 The various operating characteristics of city bus system for Hyderabad City Region are given in **Annexure 3.13.** It is apparent from the Annexure that bus fleet has been increasing steadily over the last 6 years. However, a disturbing fact is the reduction in number of passengers carried per day. Number of passengers carried per bus per day has decreased from 1500 in 1996-97 to 1180 in 2001-02. This indicates a 20% decrease in per bus productivity in last 6 years. Load factor has also decreased from 75% to 59% during this period although daily bus utilization has been more or less the same (about 240 km/day). The decreasing patronage of the available bus system indicates growing usage of motorized two wheelers and auto rickshaws (3 and 7 seaters). Incidentally whereas 3-seater auto rickshaw run as taxis, the 7 seater auto rickshaws run as stage carriage vehicles (illegally). Increased popularity of two wheelers and auto rickshaws is due to their lower operating costs, higher frequency/availability and door-to-door services. These vehicles instead of becoming complimentary have become competitors to the bus system. Due to mounting losses in city bus services, APSRTC has not been able to augment its fleet substantially. Passenger comfort level in buses has also declined. These factors have also contributed to proliferation and use of personalized and intermediate modes of transport. Higher use of two wheelers and auto rickshaws is leading to higher levels of vehicular pollution in the city. Higher average age of buses (about 7 years) is also contributing to the increased emission levels.

3.5.2.2 The large number of routes have come up due to popular demand for operation of public bus system in various interior areas and also because of urban sprawl. This has resulted in two drawbacks. Firstly the bus system has become a 'destination oriented' system in low frequencies and poor quality of service. At the same time, buses have also to ply on narrow roads that are more suitable for operation of mini buses, auto rickshaws etc. that should act as feeders to buses. The buses, accordingly, compete with their feeder system. The congested roads increase the travel time of buses reducing their productivity and attractiveness. This is also resulting in 7-seater auto rickshaws competing with bus system on wide roads, where generally buses only should ply.

3.5.3 FARE STRUCTURE

3.5.3.1 The bus fare structure of APSRTC and other major State Transport Undertakings (STUs) in India are presented in **Annexure 3.14.** This table indicates that fare rates are higher in Hyderabad than many of the other city bus services in India. This is specially so in the case of short distance travel. In this case, auto rickshaws compete favorably with buses in respect of fare structure. The auto rickshaws, because of the additional advantage of higher frequency and door-to-door service gain an edge over buses. With higher fares, commuters find two wheelers and auto rickshaws attractive. These modes, apart from lower operating costs / fares, offer better accessibility and reduce travel time. With bus routing structure becoming more destination oriented than direction oriented, travel time of bus passengers is increasing. All these factors induce bus passengers to shift to other modes.

3.5.3.2 In 1994, APSRTC introduced metro liner and metro express buses with better facilities and slightly higher fares than ordinary buses to capture the two and three wheeler users. They could achieve the objective and successfully captured a part of the two-wheeler traffic.

3.5.4 Bus Passes Scenario In Hyderabad City Region

3.5.4.1 Financial burden, due to concessional fares and free passes as announced by the government, becomes inevitable to STUs. APSRTC also has to bear financial loss due to a large number of concessional passes and free passes.

3.5.4.2 The glance of bus passes in Hyderabad City Region (HCR) is given below:

- ❖ No of bus pass counters - 17
- ❖ Types of Passes Issued - 27

(Mainly Student pass (General), APSRTC employees pass, Student Route pass, Special Student General Bus Pass, Dist. Route Pass, Setwin Trainees bus pass, Greater Hyderabad Student Pass, General Commuter bus pass, Season ticket bus pass, NGOs Pass, Free pass for below 12 years, Girls free pass up to 10th class or up to 18 years, Physically Handicapped pass, Freedom fighters pass, Journalist, Special Privilege pass especially to CM/VVIP security staff).

- ❖ Avg. no. of bus pass issues per month - 3.27 Lakh
- ❖ Avg. no. of passes in Circulation per month - 5.05 Lakh
- ❖ Amount Realized per month (Avg) - 8.00 Cr
- ❖ Loss due to concessions on bus passes (Avg) per month - 5.00 Cr

3.5.5 FINANCIALS OF THE CITY REGION

3.5.5.1 The following table shows a snapshot of the financials of APSRTC-Hyderabad City Region for the last seven years are shown in **Table 3.33.**

Table 3.33 Financial Status of APSRTC-Hyderabad City Region (Rs. in million)

Year	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
REVENUE							**(Up to Feb'02)**
Traffic Revenue	1652.980	1922.577	2216.606	2328.007	2613.040	2842.843	2458.264
Hired Revenue	0.00	0.00	0.00	0.00	0.566	74.164	178.125
Other Revenue	26.383	21.887	35.218	35.725	36.882	44.476	44.825
	1679.363	**1944.464**	**2251.824**	**2363.732**	**2650.488**	**2961.483**	**2681.214**
EXPENDITURE							
Personnel Cost	811.667	875.587	1075.951	1183.719	1331.259	1357.699	1127.791
Workshop Maintenance	80.580	94.663	99.860	94.367	112.105	104.687	84.911
Fuel Cost	304.330	351.172	434.832	455.788	594.743	752.780	690.254
Tyres & Tubes	69.950	87.763	84.436	71.572	69.755	64.740	49.796
Stores & Lubricants	59.550	68.116	70.340	68.256	72.697	65.906	56.208
MV Taxes	199.992	285.738	330.928	347.760	390.485	423.950	335.360
Depreciation	150.704	155.475	136.881	128.482	130.731	118.543	132.544
Miscellaneous	31.125	43.250	42.452	48.041	47.790	48.779	54.988
Hire Charges	0.00	0.00	0.00	0.00	0.757	117.665	277.837
Suspense	0.00	0.00	0.00	0.00	14.236	30.167	19.314
R.O. Overheads	23.887	35.210	4.022	2.739	21.229	18.057	32.680
Z.O. Overheads	28.933	28.479	38.185	41.644	42.274	39.616	43.297
H.O. Overheads	43.308	28.278	23.601	92.491	6.343	147.777	191.423
	1756.252	**1983.311**	**2341.488**	**2534.859**	**2834.404**	**3193.918**	**3096.403**
LOSS	**-76.889**	**-38.847**	**-89.664**	**-171.127**	**-183.916**	**-23.2435**	**-415.189**

Source: Ferguson & Co. Study Report, June 2002.

3.5.5.2 It can be observed from above table that the over the period of time, the expenditure has been increasing faster than the revenue, leading to increase in loss. The losses are less than the loss due to the concessional passes. If Government were to compensate APSRTC for the loss in revenues due to concessional passes, then the Hyderabad City Region Bus System could have made some profits.

3.5.6 Motor Vehicle Tax Structure for Stage Carriages in India

3.5.6.1 The comparative motor vehicle tax structure of major cities has been presented in **Annexure 3.15.** It is observed that in Karnataka, the taxes are 3% of the passenger revenue for city operation and 6% of the passenger revenue for rural operation against 10% and 12.5% respectively in Andhra Pradesh.

3.5.6.2 The total taxes and motor vehicle (M.V) Tax &permit fees per bus held per year for various major state transport undertakings during 2000-2001 are presented in **Table 3.34.**

Table 3.34: Total Tax per Bus per Year (2000-2001)

S. No	Name of the STU	Total Taxes		M.V.Tax and Permit fees per bus held per year (Rs)	Total Tax per bus held per year (Rs)
		Rs. in million	Ps./Km		
1	APSRTC	3687.6	169	192737	194639
2	MSRTC	3687.8	205	5188	218060
3	KnSRTC	330.8	67	80760	80760
4	BEST	265.6	109	4915	77449
5	CN-I&II	50.0	24	21485	21602
6	BMTC	77.0	45	34019	34019
7	DTC	240.2	65	6776	55485

Source: ***Association of State Transport Undertakings: Profile & Performance 2000-01,*** 3.5.6.3 It is observed from above table that the taxes in Andhra Pradesh are very high as compared to other STUs except Maharashtra. In 2000-2001, APSRTC paid an annual tax of about Rs. 1.94 lakh per bus per year. The APSRTC is paying tax about Rs. 470 per bus per day.

3.5.7 Motor Vehicle Taxes

3.5.7.1 The motor vehicle taxes of other modes are as follows:

- 2-Wheelers: 9% of cost of vehicle. It is about Rs. 300 per year
- Car: 9% of cost of vehicle. It is about Rs. 3000 per year
- 3-seater auto rickshaw: Rs. 100 per quarter i.e., Rs. 400 per year
- 7-seater auto rickshaw: Rs. 200 per seat per quarter i.e., Rs.1200 per quarter i.e., Rs. 4800 per year

3.5.7.2 A recent study carried out by ASCI (Administrative Staff College of India), Hyderabad has indicated that a passenger traveling by a three wheeler 3-seater auto pays less than 1paise(ps) per trip as road tax, a seven seater auto pays 4 ps and a bus passenger pays 48ps as road tax per trip. A scooterist pays 19ps per trip and a car owner pays about 45ps per trip. Hence the passenger traveling by buses pays more taxes than a richer passenger traveling by a two or three wheeler. This lop sided taxation has resulted in 3-seater and 7-seater autos offering services some times at less than bus fares. It has resulted in two-wheeler travel becoming cheaper than bus travel and hence significant increase in two-wheeler population.

4.0 TRANSPORT DEMAND MODELING & FORECASTING

4.1 TRANSPORTATION STUDY PROCESS

4.1.1 The Transportation Study Process consists of development of formulae or models, enabling future travel demand to be forecasted and alternative strategies for handling this demand to be assessed. It is not just one model, but a series of inter-linked and inter-related models of varying levels of complexity, dealing with travel demand. Through these models, the transportation study process as a whole is checked and calibrated before it is used for future travel predictions. This has been done by developing the formulae to synthesize the present day movement patterns and adjusting the same until these represent observed conditions. Only when the formulae have been adjusted or calibrated, so that they can adequately predict the present day travel movements, these are used in true predictive mode to determine future conditions.

4.1.2 In the present study, an attempt has been made to develop operational models. The normal and easily available planning variables at zonal levels such as population, employment, no of workers residing, no of students residing and student enrollment have been made use of in this transport analysis.

4.1.3 The basic functions included in the transportation study process are:

- ❖ Trip-end prediction or trip generation: the determination of the number of person trips leaving a zone irrespective of the destination and the number of trips attracted to a zone, irrespective of origin.

- ❖ Trip Distribution: the linking of the trip origins with their destinations-or of generations with attractions.

- ❖ Modal Split: the separation of trips by public transport modes or by private modes

- ❖ Assignment: the allocation of trips between a pair of zones to the most likely route(s) on the network.

4.1.4 **Trip Categorization:** The passenger transport demands in terms of daily passenger trips have been broadly categorized as intra-city and inter-city trips. The intra-city trips have further been considered as inter-zonal trips and intra-zonal trips. The inter-zonal trips are the most important so far as transport analyses are concerned and have further been classified as home-based trips and non-home based trips. Home based trips for the purpose of transport modeling have been classified as work trips, education trips and other trips. Non-motorized trips were not modeled, as they were insignificant in volumes.

4.1.5 The non-home based trips and inter-city trips, which, do not form a significant proportion of total transport demand, are not being modeled. The proportion of non-home based trips was about 4.5% of total home-based trips as observed in base year (2003) for Hyderabad.

4.2 TRIP GENERATION

4.2.1 The first of the sub-models in the conventional study process is that which predicts the number of trips starting and finishing in each zone. The techniques developed attempt to utilize the observed relationships between travel characteristics and the urban environment and are based on the assumption that trip making is a function of three basic factors:

- The land use pattern and development in the study area
- The socio-economic characteristics of the trip making population of the study area
- The nature, extent and capabilities of the transportation system in the study area

4.2.2 Mathematically can be expressed as:

Trips Generated = Function (Socio-economic, locational, etc. variables)

4.2.3 Various techniques for developing trip generation models are available and notable among these include:

- Regression analysis
- Category Analysis

4.2.4 In most of the studies conducted so far, generally least square regression analysis technique has been used to develop trip generation models. For the purpose of present study the regression analysis technique has been adopted for the development of trip generation sub models for home based trips for various purposes. Attempts have been made to develop simple equations using normally available variables, which can be forecasted with reasonable degree of accuracy. Methodology adopted for developing trip generation models is presented in **Figure 4.1**.

4.2.5 A typical regression analysis trip generation model might be:

$$G = a_1x_1 + a_2x_2 + \ldots\ldots\ldots\ldots + a_kx_k + a_0$$

Where G = Number of trips per zone for a specified purpose.

$a_0, a_1, a_2, \ldots, a_k$ = Coefficients determined by regression analysis.
$x_0, x_1, x_2, \ldots, x_k$ = Zonal planning input factors (Independent variables).

4.3 TRIP GENERATION & ATTRACTION MODELS

4.3.1 A number of trip production and attraction models for inter-zonal trips (both motorized and non-motorized) were attempted. The trip production models / trip attraction models were developed relating zone-wise trips produced/trips attracted with a various independent variables. These production models are

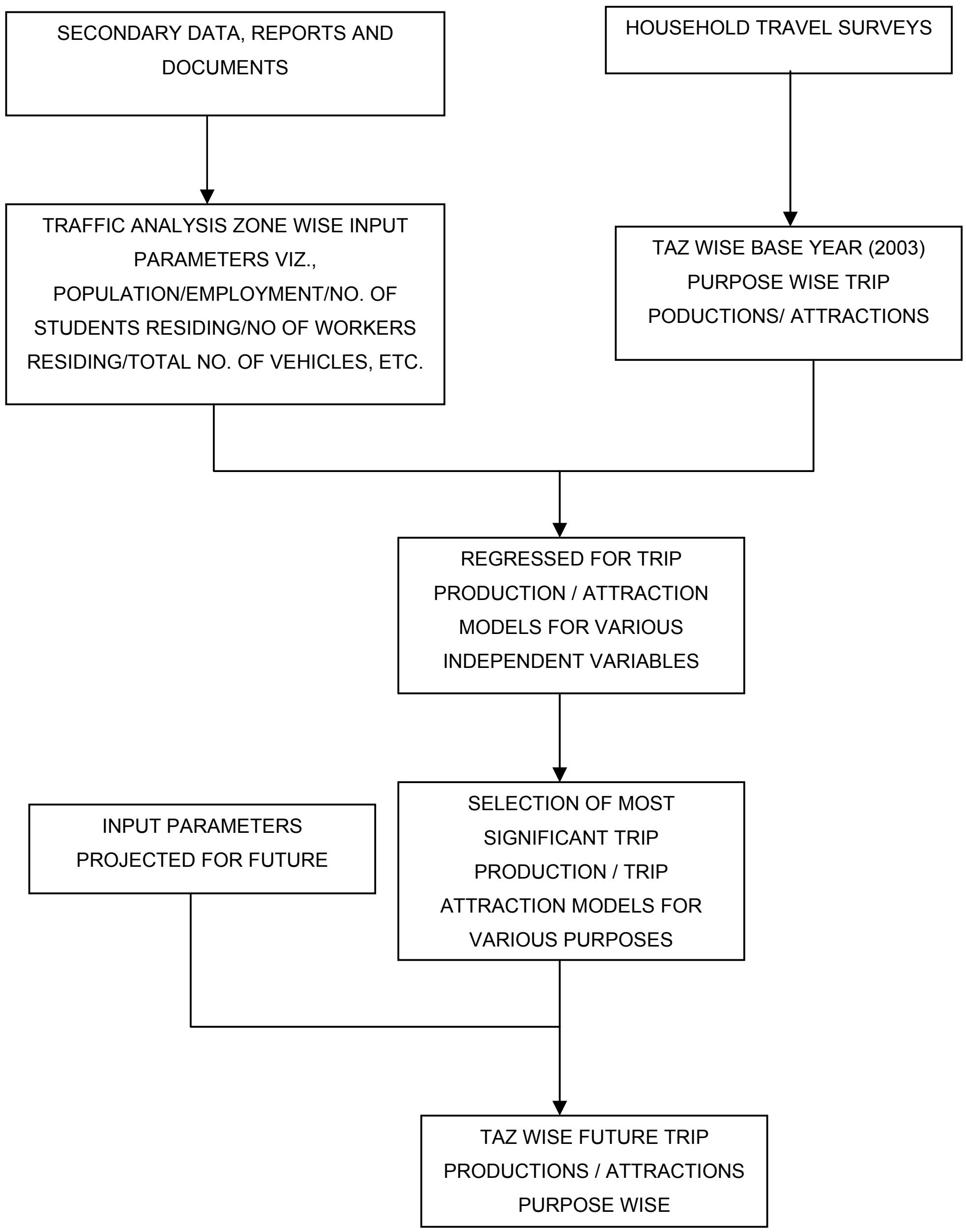


Figure 4.1 Development of Trip Generation Models

presented in **Table 4.1** and attraction models are presented in **Table 4.2**. These tables also give the statistical significance of all variables tested. Models were built separately for work, education, other purpose trips and total trips. Models developed also include combination of the some independent variables. Zone wise trip productions and attractions for the year 2003 are presented in **Annexure 4.1**.

Table 4.1: Trip Production Models Attempted

Sl No	TRIP PURPOSE	POPULATION	NO OF WORKERS RESIDING	NO. OF STUDENTS RESIDING	NO OF CARS	NO OF 2 WHEELERS	TOTAL VEHICLES	AVG. MONTHLY INCOME	ACCESSIBILITY RATING	ZONE WISE NO OF HHs	AVG. HH SIZE	DISTANCE FROM CBD	INTERCEPT	R SQUARE	F - VALUE	STANDARD ERROR
1	WORK	0.2854 (12.90)	-	-	-	-	0.041 (0.043)	-	-	-	-	-	706.57	0.92	692	3150.8
2	WORK	0.294 (37.327)	-	-	-	-	-	-	-	-	-	-	681.95	0.92	1393	3140.7
3	WORK	-	0.8622 (38.61)	-	-	-	-	-	-	-	-	-	1283.58	0.92	1491	3044.46
4	WORK	-	0.7355 (14.24)	-	-	-	0.206 (2.708)	-	-	-	-	-	1242.97	0.93	786.36	2971.27
5	WORK	-	0.862 (38.41)	-	-	-	-	- 0.002 (-0.03)	-	-	-	-	1306	0.92	739.65	3056.51
6	WORK	-	0.697 (12.76)	-	-0.125 (-0.66)	0.327 (3.34)	-	-	-	-	-	-	1112.35	0.93	536.811	2939.68
7	WORK	-	0.75 (14.64)	-	-	-	0.187 (2.47)	-	723.44 (2.250)	-	-	-	-197.01	0.93	542.91	2924.3
8	WORK	-	0.707 (13.21)	-	-0.22 (-1.17)	0.33 (3.45)	-	-	843.72 (2.64)	-	-	-	-595.16	0.93	423.62	2871.75
9	WORK	-	0.866 (39.30)	-	-	-	-	-0.039 (-0.46)	840.433 (2.54)	-	-	-	-76.399	0.92	516.5	2992.54
10	EDUCATION	0.2341 (23.29)	-	-	-	-	-	-	-	-	-	-	-403.8	0.81	542.6	4002.89
11	EDUCATION	-	-	0.6805 (22.32)	-	-	-	-	-	-	-	-	636.36	0.8	498.61	4141.4
12	EDUCATION	0.2342 (23.2)	-	-	-	-	-	- 0.0169 (-0.154)	-	-	-	-	-262.03	0.81	269.27	4018.3
13	EDUCATION	-	-	0.6808 (22.299)	-	-	-	0.085 (0.754)	-	-	-	-	- 96.15	0.78	248.7	4148.4
14	OTHERS	0.0627 (8.75)	-	-	-	-	-	-	-	-	-	-	935.9	0.38	76.56	2854.8
15	OTHERS	0.0627 (8.71)	-	-	-	-	-	- 0.006 (-0.075)	-	-	-	-	986.68	0.38	37.98	2866.1
16	OTHERS	0.08 (3.99)	-	-	-	-	-0.083 (-0.9269)	-	-	-	-	-	888.14	0.38	38.67	2856.4
17	OTHERS	0.0501 (2.24)	-	-	- 0.5865 (-3.24)	0.1546 (1.33)	-	-	344.34 (1.100)	-	-	-	116.64	0.43	23.15	2767
18	OTHERS	0.0505 (2.19)	-	-	-	0.064 (0.5596)	-	-	-	-	-	-	954.64	0.38	38.233	2862.61
19	OTHERS	0.0636 (8.784)	-	-	-	-	-	-	-	-	-	36.022 (0.9017)	540.603	0.38	38.633	2856.97
20	TOTAL TRIPS	0.0573 (11.88)	-	-	-	-	0.08 (0.386)	-	-	-	-	-	462.06	0.9	585.6	658.08
21	TOTAL TRIPS	-	0.755 (4.69)	0.682 (5.22)	-	-	0.526 (3.078)	-	-	-	-	-	2319.01	0.91	423.72	6632.53
22	TOTAL TRIPS	0.5978 (12.48)	-	-	-	-	-0.157 (-0.075)	-	2036.59 (2.74)	-	-	-	-2894.61	0.91	413.08	6709.6
23	TOTAL TRIPS	0.5913 (34.33)	-	-	-	-	-	-	-	-	-	-	1214.05	0.9	1178.9	6857.78
24	TOTAL TRIPS	-	-	-	-	-	-	-	-	536.239 (14.89)	-	-	3652.8	0.64	221.76	13270.4
25	NO OF TRIPS PER HH	-	-	-	-	-	-	-	-	-	0.3384 (1.8729)	-	1.3748	0.03	3.5	0.847

Note: (Values above represent Co-efficient for the Parameters)

(Values in brackets represent "t" statistics of the parameters)

Table 4.2: Trip Attraction Models Attempted

SI No	TRIP PURPOSE	EMPLOYMENT	STUDENT ENROLLMENT	POPULATION	DISTANCE FROM CBD (KM)	ACCESSIBILITY RATING	INTERCEPT	R SQUARE	F - VALUE	STANDARD ERROR
1	WORK	0.408 (2.841)	-	-	-	-	10074.477	0.059	8.07	20358.45
2	WORK	0.4457 (3.300)	-	-	-1143.62 (-4.32)	-	20541.83	0.181	13.9368	19074.339
3	WORK	-	-	-	-1088.267 (-3.968)	-	26701.236	0.1103	15.75	19803.41
4	EDUCATION	-	0.419 (10.023)	-	-	-	4975.195	0.441	100.4688	10700.46
5	EDUCATION (EXCLUDING WALK)	-	0.8259 (9.87)	-	-	-	922.03	0.44	97.58	9474
6	OTHERS	0.0599 (1.8246)	-	-	-	-	3344.34	0.0255	3.329	4652.849
7	OTHERS	-	-	-	-159.58 (-2.505)	-	5783.21	0.047	6.275	4601.15
8	OTHERS	0.019 (0.519)	-	0.03 (2.26)	-138.57 (2.186)	-	3680.645	0.113	5.338	4473.075
9	OTHERS	-	-	0.034 (3.026)	-133.24 (-2.136)	-	3723.5144	0.111	7.918	4460.1
10	OTHERS	0.065 (2.032)	-	-	-167.706 (-2.659)	-	4879.33	0.077	5.28	4545.45
11	OTHERS	0.061 (1.91)	-	-	-81.472 (-1.057)	1154.211 (1.908)	1884.56	0.103	4.808	4498.51
12	OTHERS	0.058 (1.823)	-	-	-	1529.17 (3.120)	422.388	0.095	6.647	4500.62
13	TOTAL TRIPS	0.374 (1.843)	2.345 (9.23)			-	9502.6	0.441	49.64	28200

Note:

(Values above represent Co-efficients for the Parameters) (Values in brackets represent "t" statistics of the parameters)

4.3.2 Various trip production models for one-way work trips were developed relating zone wise work trips produced with following independent variables:

i) Population
ii) Total number of vehicles (no of cars & 2 wheelers combined),
iii) No of workers residing in the zone
iv) Average household monthly income
v) No. of cars
vi) No. of 2 wheelers
vii) Accessibility rating (represented by no of bus routes connecting to a zone to other parts of the study area with assigned ratings –1(least connected), 2 (medium connected) and 3(highly connected))

4.3.3 It was observed from all the models tested that the variables No. of Workers Residing in the zone and zone wise Total no of cars and 2 wheelers are highly significant in estimating one-way work trips produced from a zone.

4.3.4 Attraction models for one-way work trips attracted to a zone were related to independent variables

i) Employment
ii) Distance from CBD

4.3.5 From the models developed it was found that zone wise employment is the most significant in estimating the one-way work trips attracted to a zone.

4.3.6 The selected statistical significant models for one-way work trips produced/ attracted from / to a zone by all modes are presented in **Table 4.3**.

Table 4.3 : Selected Trip Generation Sub-Models For Home Based One-Way Work Trips

Dependent Variable	Independent Variable	Constant Term	Co-efficient	R^2 Value
Work Trips Produced	No of Workers Residing	1242.97	0.7355 (14.24)	0.9258
	No. of Cars and 2 Wheelers	-	0.206 (2.708)	
Work Trips Attracted	Employment	10074.48	0.408 (2.841)	0.059

4.3.7 One-way education trips produced from a zone were related to following independent variables:

Population

i) of students residing

ii) Average Household Monthly Income

4.3.8 From all the variables tested it was found that no of students residing in zone is the most significance in estimating education trips produced from a zone.

4.3.9 One-way education trips attracted to a zone were related to zone wise student enrollment. Student enrollment is found to be most statistically significant in estimating the education trips attracted to a zone.

4.3.10 The selected statistical significant models for one-way education trips produced / attracted from / to a zone by different modes are given in **Table 4.4**.

Table 4.4 : Selected Trip Generation Sub-Models For Home Based One-Way Education Trips

Dependent Variable	Independent Variable	Constant Term	Co-efficient	R^2 Value
Education Trips Produced	No of Students Residing	636.36	0.6805 (22.32)	0.7969
Education Trips Attracted	Student Enrollment	4975.195	0.419 (10.023)	0.441

4.3.11Trip production model for one-way other purpose trips from a zone were related with following independent variables:

i) Population
ii) Average Household Monthly Income
iii) No. of Cars
iv) No. of 2 wheelers
v) Accessibility Rating
vi) Distance from CBD

4.3.12Of all the models developed it was observed that the combination of Zone wise population and Distance from CBD are the most significant in estimating other purpose trips produced from the zone.

4.3.13 One-way other purpose trips attracted to a zone were related with following independent variables

i) Employment
ii) Accessibility Rating
iii) Distance from CBD
iv) Population

4.3.14 From the models developed it was observed that zone wise employment and Accessibility Rating were statistically most significant in estimating other purpose trips attracted to a zone.

4.3.15 The most significant models considered for one-way home based other purpose trips produced / attracted from / to a zone are presented in **Table 4.5.**

Table 4.5: Selected Trip Generation Sub-Models For Home Based One-Way Other Trips

Dependent Variable	Independent Variable	Constant Term	Co-efficient	R^2 Value
Other Trips Produced	Population	540.603	0.0636 (8.784)	0.3703
	Distance from CBD	-	36.022 (0.9017)	
Other Trips Attracted	Employment	422.388	0.058 (1.823)	0.095
	Accessibility Rating	-	1529.17 (3.12)	

4.3.16 Future population and employment were derived from Master Plan for Hyderabad-2020. For estimating zone wise total no of vehicles for base year, total no of households were distributed according to the vehicle ownership viz., no vehicle owning, 1 vehicle owning, 2 vehicles owning, 3 vehicles owning, 4 vehicle owning and 5 & more vehicle owning households as obtained from household survey. Zone wise households were also classified according to household monthly income as obtained from household survey. Zone wise no of households in each income group were classified into various vehicle ownership groups. From this total no of vehicles in each zone were derived. **Figure 4.2** shows the relationship between HH Income and HH vehicle ownership. Based on yearly growth rate of State

Domestic Product it is observed that there is linear trend when extrapolated gives the growth rate as follows

Year	By Linear Trend (p.a)	Adopted (p.a)
2011	15%	10%
2021	25%	12%

4.3.17 Assuming Inflation Rate of 4% the net Income may grow at the rate of 6% up to 2011 and 8% thereon. Above procedure is repeated to obtain the total no of vehicles zone wise for the years 2011 & 2021 after classifying the households according to income and by using the relationship between household income and vehicle ownership.

4.3.18Total daily home-based inter-zonal motorized trips expected to be produced / attracted in the study in the years 2011 & 2021 are 7,706,332 and 11,833,056 against 5,459,769 trips in the year 2003. Considering the selected trip production / attraction models and projected parameters for the selected independent variables, zone wise trip productions and attractions for the years 2011 and 2021 were derived, which are presented as **Annexures 4.2 and 4.3.**

4.4 TRIP DISTRIBUTION

4.4.1 Trip distribution or inter-zonal transfers, is that part of transportation planning process which relates a given number of travel origins for every zone of the study area, to a given number of travel destinations located within the other zones of the study area. It is not necessarily concerned with the mode of travel used for neither a given trip nor the routes, which could be taken to complete this trip. Rather it is concerned with establishing links between a number of zones for which trip generation calculations have primarily been made. In other words, the output of trip generation sub-models becomes the input for trip distribution model.

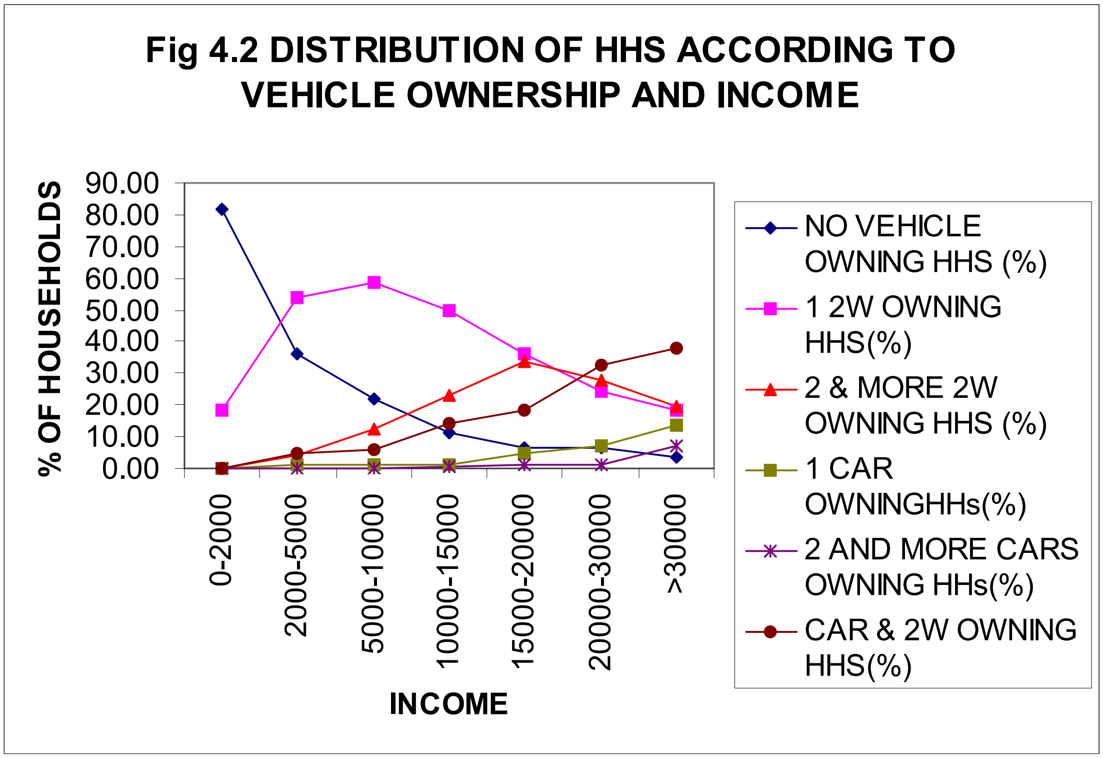


Figure 4.2 : Distribution of HHS According to Vehicle Ownership and Income

4.4.2 Various mathematical procedures have been developed and used for this purpose and these tend to fall in two main groups as under:

- Analogous or Growth Factor methods in which growth factors are applied to present day travel inter-zonal movements.

- Synthetic or inter-area travel formulae in which as attempt is made to understand the casual relationship behind patterns of movement, by assuming them to be similar to certain laws of physical behavior. Once understood, these casual relationships are projected into future and the appropriate travel pattern is synthesized.

4.4.3 Despite the diversity of formulation used in the various mathematical procedures developed, the underlying principle in all trip distribution models is the same.

" Travel between any two points will increase with attraction for such travel, but decreases as the resistance to travel increases."

4.5 TRIP DISTRIBUTION: GRAVITY MODEL

4.5.1 The gravity model is the most widely used synthetic method of trip distribution, because it is simple to understand and apply, and is well documented. For any given trip purpose, the generalized relationship is more usually expressed as

$T_{ij} = K\ P_i\ A_j\ F(C_{ij})$

Where

T_{ij} = Trips from zone i to j

K = A constant

P_i = Total number of trips produced from zone i

A_j = Total number of trips attracted to zone j

$F(C_{ij})$ is the deterrence or trip decay function and is based on the generalized cost of the journey from zones i to j.

4.5.2 The deterrence function is usually in one of the three basic forms:

A power function $F(C_{ij}) = C_{ij}^{-\alpha}$

An exponential function $F(C_{ij}) = e^{-\alpha c_{ij}}$

A gamma function attributed to J.C. Tanner $F(C_{ij}) = e^{-\alpha c_{ij} - \beta c_{ij}}$

Where α & β are impedance parameters.

4.5.3 It has been found that power function is more appropriate to longer distances, basically for inter-urban trips. The exponential function has been used in many studies and has been found to be particularly appropriate in short-distance intra-urban trips. The tanner function, which is the combination of power and exponential function, offers the opportunity to combine the advantages of each of these functions.

4.5.4 The constant K in the general formula is effectively two balancing constants **a** and **b** combined together, one each for correcting the number of generations and attractions.

Thus

$$K = a_i \, b_j$$

Where $$P_i = a_i \, E_j \, T_{ij}$$

$$A_j = b_j \, E_i \, T_{ij}$$

The determination of each of the constants in the distribution model is known as calibration.

4.5.5 For the purposes of analyses in this study, the exponential for M ($e^{-\alpha c_{ij}}$) impedance function has been utilized to have comparisons with earlier studies carried out for Hyderabad. The C_{ij} values, which should normally be based on generalized cost, have been taken only in terms of travel time for different modes due to non-availability of required data. Travel time matrices have been computed and "skim trees" built representing shortest travel paths between each pair of zones taking the congestion into consideration.

4.6 GRAVITY MODEL FORMULATION

4.6.1 For the purpose of distribution of home based trips, the formulation of gravity model used is as under:

$T_{ij}^{n} = P_i^{n} A_j^{n} \exp(-a^{n} C_{ij}^{m}) / E_j A_j^{n} \exp(-a^{n} C_{ij}^{m})$

Where

T_{ij}^{n} = The number of trips produced in zone i and attracted to zone j for n^{th} purpose

P_i^{n} = The total number of trips produced in zone i for n^{th} purpose

A_j^{n} = The total number of trips attracted in zone j for n^{th} purpose

a^{n} = Parameter calibrated for base year for n^{th} purpose

C_{ij}^{m} = Travel time between pair of zones i & j by mode m

4.7 GRAVITY MODEL – CALIBRATION PROCESS

4.7.1 The sequence of activities involved in the calibration of Gravity Model is shown in **Figure 4.3**. Only the home based motorized trips for different purposes (work, education and other), were simulated for comparison with the observed flows.

4.7.2 The calibrated values of Gravity Model Parameters for home-based trips for various purposes are presented in **Table 4.6**. Calibration process includes comparison of observed and simulated mean trip lengths as well as shapes of the trip length frequency distribution.

4.7.3 The observed trip length frequency distributions for different purposes (work, education and other) were obtained from the 2003 travel survey data. For simulated trip length frequency distributions, the parameter values (negative exponential) were varied until the simulated and observed trip length frequency distributions for each purpose exhibited the following:

- The shape and position of both curves were relatively close to each other when compared visually
- The difference between mean trip lengths was within +/- 3%.

4.7.4 The calibration procedure developed by Bureau of Public Roads was used which adjusts the measure of attraction used in the Gravity Model. 25 such iterations of trip attraction balancing procedure were carried out for each trip purpose separately.

Table 4.6 : Calibrated Gravity Model Parameters

Trip Purpose	Parameter Value	Mean Trip Length (min)
Work	0.040378	38.85
Education	0.04672	37.34
Others	0.05963	34.07
Total	0.04342	37.95

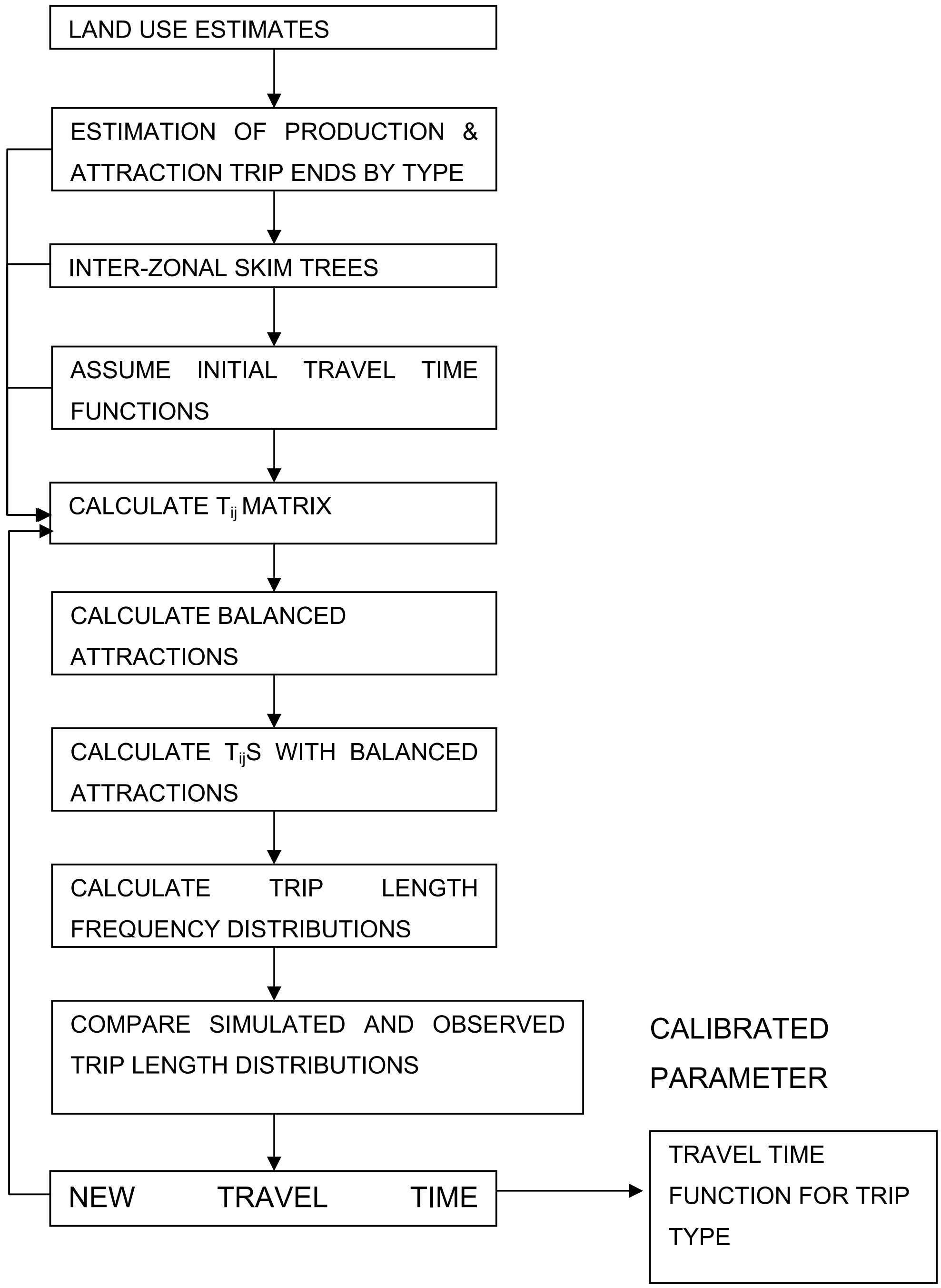
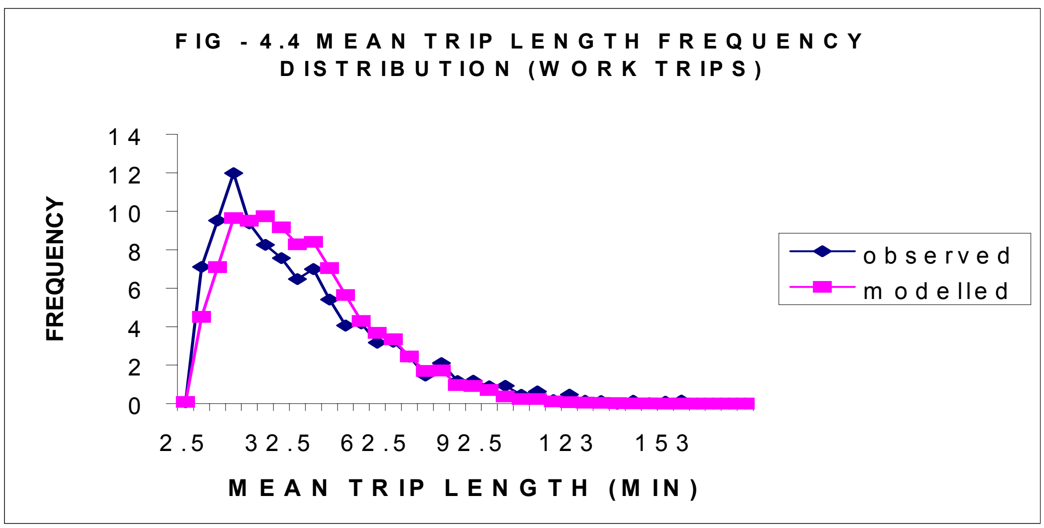


Figure 4.3 : Calibration of Gravity Model

4.7.5 Comparison of observed and simulated trip length frequency distributions for work, education and other trip purposes as well as for all trips (aggregated) are presented in **Figures 4.4 to 4.7.**

4.7.6 A further check on the quality of calibration is made when the total (as opposed to one purpose) base year (2003) synthesized flows are assigned to the road network. At this stage, although the synthesized flows correspond with observed flows, it is reasonable to expect a significant proportion of corridor flows,

Figure 4.4 : Mean Trip Length Frequency Distribution (Work Trips)



i.e., groups of more or less parallel roads, across a screen line or cordon to correspond within a reasonable limit, depending on the actual link flow level. This process is called validation of the model. This has been explained in paragraph **4.11.10.**

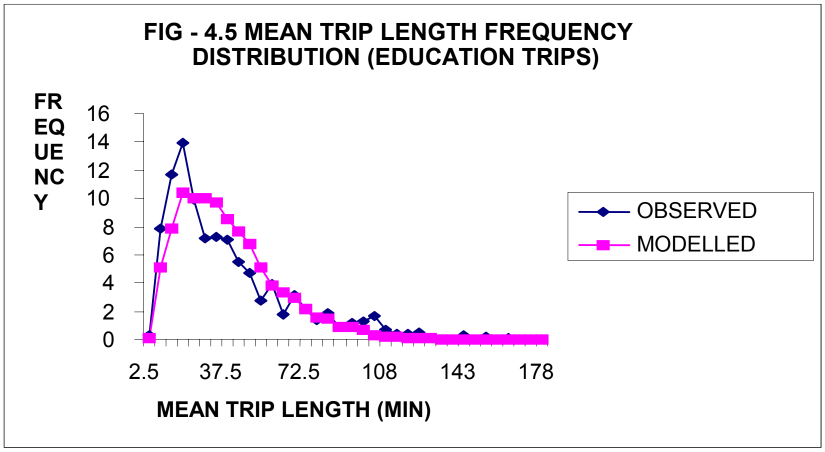


Figure 4.5 : Mean Trip Length Frequency Distribution (Education Trips)

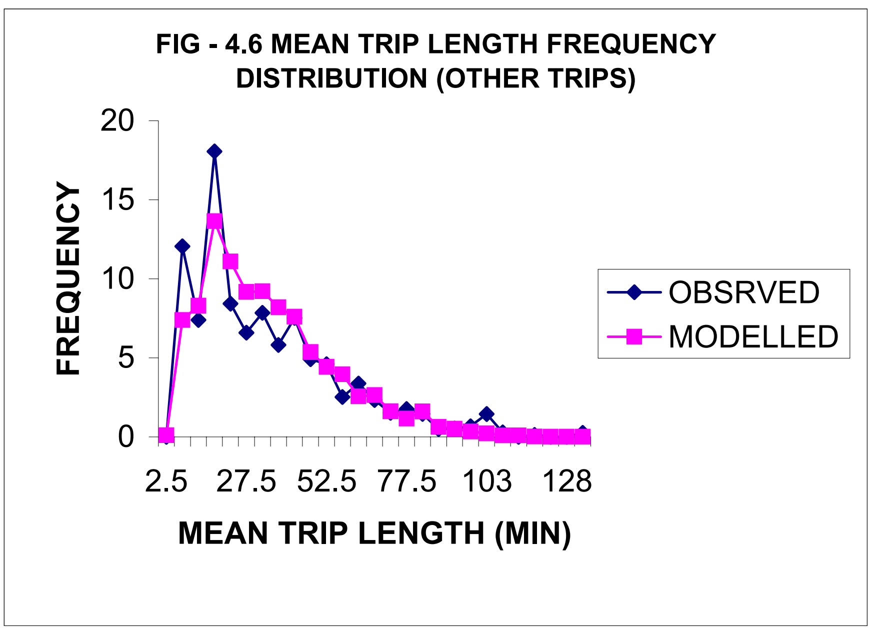
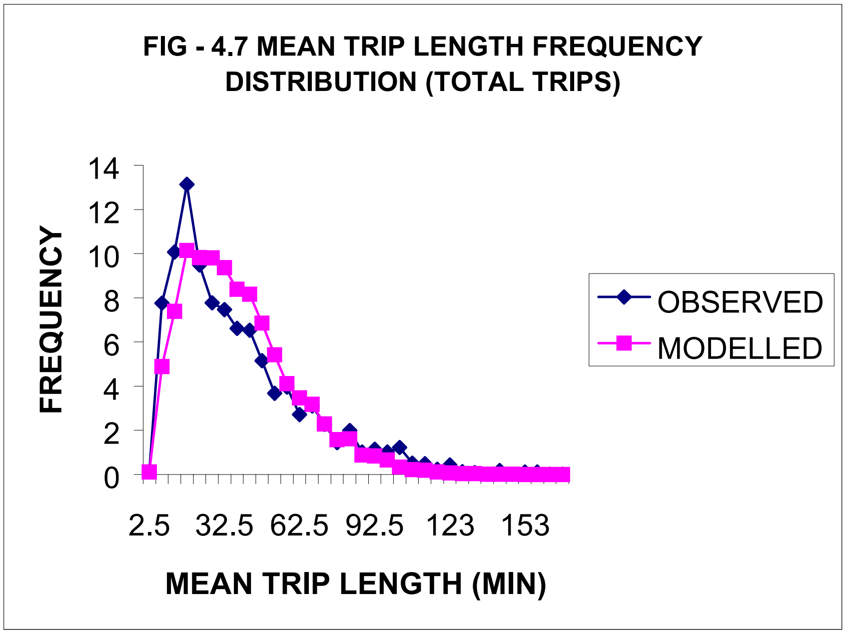


Figure 4.6 : Mean Trip Length Frequency Distribution (Other Trips)

Figure 4.7 : Mean Trip Length Frequency Distribution (Total Trips)



4.7.7 Purpose wise trip distribution, for years 2011 & 2021, was then carried out by using the trip distribution model developed as above by inputting the zone wise future trip productions and attractions as obtained from trip generation stage.

4.8 MODAL SPLIT

4.8.1 The modal split for home-based trips (all purposes) as observed in the base year (2003) was 39.81% by Public transport (Bus & Rail) modes and 60.19% by other modes (Fast and slow). The observed mode split in the base year has already been given in **Table 3.22**. Public transport share in Hyderabad has historically been strong, but public transport predominance has been slipping in recent years. The relatively low mode share of 3-seater and 7-seater auto rickshaws masks large impacts on the urban system. These auto rickshaws are powered by 2-

stroke engines, and therefore are high emitters of hydrocarbons and particulate matter. More over their size, number and aggressive driving style of auto rickshaw operators increase the congestion and hinder speed and reliability of other modes particularly buses. If the pattern observed in other developing country cities of South and East Asia is to believed, Hyderabad may face a vicious cycle of decline in bus services over the next several years with poor reliability and decreasing speeds leading to decrease in ridership as travelers switch to 2-wheelers and auto-rickshaws.

4.8.2 Recent indicators form APSRTC, which operates bus services in HUDA area, suggest that cycle of decline may come sooner than later. It is observed that there is substantial decrease in load factors and increase in loss per revenue kilometer. To reverse such trends is a critical policy question. The historic response by the policy makers in Andhra Pradesh has been to lower fares. The presumption behind such a policy is that people are more sensitive to price than to time or reliability. Purpose of this study was to examine empirically how travelers trade-off among the attributes of price, time and reliability.

4.8.3 A Stated Preference (SP) survey was designed and administered in HUDA to investigate the air quality impacts of policy measures that influence Vehicle Kilometers Traveled (VKT) and mode shares, such as More Effective Bus Transit System.

4.8.4 The Revealed Preference (RP) survey data captures observed or reported actual behavior, where as SP survey data presents observed or expressed in response to hypothetical scenarios ("experimental"). In SP survey data we can have attribute levels beyond the Revealed Preference survey data. Collection of RP data and analysis would be expensive and time consuming.

4.8.5 The Stated Preference (SP) survey designed included 3 attribute levels: Price, Time and Reliability. For simplicity in implementation, the SP survey was carried out only for Journey to Work and Journey to Education Trips. The survey was designed for 40 different combinations of questions in comparison of base mode cost, travel time and reliability with improved modes. 10 SP choice sets were presented to each respondent.

4.8.6 Wording of the questions was straightforward, except for the question on reliability. During the pilot phase, a number of potential wording structures were experimented with. The initial wording list varied with frequency in week that a certain amount of wait could be expected:

Attribute level 1: once in a week you need to wait 10 minutes or longer for the bus/ auto rickshaw

Attribute level 2: 3 times per week you need to wait 10 minutes or longer for the bus/ auto rickshaw

Attribute level 3: You need to wait 10 minutes or longer for the bus/ auto rickshaw virtually every time

4.8.7 Pilot survey revealed that a great deal of respondent confused with this wording. It was concluded that use of two numerical indicators would be too confusing. To over come this, it was decided to set up the SP choices with script that established a posted timetable. All the respondents were read the following statement prior to beginning to make SP choices: " For the buses that ply the streets of Hyderabad, suppose we were able to post schedules of all bus routes at the bus stop you most normally use for the trip you told us about, For autos, suppose that we were able to organize the services sufficiently such that auto rickshaw drivers were assigned specific routes and times, and those times were also posted at the location where you most normally would catch an auto-rickshaw for the trip you just told us about…..". The reliability questions were posed as follows:

Attribute level 1: Vehicle never leaves more than 1 minute after posted schedule time

Attribute level 2: Vehicle never leaves more than 10 minute later than posted schedule time

Attribute level 3: Vehicle never leaves more than 20 minute later than posted schedule time

4.8.8 In this respect, the reliability questions were tested for response to level of uncertainty (in minutes) in departure time. Pilot testing of this wording showed that the respondents easily understood it.

4.8.9 Levels for the other attributes to be tested – price and time – as well as methodology to derive them were determined through pilot tests. In order to remain consistent with well-understood best practices in SP, the attribute levels that were presented to the respondents were based on the characteristics of journey to work they told us about. The interview begins with a conventional travel diary for the previous day (collected only for one working or independent school age household member, selected at random). Final attribute levels used for cost were: 1 rupee less than respondent paid, same as respondent paid and 2 rupees more than respondent paid. Final attribute levels used for time were: 10 minutes less than respondent's reported travel time, same as respondent's reported travel time and 15 minutes more than respondent' reported travel time.

4.8.10 On the basis of 2700 predominantly household interviews, a total of 27000 choice set data points were collected. The approach for logit model is as follows:

The attribute values of hypothetical travel alternatives were related to the response obtained.

$$Y_i = f(X_i , \beta)$$

The objective was to determine an appropriate functional form for "f" and value for "β". The response was characterized as a rating response. For rating responses, simple linear regression models were used

$$Y_i = \text{logit}(p) = \log(p/(1\text{-}p)) = \beta_0 + \Sigma\beta_i X_i + \varepsilon_i$$

The response variable Y_i is discrete while the independent variable X_i can be either discrete or continuous.

The utility of hypothetical travel alternative is composed of an observable component (V_i) and an error (ε_I).

$$U_i = V_i + \varepsilon_i = \Sigma\beta_i X_i + \varepsilon_I$$

If an alternative "M" is chosen to an alternative "K" then

$$U_M > U_K$$

$$V_M + \varepsilon_M > V_K + \varepsilon_K$$

$$V_M + V_K > \varepsilon_M - \varepsilon_K$$

Thus, choice design is dependent on both observable components and error residuals.

Conditional logit model used to model multinomial traveler's choices in transportation modeling and shown in **Figure 4.8**.

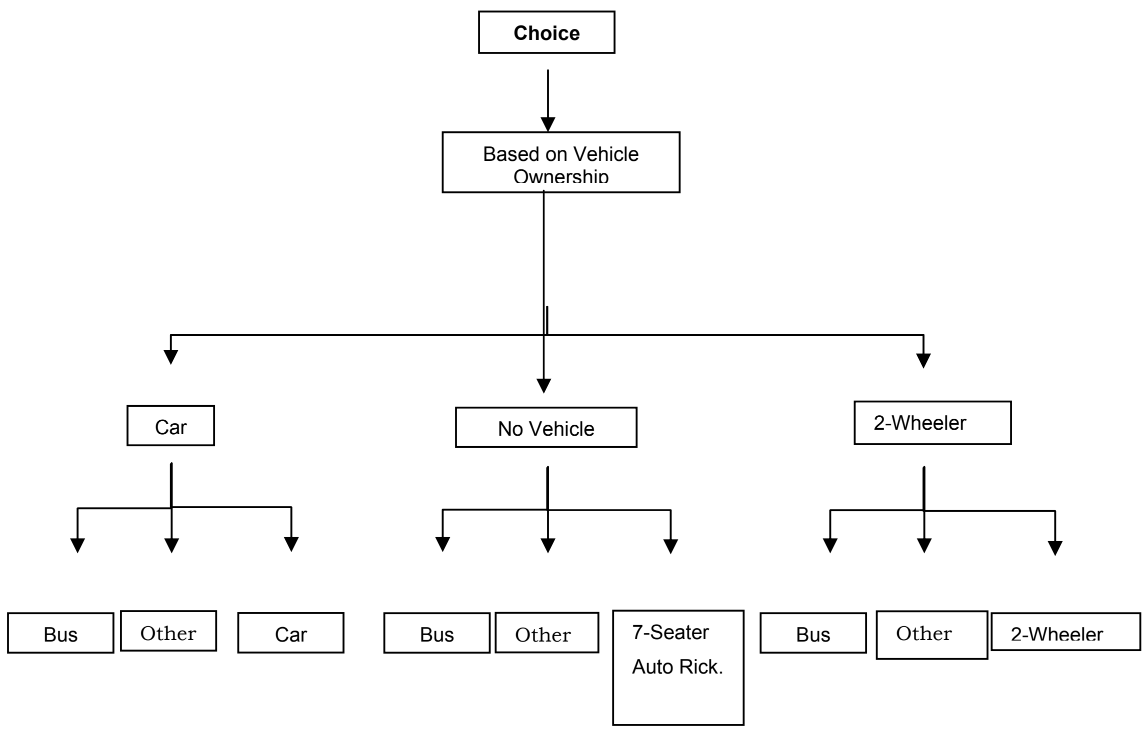


Figure 4.8 : Conditional Multinomial Logit Model Design

Choice probabilities are

$$p_i = \exp(Y_i) / \Sigma \exp(Y_s) = \exp(X_i\beta)/\Sigma \exp(X_s\beta)$$

Model Elasticity's are

$$e_{ii} = (\delta p_i/\delta X_{ik})*(X_{ik}/p_i)$$

$$e_{ii} = \beta_i X_{ik}(1-p_i)$$

4.8.11 SP data was analyzed using multinomial logit estimation with Multinomial Discrete Choice (MDC) procedure of Statistical Analysis Software (SAS) package. Separate models were run for respondents who indicated that they had no access to any individual vehicle, those who indicated that they had access to 2- Wheelers and those who indicated that they had access to a car. The model results are presented in **Table 4.7 to 4.9**.

Table 4.7: MNL Results For Households With No Access To Private Vehicles

Parameter	Estimate	t- Value
Cost	-0.113	-27.78
Time	-0.0198	-21.38
Reliability	-0.0425	-23.88
Constant – 7-seater	-0.3124	-5.46
Constant – Bus	-0.1824	-3.24

Table 4.8: MNL Results For Households With Access To 2 – Wheelers

Parameter	Estimate	t- Value
Cost	-0.022	-6.24
Time	-0.0333	-22.1
Reliability	-0.0634	-29.21
Constant – 7-seater	-0.5892	-17.6
Constant – Bus	-0.3125	-10.7

Table 4.9: MNL Results For Households With Access To Cars

Parameter	Estimate	t- Value
Cost	-0.009759	-0.6
Time	-0.0102	-1.87
Reliability	-0.0506	-6.04
Constant – 7-seater	-1.0884	-8.48
Constant – Bus	-0.6896	-6.55

4.8.12 Average cost of the commute was determined as Rs.7.90 for no-vehicle owners, Rs.11.20 for 2-wheeler owners and Rs.23.90 for car owners. Average travel time values are worked out as 36.6 minutes for no-vehicle owners, 30.9 minutes for 2-wheeler owners and 35.5 minutes for car owners. Based on these averages, and assuming the midpoint of the reliability range we asked about (10 minutes of uncertainty), we have calculated mode choice elasticity's as shown in **Table 4.10.**

Table 4.10: Calculated Mode Choice Elasticity's Based On Reported Average Time And Cost And Assumed Uncertainty Of 10 Minutes

Parameter	Respondents with access to no vehicle	Respondents with access to 2-wheeler	Respondents with access to car
Cost	-0.78	-0.19	-0.18*
Time	-0.62	-0.92	-0.29*
Uncertainty (Inverse of Reliability)	-0.34	-0.53	-0.42

*Insignificant at the 95% confidence level.

4.8.13 The results show that time, cost and reliability are important for households with access to no vehicles or access to 2-wheelers. The results are less straightforward for households with cars, where the co-efficient for cost and time, while in the proper direction, are not significant. That the cost co-efficient for these households are minuscule is expected: in India, households with cars tend to be fairly wealthy, and therefore price insensitive to alternative transport modes. Of more interest is the relationship between the time and reliability co-efficient for car-owning households. The time co-efficient is insignificant at the 95% confidence level, but significant at the 90% confidence level. One would expect time to be as important as reliability. The results indicate, however, that car-owning respondents seem to place premium on reliability.

4.8.14 The results obtained from the MNL model were utilized in estimating horizon years modal split in BAU scenario and in Policy options, which is presented in detail in subsequent chapters.

4.9 TRIP ASSIGNMENT

4.9.1 Trip assignment is the process of allocating a given set of trip interchanges to a specific transportation system and is generally used to estimate the volume of travel on various links of the system to simulate present conditions and to use the same for horizon year. The process requires as input a complete description of either the proposed or existing transportation system, and a matrix of inter-zonal trip movements. The output of the process is an estimate of the trips on each link of the transportation system, although the more sophisticated assignment techniques also include directional turning movements at intersections.

4.9.2 The Purposes of trip assignment are broadly:

- ❖ To assess the deficiencies of the existing transportation system by assigning estimated future trips on to the existing system.
- ❖ To evaluate the effects of limited improvements and extensions to the existing transportation system by assigning estimated future trips to the network, which includes these improvements.
- ❖ To develop construction priorities by assigning estimated future trips for intermediate years to the transportation system proposed for these years
- ❖ To test alternative transportation system proposals by systematic and readily acceptable procedures.
- ❖ To provide design hour volumes and turning movements.

4.9.3 The major alternative procedures which have been developed to assign estimated future trips to a transportation system include:

- ❖ All or nothing assignments
- ❖ Diversion curve assignments
- ❖ Capacity restraint assignments

4.9.4 The choice of assignment procedure to be adopted in any particular transportation study depends largely on the purposes of that study and the degree of sophistication required in the output.

4.10 ASSIGNMENT PROCEDURE

4.10.1 **Development of Road Network:** For the purpose of trip assignment, the urban area road network is broken down into links and nodes. For this study, all roads with ROW of 18m and above have been considered. A link is defined as the one-way part of the route between two intersections and depending upon the assignment technique to be used, detailed information concerning the length, speed and/or travel time etc. is coded and stored in the computer. Nodes are of two types – zone centroid and intersection identified by a numeric code, which is applied systematically whilst links are identified by node number at each end of the link.

4.10.2 Capacity Restraint Assignment Technique has been followed in this study. In the capacity restrained method of assignment, private (car & 2 wheeler) and public (Bus & Auto / 7-seater) transport trip matrices are loaded to their respective networks, using an incremental assignment method. The trip matrices are assigned to the shortest paths generated successively after assignment of each 10% increment of the matrices. The incremental assignment proceeds by updating the link speeds for both private and public transport networks, using the speed flow relationships of the links until 100% if the two matrices are assigned.

4.10.3 The assignment is largely controlled by the paths, which are built by the shortest path algorithm through the network. In this present method of capacity constrained assignment, there is simultaneous building of shortest paths for the two networks, and rules adopted were:

The paths were not allowed to be built through the zone centroids, other than the origin and the destination end.

4.10.4 **Capacity of the Road System:** Three types of roads have been considered in the network. The type of the road and their capacities are presented in **Table 4.11.**

Table 4.11: Types Of Roads And Their Capacities

SI No.	Road Type	Capacity in PCU's
1	2- Lane	2000
2	4-Lane	4000
3	6-Lane	6000

4.10.5 **Speed Flow Relationship**

In addition to the capacity values, the speed flow relationships of the three types of links are required for modifying the speeds for each incremental loading. A mathematical model representing the graphical form was developed for each link type. These mathematical models as developed are as follow:

2 – lane divided:

$S = S_f\ (1.0\text{-}0.578(V/C)^{3.0})$

4 – lane divided:

$S = S_f\ (1.0\text{-}0.636(V/C)^{2.7})$

6 – lane divided:

$S = S_f\ (1.0\text{-}0.605(V/C)^{2.5})$

Where S = Speed in kmph

S_f = Free Flow Speed in kmph

V = Assigned volume in PCU's

C = Capacity of Road link in PCU's

The initial free flow speeds taken for the assignment of public and private modes are summarized in **Table 4.12**

Table 4.12: Free Flow Speeds

Mode	**Free Flow Speed in KMPH**		
	2-Lane	**4-Lane**	**6-Lane**
Public Transport	15	20	25
Private Transport	30	35	40

4.10.6 **PCU Conversion Factors**

The results from the incremental assignment, which is in terms of person trips, have to be converted to PCU's for updating the link speeds. As the occupancy level of the private modes are drastically different from the road-based public transport modes, separate passenger to PCU conversion factors were derived for the two types of travel. For this purpose, the city was divided into three regions each one having different mix of traffic characteristics. The factors used for the three regions are given in **Table 4.13**

Table 4.13: PCU Conversion Factors

Region	PCU Conversion Factor		
		Pub. Vehicles	Goods Vehicles
MCH Core Area	0.415010	0.067579	1.2045
10 Municipalities	0.360208	0.067108	1.2393
HUDA	0.398979	0.067010	1.2814

The roads are used by goods vehicles and other slow moving vehicles simultaneously. Thus the capacity comparison and speed modifications must take these vehicles into account. Thus, after the person trips are converted to vehicles in terms of PCUs, the goods vehicle factors are used to boost up the value to incorporate the goods and the slow moving vehicles.

4.10.7 **Minimum Link Speed**

In the assignment process the link speeds get modified by appropriate modes of speed flow relationships. As the volume-capacity ratio increases towards 1.0 the link speed decreases quickly to a residual value of about 10 to 15 kmph. In case of further loading of the link (which is possible in absence of alternate path) beyond volume-capacity ratio of 1.0, the speeds may get negative. Thus to control the speed to a non-negative residual value, the lowest bound for public and private mode speeds is taken as 5.0 and 10.0 kmph respectively.

4.10.8The assigned home-based trips were increased to the extent of 5% for taking into account the non-home based trips (not modeled). The intra-zonal trips were added in the same proportion to the base year trips in future.

4.10.9 The base year assigned trips were then compared with the ground counts of 10-selected arterial links to establish the validity of models, as stated earlier. Correction factors were applied to account for the trips of empty vehicles, car taxis, government vehicles and floating population intra-city trips. The assignment model developed was utilized in trip assignment for the BAU and other policy options to derive the vehicle kilometers traveled.

Table 4.14: Comparison of Ground Counts And Assigned Trips

SI No.	Link	Actual (Vehicles)	From Model (Vehicle)
1	S.R. Nagar – Maitrivanam	90,204	75,867
2	Maitrivanam – Ameerpet	1,11,726	1,00,180
3	Lakdika Pool – Ravindra Bharati	1,52,960	1,73,473
4	L.B. Stadium – A1 Junction	1,01,863	92,987
5	Lata Talkies – Gosha Mahal	1,26,909	1,31,682
6	Chadarghat – Naiagara	1,17,346	1,29,028
7	Naiagara – Nalgonda X Road	1,50,801	1,45,728
8	NTR Junction – Paradise	73,395	68,592
9	Plaza – Hari Hara Kala Bhavan	65,601	83,181
10	East Marredpally – Sangeet Cinema	76,996	72,792

4.10.10 The intercity trips upto the horizon years 2011 and 2021 have been projected with a growth rate of 3% and 2% p.a., respectively, from base year (2003) trips and have been added to the road network.

4.10.11 **FEEDBACK LOOPS**

i) ***BAU Scenario:*** The initial speed on assignment was stabilized after 5 iterations. With new speeds, the modified origin-destination matrices have been worked out at Trips Distribution stage. The mode wise OD matrices have then been assigned on the public and private network to obtain the vehicle kilometers traveled.

ii) ***More Effective Bus Transit Services Scenario:*** The OD matrix derived after stabilizing the speeds in BAU scenario was used to derive the mode wise OD matrices by applying the modal split model results and these matrices were assigned on the pubic and private networks to derive the vehicle kilometers traveled.

iii) ***Flyover Scenario:*** the flyover network was included in the road network with stabilized speed. With this updated network, purpose- wise OD matrices were derived by using the trip distribution model and then mode- wise OD matrices were obtained by applying the modal split model results to derive the mode- wise OD matrices. The mode-wise OD matrices so developed were then assigned on to the updated network by using capacity restraint assignment.

5.0 SCENARIOS FOR MORE EFFECTIVE PUBLIC TRANSIT SERVICE

5.1 INTRODUCTION

5.1.1 Public transport system should be the soul of a city. The presence of a good public transport system can deliver better environmental conditions, faster speeds of travel, better mobility and economic growth.

5.1.2 Characteristics of existing bus transport system for Hyderabad has already been described in Chapter-3. Share of buses in city transport demand has also been described in Chapter –3. Briefly, the bus transport system has been declining and use of two wheelers and three wheelers has been growing due to a variety of reasons. Study of operation of buses on city roads indicates no special facilities for the system. There are no bus lanes or dedicated bus-ways. Proper bus-bays are not available at most of the major bus stops. There is no preferential treatment given to buses in signal timing at junctions. These factors also make bus travel slower and unattractive for passengers.

5.2 BUSINESS-AS-USUAL (BAU) SCENARIO

5.2.1 If the prevailing scenario continues in future as well, it will have serious repercussions on the transport system of Hyderabad. BAU scenario will lead to the following;

i) Further decline in bus ridership
ii) Increase in use of personalized vehicles such as motorized two wheelers and IPT modes such as auto rickshaws
iii) Increase in traffic congestion on roads
iv) Further decline in speeds of bus system which will lead to high travel time
v) Higher vehicle km by two wheelers, cars and auto rickshaws
vi) Increase in emissions from motor vehicles
vii) Decline in quality of life, including health effects

5.2.2 The above BAU scenario has been constructed upto the year 2021. Transport demand modeling exercise has been carried out to estimate transport demand that would be satisfied by various modes of transport such as motorized two wheelers, cars, auto rickshaws, buses and non-motorized transport upto the year 2021 for BAU scenario, using the calibrated and validated transport demand models as explained in **Chapter - 4**.

5.2.3 Modal Split for the Horizon Years 2011 & 2021

Given the poor bus services and very marginal increase in fleet size of buses as observed from past trends, it has been assumed that the existing headway of 12 minute for buses will increase to 18 minutes in the year 2011 (i.e., 50% more than existing condition) and to 24 minutes in the year 2021 (double of the base year).

5.2.4 In Business As Usual (BAU) scenario the following assumptions have also been considered:

a) The parking time & cost for 2-wheelers will be increased to 3 minutes & Rs. 5 in year 2011 and 7 minutes & Rs 8 in the year 2021.

b) The parking time & cost for cars will be increased by 5 minutes & Rs.5 in the year 2011 and 9 minutes & Rs.10, respectively in the year 2021.

5.2.5 From the SP survey data multinomial logit model was used to derive logit parameters for travel time, travel cost and reliability. From the base year survey the travel time and travel cost of each mode were worked out. Then these parameters were used in the MNL model to work out the modal split for the base year and a variation in modal split is observed in comparison with modal split obtained from household survey.

5.2.6 For future, the revised input parameters of travel time and travel cost were taken as per the scenarios and variation in modal split obtained was incorporated in the base year modal split to obtain the modal split for years 2011 & 2021. Modal split for years 2003, 2011& 2021 is presented in **Table 5.1**.

Table 5.1: Modal Split for BAU for Entire Study Area

SI No	Mode	2003		2011		2021	
		No of Trips	Percentage	No of Trips	Percentage	No of Trips	Percentage
1	Bus	2275244	41.67	2852225	37.01	3703651	31.30
2	Car	176605	3.23	213474	2.77	285170	2.41
3	2 Wheeler	2541161	46.54	3061846	39.73	3905991	33.01
4	Auto Rick	466759	8.55	1579089	20.49	3937940	33.28
	Total	**5459769**	**100.00**	**7706634**	**100.00**	**11832752**	**100.00**

5.2.7 Thus it can be seen from the above tables that share of trips to be satisfied by bus transport will decline to 31% by the year 2021 for BAU scenario. In BAU scenario the parking supply will not meet parking demand of private vehicles. The cost and time for parking the private vehicles will increase, which will reduce the usage of private vehicles. This will result in substantial higher use of three wheelers.

5.2.8 Traffic Speeds have their impact on vehicular emissions. For the year 2003, traffic speeds as observed from the field surveys have been used. For the study area as a whole, traffic speeds for various modes have been estimated from the transport demand exercise for the year 2011 and 2021 for BAU and policy scenarios. For individual corridors, speed-flow relationships have been developed from the primary traffic surveys conducted for the year 2003. The mathematical model, as explained in chapter-4 of this report, has been used to estimate speeds.

5.2.9 For individual corridors, average hourly traffic volumes have been worked from the trip assignment for the BAU and policy scenarios for the year 2011 and 2021. Then, considering the projected traffic volumes and capacity of the road corridors, traffic speed for private and public modes have been estimated for the year 2011 and 2021 for BAU and policy scenarios. These average traffic speeds have been indicated in the following paragraphs for various scenarios.

5.2.10 BAU Scenario

As mentioned earlier, all home-based trips (work, education and other purposes) along with inter-city trips were assigned on to the base year network through capacity restrained assignment procedure. Passenger trips obtained from assignment were converted into vehicular trips by using average occupancy factors of vehicles observed in the traffic survey. The mode-wise daily vehicle kilometers for 2003 and horizon years are given in **Table 5.2 to 5.4.** Speeds for various modes for this scenario for the years 2003, 2011 and 2021 are also presented the tables.

Table 5.2: Mode-Wise Daily Vehicle Kilometers– 2003 (BAU) For Entire Study Area

S No	Mode	Speed (Kmph)	Inter-Zonal	Intra-Zonal	Inter-City	Total
1	Bus	15.0	539128	4000	152000	695128
2	Auto Rickshaw	20.0	4412710	71000	16000	4499710
3	Car	23.0	2032863	6000	503000	2541863
4	2-Wheeler	23.0	12702337	428000	426000	13556337
	Total		19687038	509000	1097000	21293038

Table 5.3: Mode-Wise Daily Vehicle Kilometers – 2011 (BAU) For Entire Study Area

S No	Mode	Speed (Kmph)	Inter-Zonal	Intra-Zonal	Inter-City	Total
1	Bus	12	714862	6008	220769	941639
2	Auto Rickshaw	12	5710938	89957	140592	5941487
3	Car	20	2872985	7602	637101	3517688
4	2-Wheeler	20	22192865	541726	539053	23273644
	Total		31491650	645293	1537515	33674458

Table 5.4: Mode-Wise Daily Vehicle Kilometers – 2021 (BAU) For Entire Study Area

S No	Mode	Speed (Kmph)	Inter-Zonal	Intra-Zonal	Inter-City	Total
1	Bus	8	946893	7324	269116	1223333
2	Auto Rickshaw	8	14518379	109658	171381	14799418
3	Car	15	4065493	9267	776622	4851382
4	2-Wheeler	15	29069309	660361	657102	30386772
	Total		48600074	786610	1874221	51260905

5.2.11From the above tables, it can be seen that that vehicle kilometers from the year 2003 increases by about 2 to 3 times in the year 2021 due to increase in the share of autos and also the overall increase in vehicular kilometers as estimated population and employment will increase by more than two times in 18 years. Speed of various modes will also decrease by about 35% to 60% during the next 18 years for BAU scenario due to increase in vehicle kilometers traveled.

5.3 MORE EFFECTIVE BUS TRANSIT SERVICE SCENARIOS

5.3.1 **Alternative Scenarios:** On the basis of analysis of problems plaguing the bus system, the following alternative options have been considered to achieve a more effective bus service, which will result in lower emissions.

5.3.2 **Making Bus System Faster:** There are many road corridors in Hyderabad where a large number of buses ply. If bus travel can be made faster on these corridors, this will induce/shift passengers from other transport modes. The bus system can be made faster by adopting the following measures:

- ❖ Exclusive bus lanes/ways on certain corridors
- ❖ Provision of adequate and well designed bus stops
- ❖ Priority for buses at traffic signals
- ❖ Improving road surface on trunk routes

5.3.3 Exclusive Bus lane Scenario: The scenario is considered for entire study area horizon years of 2011 and 2021. In Hyderabad there are mainly three types of vehicle streams: private fast mode (Car, 2-wheeler, auto), public mode (bus) and non-motorized modes (slow moving) on roads. However, slow moving traffic is small percentage of total traffic on Hyderabad roads, except in a few areas. These traffic streams generally intermingle with each other and thereby hamper the smooth traffic flow and cause congestion, delays and accidents etc. By segregating these public and private mode streams by restricting them to operate in their lanes will have direct impact on improving the overall traffic speeds. It has been proposed to provide 2-lanes for Exclusive Bus Lanes (one lane each for each direction), which in turn will reduce the number of lanes available for other (private vehicles). The typical sketch of

Exclusive Bus lanes for 4-lane and 6-lane divided carriageway is presented in **Figures 5.1 & 5.2.**

5.3.4 **Bus Route Rationalization:** The present bus system is predominantly destination oriented. This means lower frequencies and higher travel time for most of the passengers. This scenario has also considered direction oriented bus system on major arteries of Hyderabad. High frequency of buses will be provided on the major corridors. Feeder system to this high frequency direction oriented bus system will also need to be provided in the form of mini buses, auto rickshaws, etc. Facilities for parking mini buses, auto rickshaws, two wheelers, cycles and cycle rickshaws can also be provided at (or adjacent to) major bus stops on the high frequency bus system.

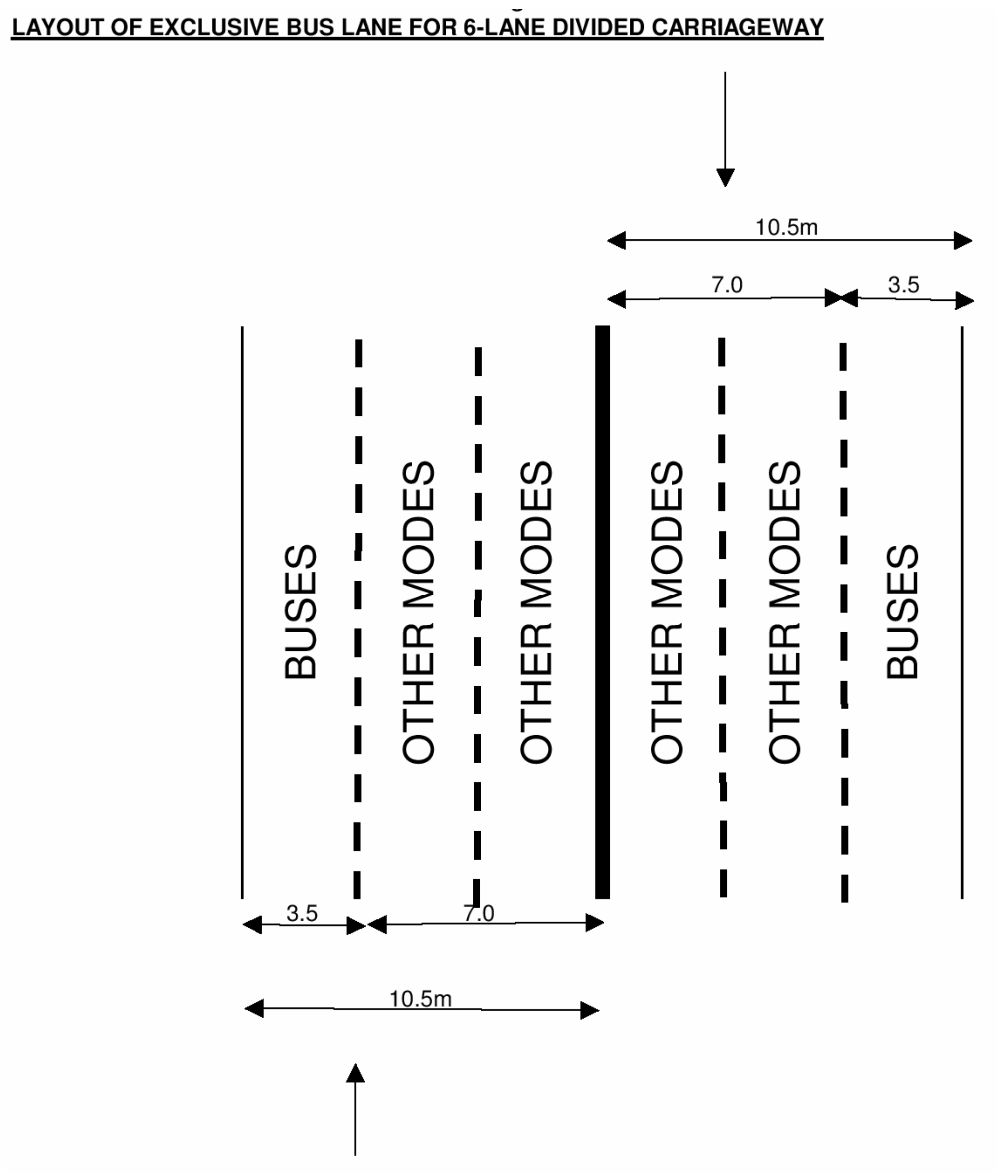
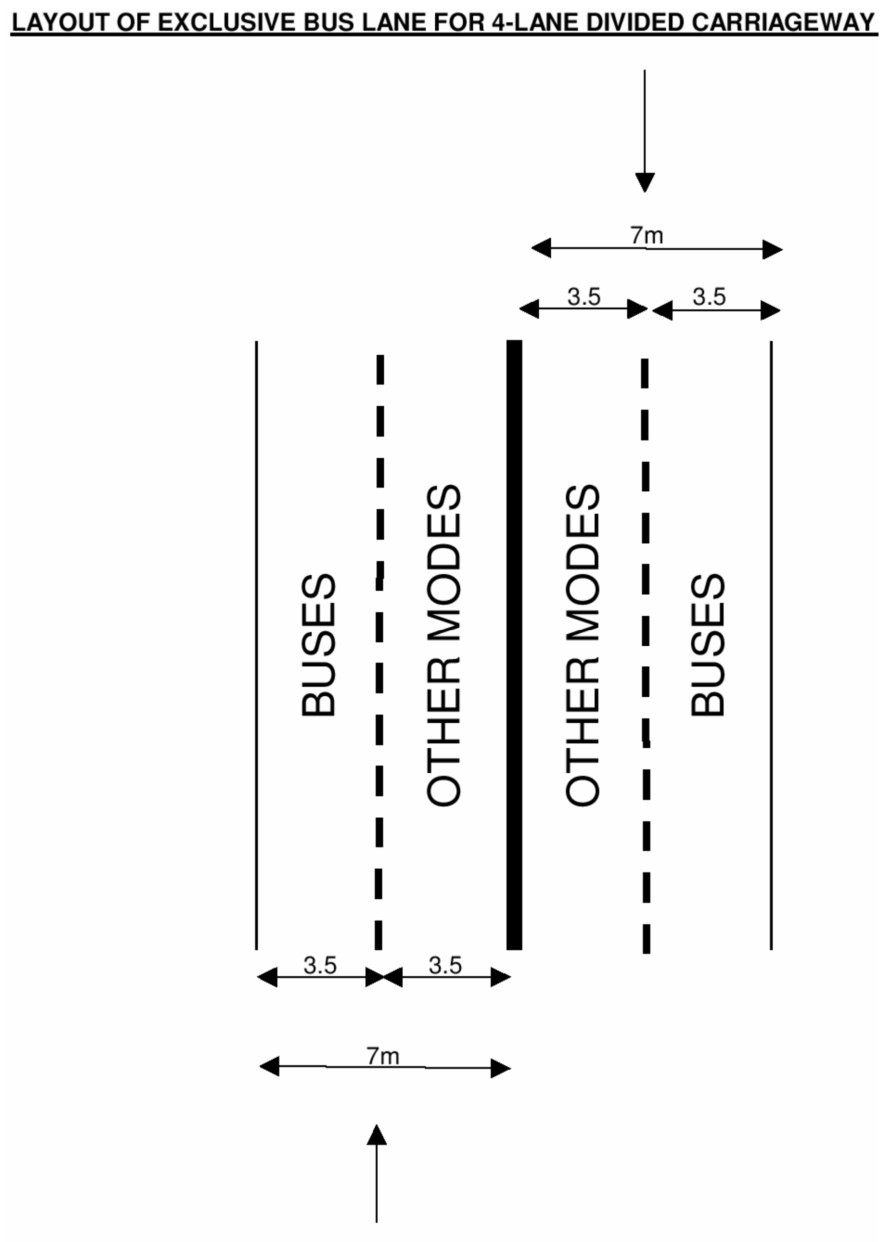


Figure 5.1: Layout of Exclusive Bus Lane for 6-Lane Divided Carriageway

Figure 5.2: Layout of Exclusive Bus Lane for 4-Lane Divided Carriageway



5.3.5 Impact of More Effective Bus Transit Services: Due to exclusive bus lane, the public transport speed has been assumed as 23 kmph and there will be a reduction of 37% travel time in public transport due to above improved bus transit service scenario. However, travel time for private vehicles i.e., Scooter and car will be increased by 5 minutes and 9 minutes for the car, 3 minutes and 6 minutes for Scooter for the years 2011 & 2021, respectively. The increase in travel time & travel cost of private vehicles is to account for parking as explained earlier. The Multinomial Logit Model has been developed and used to work out the modal split for the year 2011 & 2021 and results are given in **Table 5.5**. In this policy option it has been assumed that the modal split for auto is same for the years 2003, 2011 & 2021.

Table 5.5: Modal Split for More Effective Bus Transit Services for Entire Study Area

		2011		2021	
SI No	**Mode**	**No of Trips**	**Percentage**	**No of Trips**	**Percentage**
1	Bus	4432856	57.52	7394287	62.49
2	Car	204226	2.65	270970	2.29
3	2 Wheeler	2491555	32.33	3280039	27.72
4	Auto Rickshaw	577997	7.50	887456	7.50
	Total	**7706634**	**100**	**11832752**	**100**

Modal Split has been worked out and then mode wise trips were again assigned onto the network by Capacity Restraint Method. Vehicle kilometers for this Scenario have been worked out for the Years 2011 & 2021 for the entire study area and are presented in **Table 5.6 and 5.7**. Speed for various modes for the years 2011& 2021 is also presented in the tables.

Table 5.6: Mode-Wise Daily Vehicle Kilometers – 2011 (More Effective Bus Transit Service Scenario) – Entire Study Area

S No	Mode	Speed (Kmph)	Inter-Zonal	Intra-Zonal	Inter-City	Total
1	Bus	20	1111979	6008	220769	1338756
2	Auto Rickshaw	17	2155983	89957	140592	2386532
3	Car	17	2734930	7602	637101	3379633
4	2-Wheeler	17	18058625	541726	539053	19139404
	Total		24061517	645293	1537515	26244325

Table 5.7: Mode-Wise Daily Vehicle Kilometers – 2021 (More Effective Bus Transit Service Scenario) – Entire Study Area

S No	Mode	Speed (Kmph)	Inter-Zonal	Intra-Zonal	Inter-City	Total
1	Bus	18	1907372	7324	269116	2183812
2	Auto Rickshaw	15	3657640	109658	171381	3938679
3	Car	15	3801673	9267	776622	4587562
4	2-Wheeler	15	24162187	660361	657102	25479650
	Total		33528872	786610	1874221	36189703

Similarly, Vehicle Kilometers have been worked out for nine major corridors in study area including the two identified corridors of the study area for traffic management and are presented in subsequent paragraphs.

5.4 MMTS SCENARIO

5.4.1 Ministry of Railways and Government of Andhra Pradesh are jointly developing Multi-modal commuter transport services in the twin cities of Hyderabad and Secunderabad with the objective of providing clean, fast, efficient, regular, reliable and affordable suburban commuter transportation to Hyderabad Urban Agglomeration and its neighborhood. This is being done by upgrading the existing railway infrastructure along these corridors. In our study this scenario has been considered independently i.e. stand-alone scenario.

5.4.2 In Phase-I of the plan, the sections Falakuma-Secunderabad (Length=14km) and Secunderabad-Hyderabad-Lingampalli (Length = 33) are being covered in two streams. The corridors are shown in **Figure 5.3.** At present Secunderabad-Hyderabad-Lingampalli section has already started functioning. In this section, 6 existing stations have been utilized and 11 new stations added to cover important locations of the city. On Falaknuma-Secunderabad section, the existing 11 stations will be covered. The inter station distance on Falakuma-Secunderabad and Secunderabad-Hyderabad-Lingampalli sections are 1.3km and 1.9km respectively.

5.4.3 In this scenario a stand alone MMTS has been considered. Number of passenger trips that will be shifted to MMTS from various modes has been assessed based on transport demand model as explained earlier. When full MMTS is operational, the number of vehicle kilometers of other modes will be reduced. The following assumptions have been made for working out the demand on MMTS;

- The frequency of MMTS system would be 20 min.
- 15 min. time has been considered for interchanging between MMTS system and bus.

5.4.4 It is estimated that MMTS will carry 111045 passengers in 2011 and 236544 passengers in 2021. Thus, considering its services presently MMTS will not attract a significant number of passengers from other modes. The modal split for this scenario is presented in **Table 5.8**.

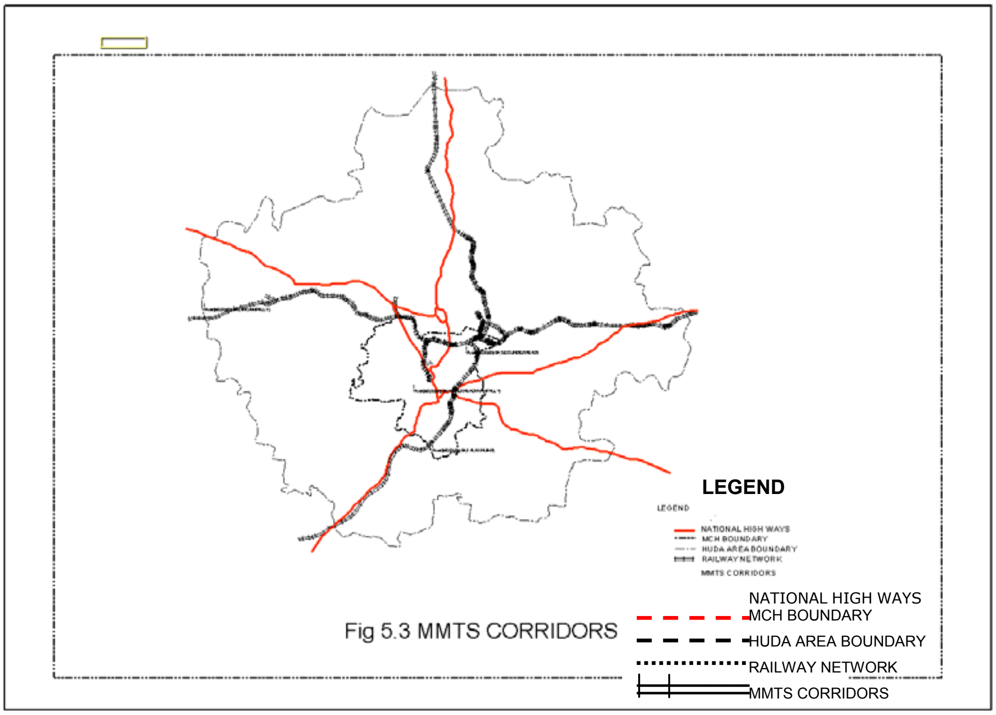


Figure 5.3: MMTS Corridors

Table 5.8: Modal Spilt For MMTS Scenario

SI No	Mode	2003		2011		2021	
		No of Trips	Percentage	No of Trips	Percentage	No of Trips	Percentage
1	Bus	2263307	41.45	2809815	36.46	3623171	30.62
2	Car	174547	3.20	210664	2.73	281808	2.38
3	2 Wheeler	2532347	46.38	3019411	39.18	3838972	32.44
4	Auto Rickshaw	465901	8.53	1555699	20.19	3852257	32.56
5	MMTS	23667	0.43	111045	1.44	236544	2.00
	Total	**5459769**	**100.00**	**7706634**	**100.00**	**11832752**	**100.00**

5.4.5 The mode wise vehicle kilometers estimated for 2003, 2011 and 2021 for MMTS scenario has been presented in **Table 5.9.** It is seen that MMTS will increase VKT by 4.6% by 2011and by 6% in 2021 over the BAU scenario. It may be due to increase in trip length. Thus, in its present form MMTS will not be very effective in reducing traffic from roads. Speed of various modes for the MMTS scenario for the years 2003, 2011 and 2021 is also presented in the **Table 5.10**.

Table 5.9: Mode-Wise Daily Vehicle Kilometers – 2003, 2011 & 2021 (MMTS Scenario)

S No	Mode	2003-VKT	2011-VKT	2021-VKT
1	Bus	690900	972262	1285568
2	Auto Rickshaw	4496449	6195115	15759569
3	Car	2522052	3732751	5194543
4	2-Wheeler	13441916	24423488	32311370
	Total	21151317	35323616	54551049

Table 5.10: Speeds in Kmph for Various Modes – MMTS Scenario

S No	Mode	2003	2011	2021
1	Bus	15.00	13	9
2	Auto Rickshow	20.00	13	9
3	Car	23.00	21	16
4	2-Wheeler	23.00	21	16

5.5 VEHICULAR EMISSIONS

5.5.1 The Vehicular Emissions have been estimated by IVE Model. The IVE (International Vehicle Emissions) Model developed by "College of Engineering-Center for Environmental Research and Technology (CE-CERT), University of California, Riverside" has been used for this purpose. Due to lack of availability of field data, the following assumptions have been made to run IVE model.

- ❖ In location file, mode wise driving style distribution and soak time distribution are same as Pune Vehicle Activity Study conducted by CE-CERT.
- ❖ The following average number of vehicle startups per day per vehicle in entire study area has been assumed based on field observations
- ❖ Car - 3.5, Two-wheeler - 3.5, Auto - 7.2, Bus – 7.2.
- ❖ The average number of vehicle startups per day per vehicle on selected corridors have been taken as follows:
- ❖ Car – 2, Two-wheeler – 3, Auto – 5, Bus – 4.

In fleet file, mode wise vehicle technology distribution has been assumed as same as Pune Vehicle Activity Study.

5.5.2 BAU SCENARIO

The vehicular emissions as estimated by IVE Model for 2001, 2003, 2011 and 2021 for the study area and nine major corridors in Hyderabad city have been presented in the following **Tables 5.11 to 5.12,** respectively. Emissions for 2001 have been back calculated.

Table 5.11: Estimated Daily Emissions for Study Area: BAU

YEAR	VKT/day	EMISSIONS IN METRIC TONNES PER DAY						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2001	16851248	503.27	27.72	0.40	5.00	2314.71	0.02	24.15
2003	21293038	630.15	34.22	0.50	6.27	2916.00	0.03	30.41
2011	33674458	1206.65	58.58	0.9	12.18	5144.47	0.04	61.21
2021	51260905	3044.78	128.17	2.08	32.54	11237.75	0.1	171.31

Table 5.12: Estimated Emissions for BAU Scenario for Nine Major Corridors

YEAR	VKT	EMISSIONS IN TONNES PER DAY						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
Corridor-I : Patanchervu to Sanatnagar (NH-9) (Length=17.45 km)								
2001	272820	5.83	0.47	0.00	0.06	38.66	0.00	0.27
2003	357640	8.19	0.58	0.00	0.09	49.76	0.00	0.40
2011	697118	19.81	0.85	0.0	0.22	82.48	0.00	1.14
2021	1109836	55.25	1.88	0.05	0.66	201.34	0.00	3.62
Corridor No-II : Sanatnagar to Nalgonda 'X' Road (NH-9) (Length=11.5 km)								
2001	1327949	36.30	2.18	0.05	0.38	198.40	0.00	1.82
2003	1546722	43.97	2.45	0.05	0.46	225.92	0.00	2.25
2011	1777942	75.36	3.39	0.05	0.87	313.13	0.00	4.48
2021	2825044	246.45	8.63	0.18	3.04	910.39	0.00	16.46
Corridor No-III : Nalgonda 'X' Road to Hayatnagar (NH-9) (Length=16.5 km)								
2001	382232	9.91	0.79	0.00	0.12	59.51	0.00	0.54
2003	467533	12.54	0.87	0.00	0.15	69.32	0.00	0.69
2011	663376	21.33	0.96	0.01	0.25	90.19	0.00	1.26
2021	1026962	52.09	1.77	0.05	0.62	188.64	0.00	3.41

Corridor No-IV : Panjagutta to Secunderabad (Length=7.6 km)								
2001	588778	18.23	1.01	0.01	0.17	94.66	0.00	0.86
2003	641933	20.36	1.08	0.01	0.19	101.88	0.00	0.97
2011	676655	26.05	0.96	0.01	0.25	91.68	0.00	1.39
2021	919585	51.14	1.62	0.02	0.57	158.35	0.00	3.17
Corridor No-V : MG Bus Station to Ghatkesar (Length=28.5 km)								
2001	451039	8.50	0.71	0.00	0.09	58.45	0.00	0.38
2003	648621	13.26	0.99	0.00	0.14	85.09	0.00	0.63
2011	1281932	38.86	1.68	0.04	0.44	173.81	0.00	2.29
2021	1683883	88.73	3.10	0.06	1.10	339.30	0.00	5.96
Corridor No-VI : Medchal to Shamshabad (NH-7) (Length=50 km)								
2001	1953133	43.49	2.80	0.04	0.54	260.71	0.00	2.48
2003	2365874	54.28	3.29	0.05	0.66	313.34	0.00	3.10
2011	2904924	92.02	4.47	0.09	1.13	442.37	0.00	5.71
2021	4579861	250.22	18.97	0.19	3.16	993.26	0.00	17.04
Corridor No-VII : Secunderabad to Charminar via RTC 'X' Road (Length=7.6 km)								
2001	587684	18.05	1.06	0.00	0.18	80.14	0.00	0.89
2003	705399	22.77	1.21	0.00	0.23	96.32	0.00	1.15
2011	1388286	99.94	4.54	0.08	1.16	434.29	0.00	5.95
2021	1797897	165.41	5.64	0.12	1.99	581.49	0.00	10.83
Corridor No-VIII : Kachiguda to Tolichowki via Mehidipatnam (Length=9.96 km)								
2001	361545	11.13	0.43	0.00	0.11	44.26	0.00	0.59
2003	437127	13.67	0.54	0.00	0.14	53.73	0.00	0.73
2011	535194	16.55	0.70	0.00	0.18	63.56	0.00	0.96
2021	605900	39.55	1.32	0.01	0.47	135.33	0.00	2.58
Corridor No-IX : Nalgonda 'X' Road to Turka Yamjal (Nagarjuna Sagar State Highway) (Length=22.11km)								
2001	177282	3.94	0.41	0.00	0.04	36.87	0.00	0.18
2003	241534	5.64	0.49	0.00	0.06	44.66	0.00	0.27
2011	530274	17.45	0.81	0.00	0.20	78.81	0.00	1.06
2021	805638	38.43	1.33	0.02	0.46	143.90	0.00	2.55

5.5.3 More Effective Bus Service Scenario

Daily emissions in the year 2011 and 2021 for the scenario on improved bus transit service are given in **Tables 5.13 & 5.14** below:

Table 5.13: Daily Emissions with More Effective Bus Transit Scenario: Entire Study Area

S. No	YEAR	VKT/day	POLLUTION LOAD IN METRIC TONNES PER DAY						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	26244325	879.45	49.87	0.75	7.92	4456.37	0.04	37.66
2	2021	36189703	1634.38	91.42	1.26	14.58	7445.06	0.07	69.56

Table 5.14: Estimated Emissions with More Effective Bus Transit Scenario: Nine Major Corridors

YEAR	VKT	EMISSIONS IN TONNES PER DAY						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH4
Corridor-I : Patanchervu to Sanatnagar (NH-9) (Length=17.45 km)								
2011	510899	13.70	0.84	0.00	0.13	81.93	0.00	0.63
2021	832029	29.68	1.71	0.03	0.28	178.17	0.00	1.36
Corridor-II : Sanatnagar to Nalgonda 'X' Roads (NH-9) (Length=11.5 km)								
2011	1245719	44.25	2.66	0.04	0.43	265.15	0.00	2.00
2021	1493143	63.23	4.14	0.07	0.62	406.27	0.00	2.85
Corridor-III : Nalgonda 'X' Road to Hayatnagar (NH-9) (Length=16.5 km)								
2011	474401	12.37	0.87	0.00	0.12	77.80	0.00	0.58
2021	614701	18.5	1.43	0.02	0.21	123.46	0.00	0.89
Corridor-IV : Panjagutta to Secunderabad Retifile Bus Station (Length=7.6 km)								
2011	489744	13.40	0.91	0.00	0.13	71.4	0.00	0.61
2021	543936	15.90	1.31	0.01	0.18	97.72	0.00	0.73
Corridor-V : MG Bus Station to Ghatkesar (Length=28.5 km)								
2011	943914	22.36	1.41	0.03	0.22	138.30	0.00	1.05
2021	1228382	32.10	2.35	0.03	0.34	222.26	0.00	1.49
Corridor-VI : Medchal to Shamshabad (NH-7) (Length=50 km)								
2011	2095652	55.25	3.79	0.07	0.59	370.86	0.00	2.65
2021	2797222	87.90	6.58	0.11	0.98	625.06	0.00	4.22

Corridor-VII : Secunderabad to Charminar via RTC 'X' Road (Length=7.6 km)								
2011	989134	44.95	2.18	0.04	0.38	238.53	0.00	1.96
2021	1069234	49.05	2.82	0.04	0.45	282.03	0.00	2.16
Corridor-VIII : Kachiguda to Tolichowki via Mehidipatnam (Length=9.96 km)								
2011	317326	9.43	0.58	0.00	0.10	50.85	0.00	0.44
2021	408384	14.05	0.89	0.00	0.14	77.46	0.00	0.67
Corridor-IX : Nalgonda 'X' Road to Turka Yamjal (N. Sagar SH) (Length=22.11 km)								
2011	380523	9.43	0.67	0.00	0.10	62.39	0.00	0.44
2021	486422	13.49	1.10	0.01	0.15	96.04	0.00	0.65

5.5.4 Multi-Modal Transport System (MMTS) Scenario

Daily emissions in the year 2011 and 2021 for the MMTS scenario are given in **Tables 5.15** below:

Table 5.15: Daily Emissions in MMTS Scenario

YEAR	VKT/DAY	POLLUTION LOAD IN TONNES PER DAY						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2003	21151317	627.94	34.05	0.50	6.25	2896.94	0.03	30.31
2011	35323616	1190.58	56.64	0.89	11.88	5034.41	0.04	60.17
2021	54551050	2943.27	114.46	1.89	31.04	10089.88	0.07	165.33

5.5.5 Summary of Percentage Reduction In Emissions

The reduction in quantity & percentage of pollution reduction due to implementation of various scenarios are shown in following **Tables 5.16.**

Table 5.16: Reduction in Emissions for Various Scenarios Reduction Due To More Effective Bus Transit Scenario in Entire Study Area (In Tons)

YEAR	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2011	327.20 (27)	8.71 (15)	0.15 (17)	4.26 (35)	688.05 (13)	0.00 (0)	23.55 (38)
2021	1410.40 (46)	36.75 (29)	0.82 (39)	17.96 (55)	3792.69 (34)	0.03 (30)	101.75 (59)
REDUCTION DUE TO MORE EFFECTIVE BUS TRANSIT SCENARIO IN MAJOR NINE CORRIDORS							
Corridor No : I							
YEAR	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
2011	6.11 (31)	0.01 (1)	0.00 (-)	0.09 (41)	0.55 (1)	0.00 (-)	0.51 (45)
2021	25.57 (46)	0.17 (9)	0.02 (40)	0.38 (58)	23.17 (12)	0.00 (-)	2.26 (62)
Corridor No : II							
2011	31.11 (41)	0.73 (22)	0.01 (20)	0.44 (50)	47.98 (15)	0.00 (-)	2.48 (55)
2021	183.22 (74)	4.49 (52)	0.11 (61)	2.42 (80)	504.12 (55)	0.00 (-)	13.61 (83)
Corridor No : III							
2011	8.96 (42)	0.09 (9)	0.01 (100)	0.13 (52)	12.39 (14)	0.00 (-)	0.68 (54)
2021	33.59 (64)	0.34 (19)	003 (60)	0.41 (66)	65.18 (35)	0.00 (-)	2.52 (74)
Corridor No : IV							
2011	12.65 (49)	0.05 (5)	0.01 (100)	0.12 (48)	20.28 (22)	0.00 (-)	0.78 (56)
2021	35.24 (69)	0.31 (19)	0.01 (50)	0.39 (68)	60.63 (38)	0.00 (-)	2.44 (77)
Corridor No : V							
2011	16.50 (42)	0.27 (16)	0.01 (25)	0.22 (50)	35.51 (20)	0.00 (-)	1.24 (54)
2021	56.63 (64)	0.75 (24)	0.03 (50)	0.76 (69)	117.04 (34)	0.00 (-)	4.47 (75)
Corridor No : VI							
2011	36.77 (40)	0.68 (15)	0.02 (22)	0.54 (48)	71.50 (16)	0.00 (-)	3.06 (54)
2021	162.32 (65)	2.39 (27)	0.08 (42)	2.18 (69)	368.20 (37)	0.00 (-)	12.82 (75)
Corridor No : VII							
2011	54.99 (55)	2.36 (52)	0.04 (50)	0.78 (67)	195.77 (45)	0.00 (-)	3.99 (67)
2021	116.36 (70)	2.82 (50)	0.08 (67)	1.54 (77)	299.46 (51)	0.00 (-)	8.67 (80)

Corridor No : VIII							
2011	7.12 (43)	0.12 (170	0.00 (-)	0.08 (44)	12.71 (20)	0.00 (-)	0.52 (54)
2021	25.5 (64)	0.43 (33)	0.01 (100)	0.33 (70)	57.87 (43)	0.00 (-)	1.91 (74)
Corridor No : IX							
2011	8.02 (46)	0.14 (17)	0.00 (-)	0.10 (50)	16.42 (21)	0.00 (-)	0.62 (58)
2021	24.94 (65)	0.23 (17)	0.01 (50)	0.31 (67)	47.86 (33)	0.00 (-)	1.90 (75)
Reduction Due to MMTS Scenario in Study Area							
2003	2.21 (0.35)	0.17 (0.50)	0 (-)	0.02 (0.32)	19.06 (0.65)	0 (-)	0.1 (0.33)
2011	16.07 (1.33)	1.94 (3.31)	0.01 (1.11)	0.30 (2.46)	110.01 (2.14)	0.00 (-)	1.04 (1.70)
2021	101.51 (3.33)	13.71 (10.70)	0.19 (9.13)	1.50 (4.61)	1147.87 (10.21)	0.03 (30.00)	5.98 (3.49)

Note: figures in braces indicate the percentage reduction.

From above table it can be observed that there are significant reductions in all pollutants for all scenarios.

5.6 BROAD COST ESTIMATES FOR MORE EFFECTIVE PUBLIC TRANSIT SERVICES

5.6.1 Broad cost estimates for implementation of most effective public transit services as identified were prepared based on the unit rates of the items as prevalent in the study area as per 2003 price levels and are presented in **Tables 5.17 to 5.19**. Cost estimate for MMTS has been taken from Municipal Corporation of Hyderabad.

Table 5.17: Broad Cost Estimates for More Effective Bus Transit Services
Sanatnagar-Nalgonda 'X' Road Corridor

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
1	More Effective Bus Transit Service				
	(I) Bus Lane markings	Sq.m	2400	550	1.320
	(ii) Construction of Bus-bays	Each	17	300,000	5.100
	(iii) Traffic Signs	Each	200	3,000	0.600
	(iv) Overhead Signs	Each	6	180,000	1.080
	(v) Pavement Markings	Km	24	15,000	0.360
	Total				8.46
	Contingencies @ 5%			Rs	0.423
	Project Management Consultancy(PMC) @ 10%			Rs	0.846
	Supervision Cost @ 5%			Rs	0.423
	GRAND TOTAL			*Rs*	10.152
				Approx. Rs.10 millions	

Table 5.18: Broad Cost Estimates for More Effective Bus Transit Services Panjugutta to Secunderabad Corridor

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
(1)	More Effective Bus Transit Service				
	(I) Bus Lane markings	sq.m	1600	550	0.880
	(ii) Construction of Bus bays	Each	12	300,000	3.600
	(iii) Traffic Signs	Each	130	3,000	0.390
	(iv) Overhead Signs	Each	4	180,000	0.720
	(v) Pavement Markings	Km	16	15,000	0.240

Total		5.83
Contingencies @ 5%	Rs	0.292
Project Management Consultancy(PMC) @ 10%	Rs	0.583
Supervision Cost @ 5%	Rs	0.292
GRAND TOTAL	*Rs*	6.996

Approx. Rs7 Millions

Table 5.19: Cost Estimates for More Effective Public Transit Services Total HUDA Area

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
(I)	*More Effective Bus Transit Service*				
	(I) Bus Lane markings	Sq.m	190000	550	104.500
	(ii) Construction of Bus-bays	Each	1500	300,000	450.000
	(iii) Traffic Signs	Each	3000	3,000	9.000
	(iv) Overhead Signs	Each	190	180,000	34.200
	(v) Pavement Markings	Km	1900	15,000	28.500
				Sub Total	626.200
(II)	MMTS - Construction Cost				1500.000

Total	Rs	2126.200
Contingencies @ 5%	Rs	106.310
Project Management Consultancy (PMC) @ 10%	Rs	212.620
Supervision Cost @ 5%	Rs	106.310
GRAND TOTAL	*Rs*	2551.440

Approx. Rs.2551 Millions

6.0 TRAFFIC MANAGEMENT AND MEASURES TO IMPROVE TRAFFIC FLOW

6.1 ROLE OF TRAFFIC MANAGEMENT MEASURES

6.1.1 It has been the experience of many traffic & transport planners that most transportation plans rarely progress beyond the drawing board for lack of financial resources and other related constraints. In many urban areas, socio-economic constraints, hutments, ribbon developments, etc. are serious impediments to further development, even if the problem of funds is overcome. Provision of new urban transport infrastructure is both long-term and capital intensive, and resources are simply not available at a scale that matches the escalating demand.

6.1.2 The only recourse open to the traffic manager, therefore is the option of optimizing the existing facilities to provide improved accessibility and mobility at a satisfactory level of safety and comfort to most of the road users. This can be achieved after studying and evaluating the problems in the light of sound and tested traffic management techniques, which are essentially low-cost, easily implementable and flexible. These are short-term solutions, primarily intended to reduce the intensity of inconvenience caused by congestion and the multiplicity of the modes of transport traversing in the common space. They may not offer a permanent solution, yet they lend themselves to some time saving relief, to a point where the administration may launch a long-term solution.

6.1.3 The fundamental approach in traffic management measures is to retain as much as possible the existing pattern of streets but to alter the pattern of traffic movement on these, so that the most efficient use is made of the system. In doing so, minor alterations to street furniture are inevitable, and are part of management measures.

6.1.4 The aim of Traffic Management lies in achieving the best use and extension of facilities & services available through use of low-cost solutions. Some of these could be regulations only, which may not cost anything. For this purpose, the greatest emphasis is placed on:

i) Rationalisation of the use of urban transport facilities; particularly road space.

ii) Provision of better access through cost-effective improvements and extensions of road networks.

iii) Traffic Management by adopting measures like one-way streets, pedestrian friendly policies, signals, junction design & improvements, tidal flow, and better facilities for bicycles.

iv) Improvement of the standards and viability of public transport and giving better access to public transport priority measures like bus lanes, etc.

v) Strengthening of urban transport institutions including technical assistance and training.

6.2 TRAFFIC MANAGEMENT CORRIDORS

6.2.1 RITES has identified 3 more corridors in addition to the GEP Corridor (ESI Hospital to Khairatabad Junction, Length=4.6km) as a part of the study. Only GEP corridors were to be considered as per terms of reference of the study. The corridors are:

a) Erragadda junction to ESI Hospital (NH-9), L=0.9km

b) Khairatabad junction to Nalgonda 'X' roads (NH-9) via Nampally Public Garden and MJ Market, L=7.1km

c) Panjagutta junction to Secunderabad Retifile bus station via Green lands and Begumpet road, L=8.05km

6.2.2 However, the above (iv) and (v) corridors are extensions of the GEP corridor. Hence, the total selected/identified corridors effectively are two i.e.,

a) Erragadda to Nalgonda 'X' Road Corridor
b) Panjagutta to Secunderabad Corridor

The two corridors are shown in Figure 6.1.

6.3 TRAFFIC SCENARIO ON TRAFFIC MANAGEMENT SCENARIO CORRIDORS

6.3.1 Erragadda to Nalgonda 'X' Road Corridor

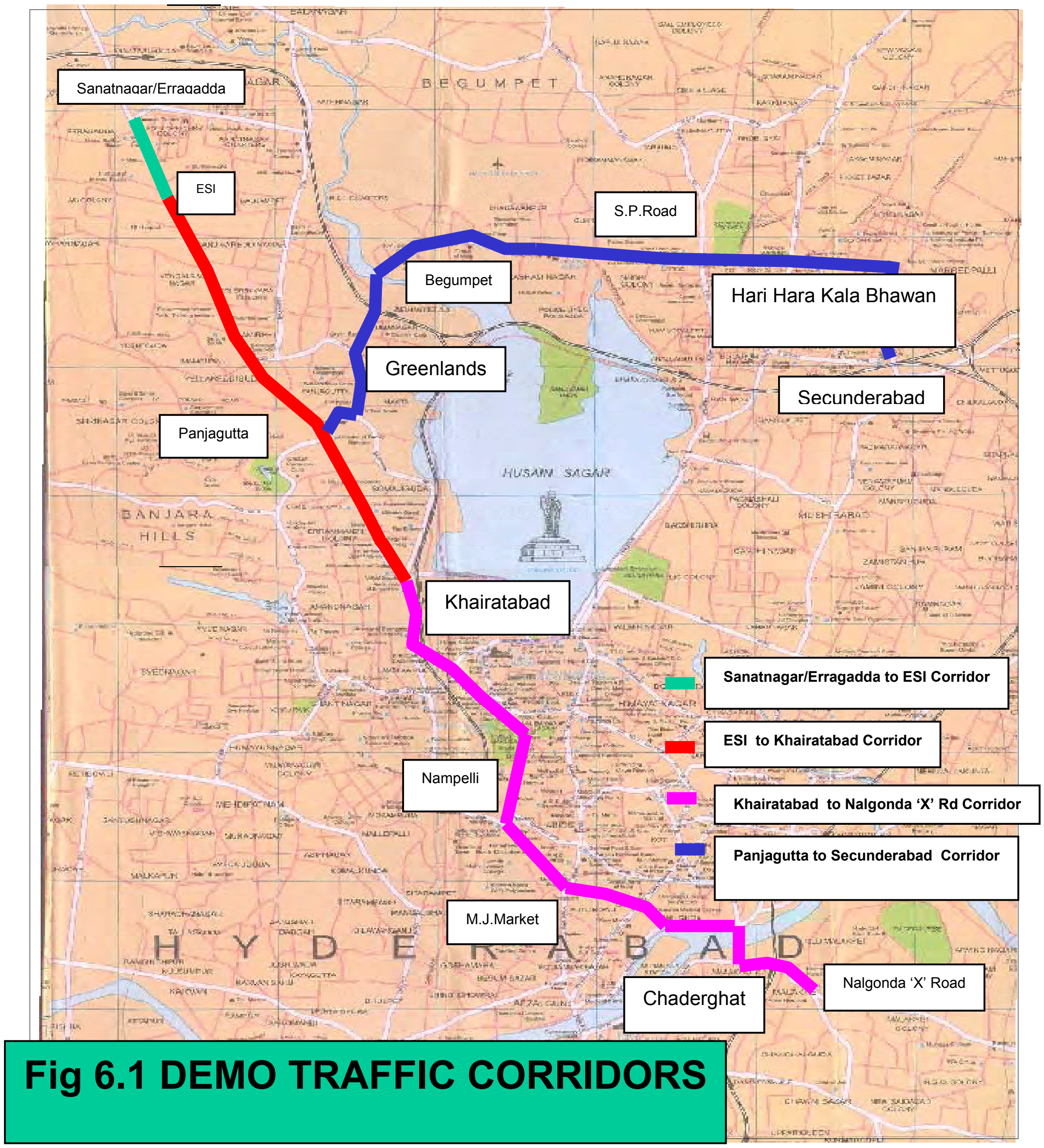
This identified corridor abuts densely populated commercial complexes, administrative and corporate offices. This corridor lies on NH-9 and connects Mumbai in the North and Vijayawada in the Southeast. The length of NH-9 in this section is about 12 km. The ROW on this corridor varies from 14m to 36m but at assembly and police control room the ROW is more than 40m. The peak hour approach volumes of the junctions falling under this corridor have been described in **Chapter 3** of this report.

The mid block peak hour traffic on the corridor varies from 4260 pcus to 10680 pcus. The section- wise peak hour traffic is presented in **Table 6.1.**

Table 6.1: Section-wise Peak Hour Traffic (Erragadda to Nalgonda 'X' Road) – 2003

Name of the Section	Peak Hour (PCUs)
Erragada to E.S.I.	7593
E.S.I to S.R.Nagar	6510
S.R.Nagar to Maitrivanam	6060
Maitrivanam to Ameerpet	7249
Ameerpet to Panjagutta	7491
Panjagutta to Khairatabad	7436
Khairatabad to Saifabad New Police Station	8401
Lakidikapool to Ravindra Bharati	9303
Ravindra Bharati to Control Room	10679
Control Room to L.B.Stadium	10063
L.B. Stadium to A1-Junction	8047
A1-Junction to Lata Talkies	9396
Lata Talkies to Goshamahal	8700
Goshamahal to M.J.Market	9619
M.J.Market to PutliBowli	4256
Putlibowli to Rangamahal	5251
Rangamahal to Chadarghat	7641
Chadarghat to Naigara	8257
Naigara to Nalgonda X Road	7573

Figure 6.1: Demo Traffic Corridors



6.3.2 Panjagutta to Secunderabad Corridor

This corridor passes through densely populated commercial complex and corporate offices. In this corridor one ROB, Begumpet and three flyovers, Begumpet Airport, Paradise and Hari Hara Kala Bhawan exist. The length of this corridor is about 8 km. The ROW on this corridor varies from 18m to 38m. The peak hour approach volumes of the junctions falling under this corridor have been described in **Chapter 3** of this report. The mid block peak hour traffic on the corridor various from 4000 PCUs to 14850pcus.The section wise peak hour traffic is presented in **Table 6.2.**

Table 6.2: Section-wise Peak Hour Traffic (Panjagutta to Secunderabad) – 2003

Name of the Section	Peak Hour (PCUs)
Panjagutta to Rajeev Gandhi Statue	6237
Rajeev Gandhi Statue to Greenlands	9846
Greenlands to N.T.R. Junction	14848
N.T.R. Junction to Paradise	5061
Paradise Road to Plaza	4898
Plaza to Hari Hara Kala Bhavan	4697
Hari Hara Kala Bhavan to YMCA	3977
YMCA to East Marredpally	6108
East Marredpally to Sangeet Cinema	5230
Sangeet Cinema to Secunderabad Rethifile Bus Terminus	5049

6.3.3 PEAK HOUR TRAFFIC COMPOSITION

The average peak hour traffic composition on the two corridors is presented in **Tables 6.3 & 6.4.**

Table 6.3: Peak Hour Traffic Composition (Erragadda to Nalgonda X Roads Corridor) – 2003

S No	Type of Vehicle	Numbers	Percentage
1	Bus	398	3.92
2	Goods	87	0.86
3	Cars	1427	14.07
4	2-Wheelr	5356	52.80
5	3-Seater Auto	1789	17.64
6	7-Seater Auto	350	3.45
7	Slow Moving Vehicles	729	7.19
8	Others	8	0.08

Table 6.4: Peak Hour Traffic Composition (Punjagutta to Secunderabad Corridor) – 2003

S No	Type of Vehicle	Numbers	Percentage
1	Bus	293	3.57
2	Goods	91	1.11
3	Cars	1949	23.76
4	2-Wheeler	4283	52.22
5	3-Seater Auto	1170	14.26
6	7-Seater Auto	13	0.16
7	Slow Moving Vehicles	397	4.84
8	Others	6	0.07

It is observed from above table that car traffic composition is significantly high on Panjagutta to Secunderabad corridor compared to Erragadda to Nalgonda 'X' road corridor.

6.3.4 Volume – Capacity (V/C) ratio

The estimated V/C ratios on selected corridors are shown in **Table 6.5.**

Table 6.5: V/C Ratios – 2003

S. No.	Name of the Section	V/C Ratio
Erragadda to ESI Corridor		
1	Erragada to E.S.I.	1.7
2	E.S.I to S.R.Nagar	1.5
3	S.R.Nagar to Maitrivanam	0.7
4	Maitrivanam to Ameerpet	1.1
5	Ameerpet to Panjagutta	1.1
6	Panjagutta to Khairatabad	1.1
7	Khairatabad to Saifabad New Police Station	1.3
8	Lakidikapool to Ravindra Bharati	1.4
9	Ravindra Bharati to Control Room	1.0
10	Control Room to L.B.Stadium	1.1
11	L.B. Stadium to A1-Junction	1.2
12	A1-Junction to Lata Talkies	2.1
13	Lata Talkies to Goshamahal	1.0
14	Goshamahal to M.J.Market	1.1
15	M.J.Market to PutliBowli	1.0
16	Putlibowli to Rangamahal	1.2
17	Rangamahal to Chadarghat	1.7
18	Chadarghat to Naigara	1.3
19	Naigara to Nalgonda X Road	1.7
Panjagutta to Secunderabad corridor		
1	Panjagutta to Rajeev Gandhi Statue	0.9
2	Rajeev Gandhi Statue to Greenlands	1.1
3	Greenlands to N.T.R. Junction	1.7
4	N.T.R. Junction to Paradise	0.8
5	Paradise Road to Plaza	0.6
6	Plaza to Hari Hara Kala Bhavan	0.5
7	Hari Hara Kala Bhavan to YMCA	0.5

S. No.	Name of the Section	V/C Ratio
8	YMCA to East Marredpally	1.4
9	East Marredpally to Sangeet Cinema	0.8
10	Sangeet Cinema to Secunderabad Rethifile Bus Terminus	0.8

It is observed from above table that in many of the road sections, V/C value exceeds 1.

6.4 SCENARIOS FOR TRAFFIC MANAGEMENT AND MEASURES TO IMPROVE TRAFFIC FLOW

6.4.1 The various Traffic Management measures have been proposed for improvement in traffic flow along identified corridors. These measures are readily implementable. Various models were developed to estimate the impact of speed with various traffic measures. A total of three scenarios have been developed for the identified corridors as mentioned below;

1. Business As Usual Scenario (BAU)
2. Flyover Scenario
3. GEP Scenario

The above scenarios have been evaluated on the basis of various developed models.

6.5 BUSINESS AS USUAL SCENARIO (BAU)

6.5.1 The scenario has considered for the study area i.e., HUDA and the traffic management for the base year 2003 and horizon years of 2011 and 2021. The traffic volumes in the study area and on the nine major corridors including two identified corridors for traffic management scenario were obtained by transport demand modeling as explained in Chapter 4 & 5. Accordingly, Vehicle Kilometer Traveled (VKT) has been estimated for the two corridors. The estimated vehicular emissions in this scenario have already been presented in chapter on scenarios for more effective public transit service.

6.6 FLYOVER SCENARIO

6.6.1 In this scenario, a flyover of length about 12km has been proposed from Sanatnagar to Nalgonda 'X' Road identified corridor with suitable number of up & down ramps. The location of proposed flyover is shown in Figure 6.2. Accordingly road network was updated with increased speed of public and private modes due to inclusion of flyover. Speeds for BAU and Flyover scenario were estimated from speed-flow relationship as discussed in Chapter-4 and given in Table 6.6. Accordingly Vehicle Kilometer Traveled (VKT) has been estimated. The estimated vehicular emissions are presented in Tables 6.7 and 6.8 for BAU and Flyover scenario respectively. Reduction in pollution quantity loads and percentage reduction is mentioned in Table 6.9

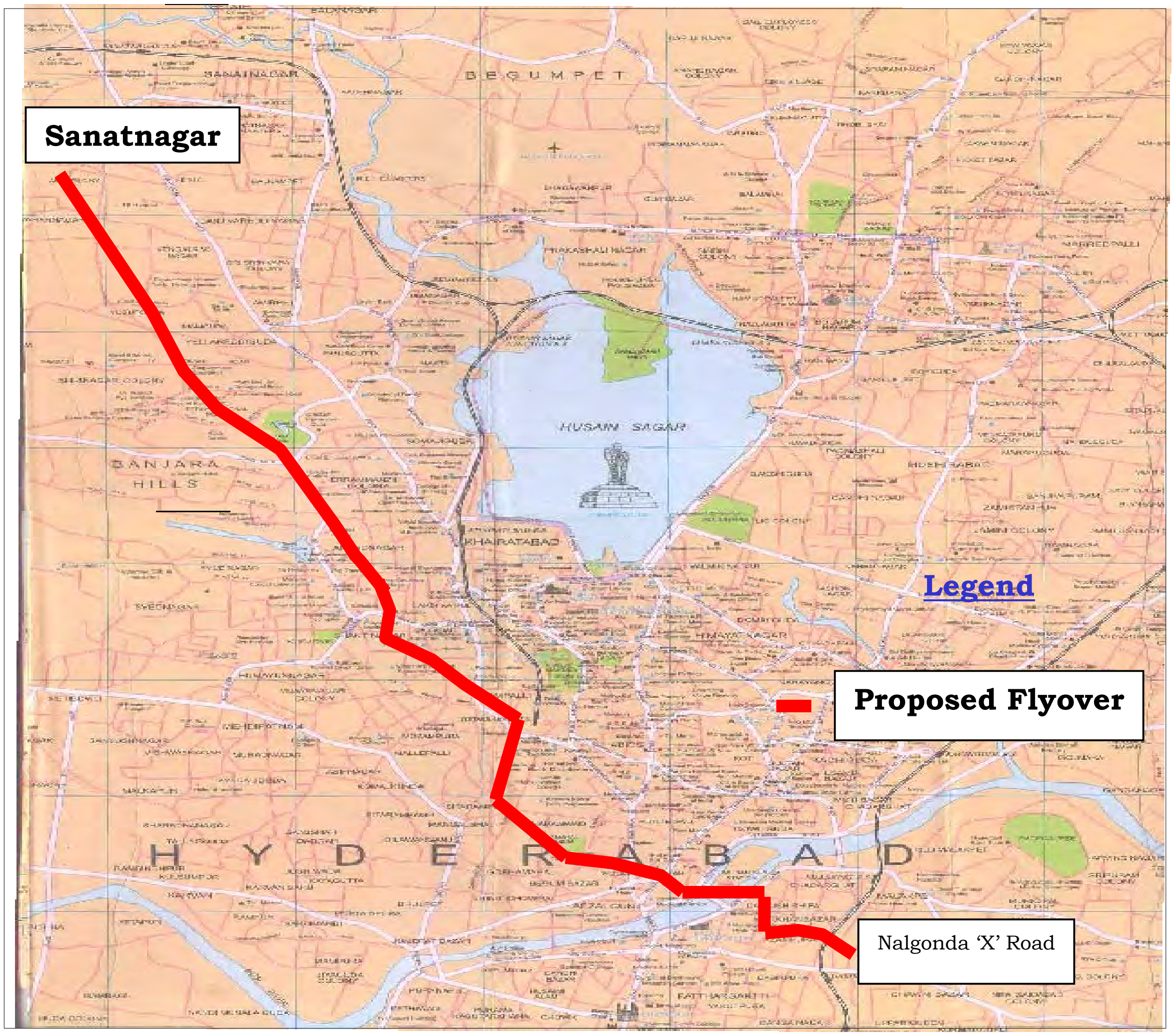


Figure 6.2: Proposed Flyover on Demo Corridor

Table 6.6: Expected Traffic Speeds (kmph) for BAU and Flyover Scenario (Sanatnagar to Nalgonda 'X' road corridor)

MODE	2003	2011		2021	
		BAU	FLYOVER	BAU	FLYOVER
Car	23	18.10	38.50	10.00	31.50
2-w	23	18.10	38.50	10.00	31.50
Bus	15	10.30	21.40	5.00	17.50
Auto	20	10.30	21.40	5.00	17.50

Table 6.7: Emissions: Sanatnagar to Nalgonda 'X' Road BAU Scenario

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	1777942	75.36	3.39	0.05	0.87	313.13	0.00	4.48
2	2021	2825044	246.45	8.63	0.18	3.04	910.39	0.00	16.46

Table 6.8: Emissions: Sanatnagar to Nalgonda 'X' Road Flyover Scenario

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	2831374	75.23	3.26	0.05	0.80	292.84	0.00	4.12
2	2021	4443724	213.04	7.16	0.14	2.46	734.91	0.00	13.59

Table 6.9: Reduction in Emissions Flyover from Sanatnagar to Nalgonda 'X' Road over BAU Scenario

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	0.13 (0.20)	0.13 (3.80)	0.00 (-)	0.07 (8.00)	20.29 (6.50)	0.00 (-)	0.36 (8.00)
2	2021	33.41 (13.60)	1.47 (17.00)	0.04 (22.20)	0.58 (19.10)	175.48 (19.30)	0.00 (-)	2.87 (17.40)

Note: figures in braces indicate percentage reduction

6.6.2 It can be observed that VKT increases considerably on the corridor. Although reduction in emissions is expected to be small but there is a reasonable reduction for the year 2021.

6.7 GEP SCENARIO

6.7.1 Reduction of Side Friction

The zig-zag parking, on-street parking, encroachments and presence of hawkers significantly reduce the effective carriageway width of roads. These factors directly affect the capacity of road. Besides these, on-street and unplanned parking reduces the degree of maneuverability and decreases the average journey speed. The provision of on-street parking on road sections with wider carriageway and banning of on-street parking on sections with smaller carriageway would result in increase in road capacity as well as average speed. Accordingly Vehicle Kilometer Traveled (VKT) has been estimated. Speeds for BAU and GEP scenario for the two corridors for the year 2011 & 2021 are given in **Table 6.10.** The vehicular emissions and corresponding percentage reductions in this scenario are presented in **Tables 6.11** to **6.14.**

Table 6.10: Expected Traffic Speeds (kmph) for Removal of Side Friction Scenario (Sanatnagar to Nalgonda 'X' road & Panjagutta to Secunderabad corridors)

MODE	2011				2021			
	BAU		Removal of Side Friction		BAU		Removal of Side Friction	
	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad
CAR	18.10	18.97	19.30	19.60	10.00	17.19	16.60	18.10
2W	18.10	18.97	19.30	19.60	10.00	17.19	16.60	18.10
BUS	10.30	15.72	16.70	17.00	5.00	9.99	14.00	15.50
AUTO	10.30	15.72	16.70	17.00	5.00	9.99	14.00	15.50

Table 6.11: Emissions from GEP Scenario:
Sanatnagar to Nalgonda 'X' Road (NH-9) - Identified Corridor-I

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	1777942	60.39	2.36	0.04	0.64	232.14	0.00	3.37
2	2021	2825044	121.16	3.71	0.08	1.32	399.29	0.00	7.35

Table 6.12: Reduction in Emissions-GEP Scenario
Sanatnagar to Nalgonda 'X' Road (NH-9) - Identified Corridor-I

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	-	14.97 (20)	1.03 (30)	0.01 (20)	0.23 (26)	80.99 (26)	0.00 (-)	1.11 (25)
2	2021	-	125.29 (51)	4.92 (57)	0.10 (56)	1.72 (57)	511.10 (56)	0.00 (-)	9.11 (55)

Note: figures in braces indicate percentage reduction

Table 6.13: Emissions from GEP Scenario:
Panjagutta to Secunderabad - Identified Corridor-II

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	676655	25.10	0.92	0.01	0.24	86.69	0.00	1.33
2	2021	919585	41.46	1.20	0.02	0.43	120.04	0.00	2.42

Table 6.14: Reduction in Emissions-GEP Scenario over BAU
Scenario Panjagutta to Secunderabad - Identified Corridor-II

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	-	0.95 (4)	0.04 (4)	0.00 (-)	0.01 (4)	4.99 (5)	0.00 (-)	0.06 (4)
2	2021	-	9.68 (19)	0.42 (26)	0.00 (-)	0.14 (25)	38.31 (24)	0.00 (-)	0.75 (24)

Note: figures in braces indicate percentage reduction

Here it can be seen that emissions are substantially reduced due to traffic management improvements under GEP scenario. All pollutants are reduced considerably.

6.7.2 Separation of Vulnerable Road Users (Provision of Footpath)

The intermixing of vehicles and pedestrians in the absence of footpaths results in reduced speeds and increase in number of accidents. The provision of footpaths and pedestrian crossings can reduce these conflicts to a great extent, which results in increase of the average speed. Accordingly Vehicle Kilometer Traveled (VKT) has been estimated. Speeds for BAU and separation for vulnerable road users scenario for the two corridors for the years 2011 and 2021 are given in **Table 6.15.** The vehicular emissions and corresponding percentage reductions in this scenario are presented in **Tables 6.16** to **6.19.**

Table 6.15: Expected Traffic Speeds (kmph) for Providing for Effective Utilization of Footpath Scenario

MODE	2011				2021			
	BAU		Foot Path Scenario		BAU		Foot Path Scenario	
	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad	S.nagar-Nalgonda	P.gutta-Sec.bad
CAR	18.10	18.97	18.95	19.38	10.00	17.19	15.63	17.52
2W	18.10	18.97	18.95	19.38	10.00	17.19	15.63	17.52
BUS	10.30	15.72	16.64	17.16	5.00	9.99	12.58	14.89
AUTO	10.30	15.72	16.64	17.16	5.00	9.99	12.58	14.89

Table 6.16*:* Emissions from Separation of Vulnerable Road Users: Sanatnagar to Nalgonda 'X' Road (NH-9) - Identified Corridor-I

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	1777942	61.02	2.39	0.04	0.64	235.19	0.00	3.40
2	2021	2825044	129.75	4.03	0.08	1.43	434.90	0.00	7.95

Table 6.17: Reduction in Emissions from Separation of Vulnerable Road Users (Compared to BAU Scenario) Sanatnagar to Nalgonda 'X' Road (NH-9)

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	-	14.34 (19)	1.00 (29)	0.01 (20)	0.23 (26)	77.94 (25)	0.00 (-)	1.08 (24)
2	2021	-	116.70 (47)	4.60 (53)	0.10 (56)	1.61 (53)	475.49 (52)	0.00 (-)	8.51 (52)

Note: figures in braces indicate percentage reduction

Table 6.18: Emissions from Separation of Vulnerable Road Users: Panjagutta to Secunderabad

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	676655	25.11	0.91	0.01	0.24	86.67	0.00	1.33
2	2021	919585	42.51	1.24	0.02	0.44	124.46	0.00	2.50

Table 6.19: Reduction in Emissions from Separation of Vulnerable Road Users (Compared to BAU Scenario) Panjagutta to Secunderabad- Identified Corridor II

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2011	-	0.94 (4)	0.05 (5)	0.00 (-)	0.01 (4)	5.01 (50	0.00 (-)	0.06 (4)
2	2021	-	8.63 (17)	0.38 (23)	0.00 (-)	0.13 (23)	33.89 (21)	0.00 (-)	0.67 (21)

Note: figures in braces indicate percentage reduction

The above tables indicate that this low cost traffic improvement measure can bring out substantial reduction across all pollutants.

6.7.3 Synchronization Of Traffic Signals Along With Junction Improvements To Reduce Intersection Delays

Signal coordination is one of the important measures in traffic management system. In this study, signal coordination exercise was done by TRANSYT 11 version (Traffic Network Study Tool) developed by TRL, UK. Junction Improvement measures also have positive impact on the average speeds. The junction improvements such as proper signages, zebra crossings, stop lines, removal of encroachments, provision of channelisers for free left traffic movement etc. increase intersection capacity and reduce delays at the intersections. These measures when implemented shall result in improved speeds along the corridor. The increase in speed has been directly computed from reduction in delays expected after implementation of the measures. The instances of frequent acceleration and de-acceleration will also be reduced due to the synchronized/smooth traffic movement. A total of 8 junctions have been coordinated in corridor No. 1 from Sanatnagar to Nalgonda Crossroad. The second identified corridor from Panjagutta to Secunderabad has not been considered for the scenario as this corridor has many flyovers, roundabouts and un-signalized junctions. The expected speeds on various sections by junctions signal coordination vis-à-vis isolated control for this corridor No. 1 is shown in the **Table 6.20.** These tables shows that signal coordinating offers improved traffic flow on the identified corridors. On the basis of improved traffic speeds, the above signal coordinated two sections, average speeds on the existing corridor from Sanatnagar to Nalgonda X Crossroad haven been worked out for 2003, 2011 and 2021 and presented in **Table 6.21.** Expected emissions with this scenario are given in **Table 6.22. Table 6.23** shows that this option can bring substantial reduction in emission levels.

Table 6.20: Synchronization of Traffic Signals
Erragadda to Maitrivanam Section: Corridor No. 1

Name of the Junction	Node	Link No	Mean Delay Time (Sec)		Mean Journey Speed (kmph)	
Erragadda	1	11	10	12	8	22
		12	62	18		
		13	667	57		
		14	64	73		
ESI	2	15	229	22	9.9	
		16	156	54		
		17	4	26		
		18	46	44		
Sanjeev Reddy Nagar	3	19	109	34	6.5	
		20	268	82		
		21	419	69		
		22	305	89		
		23	75	41		
		24	556	66		
		25	202	50		
		26	231	58		
Maitrivanam	4	27	44	34	17.3	
		28	1	1		
		29	58	63		
		30	1	1		
		33	55	74		

Ameerpet to KCP Section: Identified Corridor No. 1

Name of the Junction	Node	Link No	Mean Delay Time (Sec)		Mean Journey Speed (kmph)	
			Isolated	Coordination	Isolated	Coordination
Ameerpet	101	101	8	11	11.9	19.5
		102	71	49		
		103	71	70		
		104	91	46		
		105	58	64		
		106	84	63		
		107	60	49		
Shalimar	102	201	14	12	16	
		202	38	25		
		203	124	64		
		204	60	44		
Panjagutta	103	301	36	28	17.4	
		302	19	31		
		303	15	18		
		304	34	30		
KCP	104	401	23	21	17.7	
		402	46	32		
		403	120	80		
		404	73	48		

Table 6.21: Expected Traffic Speeds (Kmph) For Synchronization of Traffic Signals and Junction Improvement Scenario (Sanatnagar to Nalgonda 'X' Road Corridor)

Mode	2003	2011	2021
Car	30	23.50	13.00
2-w	30	23.50	13.00
Bus	20	13.40	6.50
Auto	25	13.40	6.50

Table 6.22: Signal Coordination Scenario Emissions

S. No	YEAR	VKT	EMISSIONS PER DAY IN TONNES						
			CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2003	1546722	37.03	1.93	0.04	0.39	173.38	-	1.88
2	2011	1777942	61.54	2.67	0.04	0.70	241.62	-	3.61
3	2021	2825044	196.17	6.75	0.14	2.39	701.47	-	12.95

Table 6.23: Emissions Reduction Due To Signal Coordination as Compared to BAU Scenario

S. No	YEAR	EMISSIONS PER DAY IN TONNES						
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4
1	2003	6.94 (15.78)	0.52 (21.22)	0.01 (20.00)	0.07 (15.22)	52.54 (23.26)	0.00 (-)	0.37 (16.44)
2	2011	13.82 (18.00)	0.72 (21.00)	0.01 (20.00)	0.17 (20.00)	71.51 (23.00)	0.00 (-)	0.87 (19.00)
3	2021	50.28 (20.00)	1.88 (22.00)	0.04 (22.00)	0.65 (21.00)	208.92 (23.00)	0.00 (-)	3.51 (21.00)

Note: figures in braces indicate percentage reduction

6.8 BROAD COST ESTIMATES FOR TRAFFIC MANAGEMENT MEASURES

6.8.1 The preliminary cost estimates for the proposed improvement schemes have been worked out for identified corridors on the basis of the unit rates as prevalent in the region for such works as per 2003 price level. The rates for signal installation and lane marking, etc. are obtained from the signal manufactures and from various studies done by the consultants The cost estimates are presented in **Table 6.24** to **6.25.**

Table 6.24: Broad Cost Estimates for Traffic Management Measures Sanatnagar to Nalgonda 'X' Road Corridor

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
(A)	*Flyover Construction*	Km	16	140,000,000	2240.000
(B)	*Construction of Footpath*	Sq.m	4000	650	2.600
(C)	*Synchronization of Signals & Junction Improvements*				
	(i) Junction Improvements	Each	21	500,000	10.500
	(ii) Street Furniture (Road Markings & Traffic Signs)	Each	21	50,000	1.050
	(iii) Signal Coordination of existing signals about 10 junctions (Cost of cables, soft & hard cutting and hardware up-gradation etc)	Lump sum			2.000
				Sub Total	13.550
(D)	*Side friction Removal*				
	(i) Construction of Guard Rails	m	24000	1,100	26.400
	(ii) Traffic Sign Boards	Each	100	3,000	0.300
	(iii) Carriageway edge lane marking with Thermoplastic paint	Sq.m	7200	550	3.960
	(iv) Cost of mini bollards, studs, reflectors etc	Km	24	50,000	1.200
	(v) Overhead Signs	Each	12	180,000	2.160
				Sub Total	34.02
	Total			Rs	2290.17
	Contingencies @ 5%			Rs	114.509
	Project Management Consultancy (PMC) @ 10%			Rs	229.017
	Supervision Cost @ 5%			Rs	114.509
	GRAND TOTAL			Rs	2748.204
				Approx. Rs	*2750 Millions*

Table 6.25: Broad Cost Estimates for Traffic Management Measures Panjugutta to Secunderabad Corridor

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
(A)	*Construction of Footpath*	Sq.m	6000	650	3.900
(B)	*Side friction Removal*				
	(i) Construction of Guard Rails	m	16000	1100	17.600
	(ii) Traffic Sign Boards	Each	60	3,000	0.180
	(iii) Carriageway edge lane marking with Thermoplastic paint	Sq.m	4800	550	2.640
	(iv) Junction Improvements	Each	12	500,000	6.000
	(v) Street Furniture with Thermoplastic paint	Each	12	50,000	
	(vi) Overhead Signs	Each	8	180,000	1.440
	(vii) Cost of mini bollards, studs, reflectors etc	Km	16	50,000	0.800
	Sub Total				28.660
	Total			Rs	32.560
	Contingencies @ 5%			Rs	1.628
	Project Management Consultancy (PMC) @ 10%			Rs	3.256
	Supervision Cost @ 5%			Rs	1.628
	GRAND TOTAL			*Rs*	39.072
				Approx. Rs	*40 Millions*

7.0 VEHICLE TECHNOLOGY / TRAINING MEASURES RELATED TO TWO-STROKE VEHICLES

7.1 INTRODUCTION

7.1.1 Vehicular air pollution is common in growing metropolitan areas in India; where about more than half of all vehicles are two and three wheel vehicles with two stroke engines. Hyderabad has a large number of 2-wheelers, many of which are powered by 2-stroke engines. All 3-wheelers in Hyderabad have 2-stroke engines. These engines operate at relatively low compression ratios (resulting in high CO_2 emissions), do not burn their fuels completely (resulting in high gaseous and particulate hydrocarbon and carbon monoxide emissions) and burn a mix of petrol and lubricating oil (which, if not properly proportioned, can result in high particulate emissions). In addition, the motor fuels are often blended with lesser quality fuels or otherwise adulterated in order to save cost, which further increases emission levels. As a result, 2 stroke two or three wheelers in Hyderabad contribute quite disproportionately to air quality problems. In addition, the drivers of two wheelers and auto rickshaws also add to the air pollution with their inconsistence driver habits.

7.1.2 The technology for four stroke vehicles is gaining ground in India. However, the people owning old technology vehicles may not be in a position to spend more money for better technology. The switch over will be gradual and phase out depends upon policy interventions/incentives provided by the Government.

7.1.3 The performance of any vehicle deteriorates gradually over time but regular inspection and maintenance can improve performance and keep emissions under control.

7.1.4 Large scale ban on gasoline powered two-stroke engine vehicles would be extremely difficult. However, emissions can be reduced significantly through other measures. The immediate and simple solution is to use the correct type and concentration of lubricant and to carry out regular maintenance. These measures would significantly reduce emissions from two stroke engines while saving drivers money and ultimately improving air quality. Promoting these “win-win” measures requires building public awareness by disseminating information on the health impacts of emissions. Partnerships among government, industry and the public will be crucial to bring about the correct driving, proper vehicle maintenance and changes required to achieve air quality goals. Fine particulate matter has been shown in studies in a number of cities around the world to have serious health effects, including premature mortality, respiratory symptoms, exacerbation of asthma and changes in lung function. Vehicle emissions of fine particles are particularly harmful because they occur near ground level, close to where people live and work.

7.1.5 Two stroke engines typically have a lower fuel efficiency than four stroke engines, with as much as 15-40 percent of the fuel-air mixture escaping from the engine through the exhaust port. These ‘scavenging losses’ contain a high level of unburned gasoline and lubricant, which increases emissions of hydrocarbons and organic lead (if leaded gasoline is used). The factors affecting vehicular emissions are poor vehicle maintenance, the misuse of lubricant, adulteration of gasoline, and lack of catalytic converters. These exacerbate two stroke engine harmful emissions. Both the quantity and quality of lubricant used affect the level of hydrocarbon and particulate emissions from two stroke engines.

7.2 OPINION & TECHNOLOGY DISTRIBUTION SURVEYS

To assess the present vehicle technology distribution and opinion of two/ three wheeler passengers, limited surveys were carried out at petrol pumps and bus stops on the two identified corridors as a part of this study. About 4,399 samples were collected. Out of which 891 were IPT, 1,428 were 2-wheelers, 89 were cars and 1,991 were bus transport passengers. The survey proforma was designed after discussions with stake holders and covered information such as vehicle owner ship, fuel options, type of engine (2/4 stroke), Trip Length (km), Travel time, Make, Model, Year of manufacturing, Mileage (km/lit), Type of Lubricant, Average km. traveled per day, vehicle service frequency, pollution check up, measures to control pollution etc. The data was compiled and analyzed. The major findings of this survey have been presented in **Annexure 7.1.** It has been observed that about 80% of 2-wheelers have 2-stroke engines and all 3-wheelers (3 & 7 seater) have two stroke engines.

7.3 DRIVING HABITS OF TWO-WHEELERS AND AUTO RICKSHAW OPERATORS

To assess the driving style of two and three wheeler drivers, reconnaissance survey was carried out at a few Intersections on selected corridors of the study area. The major observations of the survey are posted in **Annexure 7.2.** Improper driving habits of people have been observed during this survey.

7.4 MAINTENANCE & OPERATION (M&O) TRAINING PROGRAMS

7.4.1 Emission loads of these 2 stroke vehicles can be reduced by better vehicle maintenance and operations. But most of the drivers of these vehicles are ignorant of these practices. Some may be aware about the benefits of such measures but generally do not know how to practice them. Therefore conducting maintenance and operation training programs for drivers of these vehicles can help in spreading awareness in reducing emissions. Better maintenance practices will include better engine tuning, using better lubricants etc. Better operations of the vehicle will include improved driving styles such as driving at steady speed instead of driving very fast and very slow by changing gears frequently, switching off the engine at signalized junctions, not constantly keeping the foot on the gear etc.

7.4.2 These training programs could be organized by targeting various groups such as office goers, 3-wheeler operators associations etc. Non-Governmental Organizations such as Lions Club, Rotary Club etc along with Government organizations such as HUDA, Municipal Corporation of Hyderabad, Andhra Pradesh State Pollution Control Board may be included in this exercise of training drivers of 2-stroke vehicles. Awareness of better vehicle maintenance and operation programs can be further spread through television, radio and by placing small captions in prime time on TV. Help of print media can also be taken in this regard.

7.5 EMISSION REDUCTIONS DUE TO M&O TRAINING PROGRAMS

7.5.1 Discussions have been held with The Energy Research Institute (TERI) officials regarding the extent of emissions reductions through these measures. Although no hard data is available on the potential of reduction of emissions for these M&O training programs, the discussions have revealed that these measures can reduce emission levels by 10% to 30%. However on a conservative side, reduction of emissions by 10% over BAU scenario for 2-stroke vehicles has been assumed in this study.

7.5.2 All the vehicle owners cannot be trained, as everybody may not have time or inclination to join these training programs. Moreover, resources may not be available to train all the drivers. Therefore, only a part of existing 2-stroke engine vehicle operators can be called under this program. Penetration rate of 5% for 2-stroke two wheeler drivers by 2011 and additional 8% by 2021 for the training programs has been assumed. It may be easier to bring in 3-wheeler drivers to these training programs through their unions/associations. Therefore a penetration rate of about 8% of 2-stroke three wheeler drivers by 2011 and additional 12% by 2021 for these training programs has been assumed.

7.5.3 Assuming above reduction in emissions in 2-stroke vehicles and their penetration rates, over all reduction in emissions has been worked out for the year 2011 and 2021 and is presented in following paragraphs.

7.5.4 The estimated daily vehicle kilometers and emissions in BAU scenario for two wheeler and three wheelers for 2001, 2003,2011 and 2021 have already been presented in Chapter-5.The daily emissions for BAU scenario for two and three wheelers for 2011 and 2021 are presented in Table. 7.1.

Table 7.1: Daily Emissions for BAU for 2 and 3 wheelers

YEAR	DAILY VKT	EMISSIONS PER DAY IN TONES							
		CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4	TOTAL
2011	29215131	1055.9	12.00	0.41	9.58	1628.18	0.0	59.18	2765.25
2021	45186190	2692.33	30.19	1.09	27.22	4262.66	0.01	166.79	7180.29

As discussed in Chapter-5, modal split (motorized trips) for 3-wheelers is expected to be 20% and 33% in 2011 and 2021 for BAU scenario. The total daily VKT for 2 and 3-wheelers are expected to be 88% of total VKT of all vehicles by 2021 for BAU scenario. Daily emissions for 2 and 3 wheelers are expected to be 49% of total emissions from all vehicles for BAU scenario by 2021. Further, from 2 and 3 wheelers, the daily PM_{10} and CO2 emissions are estimated as 84% and 38% respectively of total emissions for BAU scenario in 2021. This shows that 2 and 3 wheelers are expected to be the major contributors to vehicular emissions in Hyderabad.

7.5.5 The daily emissions after implementation of M&O training program for 2-stroke vehicles are presented in **Table 7.2**. The reduction in daily emissions due to M&O training programs is presented in **Table 7.3** after using the assumed share of 2-stroke two wheelers and penetration rates of users of 2-stroke vehicles.

Table 7.2: Daily Emissions (in Tons) after M&O Training Programs for 2-Stroke Vehicles

Year	CO	NO_X	SO_X	PM_{10}	CO_2	N_2O	CH_4	TOTAL
2011	1049.92	11.93	0.41	9.52	1618.80	0.00	58.81	2749.40
2021	2648.90	29.71	1.07	26.75	4192.65	0.01	163.90	7062.99

Table 7.3: Reduction in Daily Emissions due to M & O Training Programs for 2-Stroke Vehicles

YEAR	REDUCTION IN EMISSIONS PER DAY IN TONNES							
	CO	NO_X	SO_X	PM_{10}	CO2	N_2O	CH_4	TOTAL
2011	5.98	0.07	0.00	0.06	9.38	0.00	0.37	15.85
2021	43.43	0.48	0.02	0.47	70.01	0.00	2.89	117.30

The above emission reductions through M & O training programs are for the years 2011 and 2021 only. Corresponding reductions can also be accounted for other years up to the year 2021.

7.6 Cost For M&O Training Programs

The training programs cost primarily includes cost of course material, remuneration to experts, arrangements for classroom etc. and publicity through radio, TV and newspapers.

For estimating number of drivers it has been assumed that the average distances traveled by 2 and 3 wheelers per day are 24 and 95 km respectively.

Assuming training cost per person as Rs. 50, cost of M & O training programs for 2-stroke vehicles operators is estimated as Rs. 2.19 millions by 2011 and Rs. 8.14 millions by 2021 as shown in Table 7.4.

Table 7.4: Cost Estimates for M & O Training Programs

	Trained Drivers by	
	2011	**2021 (Cumulative)**
2-stroke 2-wheelers	38789	131676
3-wheelers	5003	31157
Training Cost (Rs in Million)	2.19	8.14

7.7 EVALUATION

Considering the emissions reduction due to M & O training programs and cost for the training programs, cost effectiveness of this programs has been estimated. Emission reduction due to these programs will not be for a single day but for the future as well. It has been assumed that penetration rate of trainees would be equally distributed in various years up to 2011 and 2021. The emission reduction per rupee invested in these programs has then been worked out up to 2011 and 2021. The cost effectiveness of these programs is given in **Table 7.5**. The table indicates that 10kg and 38kg of emissions are expected to be reduced by per rupee invested in these programs cumulatively up to year 2011 and 2021, respectively. This indicates these programs are significantly cost effective. A TERI study has indicated that damage (health) cost of harmful emissions per kg is Rs. 32(updated to present price level). Considering this value, cumulative damage (health) cost is estimated as Rs. 314 by 2011 and Rs. 1213 by 2021 against the investment of one rupee. Therefore these training programs can be considered highly cost effective.

Table 7.5: Cost Effectiveness of M & O Training Programs

Item	2011	2021
Annual reduction in emissions (in tones) due to M & O training programs for 2-stroke vehicles	5389	39882
Cost of M & O training programs (Rs)	2189638	8141634
Emission reduction in kg per rupee invested in training programs in year 2011 and 2021	2.46	4.89
Cumulative reduction in emissions in kg per rupee invested in M & O training programs	9.81	37.9

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 Hyderabad is one of the fastest growing centers of urban development in India with population of 68.04 lakhs (in HUDA area, including Secunderabad Cantonment Area) in 2003 and is expected to grow upto136.4 lakhs by 2021.

8.1.2 Of the total registered vehicles in 2002 in Hyderabad, about 28% were 2-wheelers. Auto rickshaws (3 and 7 seaters) numbered a high figure of 71,000. Two wheelers account for about 45% of total daily trips made (exclusive of walk trips). 3 wheelers account for another 8%. These statistics indicate the importance of these modes.

8.1.3 In comparison, bus transport service operated by state-owned APSRTC, caters to less than 40% of total trips (exclusive of walk trips). Rail transport serves negligible transport demand. Productivity of bus transport is declining.

8.1.4 At present, 30% of total daily trips are made by walk. However facilities for pedestrians are inadequate.

8.1.5 Per capita rate is worked out as 1.203 (including walk trips) and 0.84 (excluding walk trips) in the year 2003. A total of 8.2 millions trips per day were made including walk trips.

8.1.6 The peak hour approach traffic volumes on certain intersections of the road network are in the range of 10,000 PCUs to 25,000 PCUs. Some of the road sections cater to traffic more than their capacities can handle.

8.1.7 At most of the locations along the identified two road corridors, emission levels exceed the permissible levels. If the usage of private vehicles and auto rickshaws continues to grow, the situation will further worsen.

8.1.8 The situation is further compounded by the fact that most of the 2 wheelers have 2 stroke engines. All the 3 wheelers have 2 stroke engines. These vehicles are more polluting.

8.1.9 If the present trend continues there would be further decline in bus ridership, increase in vehicle kilometers traveled by 2-wheelers and auto rickshaws. This would further reduce traffic speeds and increase vehicular emissions. (Business As Usual Scenario).

8.1.10 The Stated Preference Survey indicates that travelers are more sensitive to time and reliability and relatively less sensitive to cost.

8.1.11 Trip generations are found to be significantly related to number of workers residing, number of 2 wheelers and cars, number of students residing, population in a zone and distance from CBD from a zone for different trip purposes. Trip attractions are observed to be significantly related to zone wise employment, student enrolment and accessibility rating.

8.1.12 In BAU scenario, the share of the buses is expected to fall from 42% in total motorized trips in 2003 to 31% by 2021 and of 3 wheelers is expected to increase from 9% in 2003 to 33% by 2021.

8.1.13 Daily Vehicle Kilometers Traveled (VKT) has been estimated at about 21 million for 2003. This figure is estimated to go up to about 51 million by 2021 i.e. about 2.4 times for the BAU scenario.

8.1.14 Enormous increase in VKT in BAU scenario will lead to reduction in travel speeds on roads. The daily emissions are expected to increase by more than 4 times in 2021.

8.1.15 The problem can be addressed by implementing the following policy options:

i) More Effective Public Transit Services
ii) Traffic Management and Measures to Improve Traffic Flow
iii) Technology / Training Measures related to 2-Stroke Vehicles

8.1.16 The bus system can be made faster and more reliable by providing exclusive bus lanes, provision of adequate and well-designed bus bays, bus route rationalization, high frequency buses, etc.

8.1.17 If more effective bus transit services are provided, the modal share of bus travel would increase from 42% in 2003 to 62% in 2021. The total daily VKT will decrease by about 15 million in 2021 as against BAU scenario for the study area. Reduction in daily emission levels of CO would be about 1410 Metric Tones, CO_2 – 3792 Metric Tones and Particulate Matter – 18 Metric Tones in 2021 as compared with BAU scenario for the study area. Particulate matter will be reduced by 55% and CO_2 by 34% by 2021 over the BAU scenario. Similarly significant reduction in emissions is expected on the major road corridors.

8.1.18 More effective bus transit system is estimated to cost Rs. 626 million for the entire study area.

8.1.19 Multi-Modal Transit Services being implemented by upgrading the existing two rail corridors would increase the VKT in 2021 by about 3.3 million over the BAU scenario. This is expected to reduce daily emission levels of CO by 101 Metric Tones, CO_2 by 1148 Metric Tones and Particulate Matter by 1.5 Metric Tones when compared with BAU. MMTS is estimated to cost Rs. 1,500 million.

8.1.20 A long flyover of length 12km with appropriate number of ramps on Sanath- Nagar to Nalgonda X Road Corridor can reduce the daily emission levels in 2021 by about 14% to 22% for various pollutants even with substantial increase in VKT when compared with BAU scenario. This flyover is estimated to cost Rs. 2240million.

8.1.21 On the two identified corridors i.e., Sanath Nagar to Nalgonda X Road and Punjagutta to Secunderabad, traffic management measures such as removal of on-street parking, encroachments and hawkers (removal of side frictions) can increase the traffic speeds substantially. It is estimated that these measures can reduce emission levels of various pollutants by 51% to 57% for the first corridor and by 19% to 26% for the second corridor in 2021 when compared with BAU scenario. Cost of these measures is estimated as Rs. 34 million for the first corridor and Rs. 28.7 million for the second corridor.

8.1.22 Segregation of vulnerable road users (provision of foot paths and related facilities) on the two identified corridors i.e., Sanath Nagar to Nalgonda X Road and Punjagutta to Secunderabad can increase traffic speeds on these corridors. It is estimated that the emission levels of various pollutants can be reduced when using these measures by 17% to 56% in 2021 on these corridors in comparison with BAU scenario. Cost of these measures is estimated as Rs. 2.6 million for the first corridor and Rs. 3.9 million for the second corridor.

8.1.23 Synchronization of signals on the Sanath Nagar to Nalgonda X Road corridor can reduce the delays and increase the traffic speeds. These measures along with intersection improvements on the corridor can reduce emissions levels of various pollutants in 2021 by 20% to 23% over BAU scenario. Cost of these measures is estimated as Rs. 13.6 million for this corridor.

8.1.24 About 80% of all 2 wheelers are estimated to have 2 stroke engines. All 3 wheelers have 2 stroke engines.

8.1.25 Emissions can also be reduced by proper training of drivers of 2-stroke engine vehicles (2 wheelers and 3 wheelers) in vehicle maintenance and operations. On a conservative estimate, these measures can reduce emissions by 10%.

8.1.26 Penetration rate of 5% by 2011 and 8% by 2021 for 2 wheelers and 8% and 12% respectively for 3 wheelers for these M& O training programs is considered reasonable.

8.1.27 Cost of the M & O training programs is estimated to be Rs 2.19 million by 2011 and additional Rs. 8.14 million by 2021.

8.1.28 It is estimated that these M & O training programs can reduce emissions by 38 kg cumulatively by 2021 per one rupee invested, which indicates superior cost effectiveness of these training programs

8.2 RECOMMENDATIONS

8.2.1 Improved bus transit can attract traffic from modes such as 2 and 3 wheelers and cars and can reduce vehicular emissions significantly. Therefore, more effective bus transit services should be provided in Hyderabad.

8.2.2 Traffic management and measures such as removal of side friction, segregation of vehicular and pedestrian traffic and synchronization of traffic signals should be implemented on all the corridors wherever they are feasible. These measures do not cost much and are very effective in reducing vehicular emission levels.

8.2.3 Although long flyovers with numerous ramps attract higher traffic as compared to BAU scenario, they can still reduce emissions. However, construction of flyovers should be carefully planned keeping in view the issue of sustainable development.

8.2.4 Training programs and publicity for better maintenance of vehicle and proper driving habits for 2-stroke vehicle drivers should be carried out regularly

ANNEXURES

Annexure 3.1

TRAFFIC ANALYSIS ZONES

Zone No	Zone Name	Zone No	Zone Name
1	Charminar	50	Sithaphal mandi
2	Darulshifa	51	Ramnagar
3	Yakutpura	52	Nallakunta
4	Sultan Shahi	53	Kachiguda
5	Shamsher Gunj	54	Kachiguda quarters
6	Shahali banda	55	Amberpet
7	High court	56	Golnaka
8	Qilwat Palace	57	Mettuguda
9	Syed ali chabutra	58	Osmania university
10	Jahanuma	59	Ramanthapur
11	Petla burz	60	Begumpet
12	Chandulal baradari	61	Prakash nagar
13	Zoo park	62	Ramgopalpet
14	Old malakpet	63	Patny
15	Chanchal Guda	64	Monda market
16	Rain bazar	65	Secunderabad rlw. Station
17	Uppu guda	66	Nehru nagar
18	Chandrayan gutta	67	Subhash nagar
19	Musaram bagh	68	Malkajgiri
20	Malakpet colony	69	Bowenpally
21	Indira Seva Sadan	70	Mudfort
22	Ibrahim Bagh	71	Bolaram
23	Jubilee Hills colony	72	Thirumalagiri
24	Golconda Fort	73	A.O.C.Gate
25	Erragadda	74	Himayath sagar
26	Banjara Hills	75	Peeram cheruvu
27	S.D.Hospital	76	Bandlaguda
28	Mehdipatnam	77	Rajendra nagar
29	Karwan	78	Katedan
30	Sanathnagar	79	Chintala kunta
31	S.R.Nagar	80	Nadergul
32	Panjagutta	81	Karman ghat
33	Erramanzil	82	L.B.Nagar
34	Vijaynagar colony	83	Gaddi Annaram
35	Dhoolpet	84	Dilsukh nagar
36	Ziaguda	85	Nagole
37	Nampally	86	Mansoorabad
38	Mallepally	87	Hathiguda
39	Goshamahal	88	Kuntloor
40	Secratariat	89	Vanasthalipuram

Zone No	Zone Name	Zone No	Zone Name
41	Public gardens	90	Amberpet kalan
42	Mozamjahi market	91	Ramchandrapuram
43	Afzal Gunj	92	Narsingi
44	Indira park	93	Tellapur
45	Himayath nagar	94	Patancheruvu
46	Sultan bazar	95	Kondapur
47	Bhoi guda	96	Sherlimgampalli
48	Kavadi guda	97	Hafisguda
49	Ashok nagar	98	Madhapur
99	Manikonda	115	Kapra
100	Kaithapur	116	Cherlapally
101	Moosapet	117	Nacharam
102	Gajula ramaram	118	Shamirpet
103	Hydernagar	119	Cheryala
104	Kukatpally	120	Keesara
105	Dindigul	121	Boduppal
106	Srirangaram	122	Ghatkesar
107	Dhoolapally	123	Pocharam
108	Jeedimetla	124	Uppal
109	Medchal	125	Survey of India
110	Yamjal	126	Ankushapur
111	Poodur	127	Shamshabad
112	Alwal	128	Watte Nagulapally
113	Yapral	129	Maheshwaram
114	R.K.Puram		

Annexure 3.2

ZONEWISE POPULATION DISTRIBUTION

ZONE NO.	2003	2011	2021
1	39833	42984	47281
2	39591	43745	49876
3	36703	38928	41750
4	60337	66595	75998
5	47290	52675	60978
6	29218	31659	35059
7	38008	39394	41132
8	61228	63021	65272
9	35232	37303	40144
10	66563	72274	79492
11	30475	31585	32967
12	40479	43874	48076
13	100235	108641	119044
14	40400	45599	53603
15	29905	33703	39540
16	51436	54599	58632
17	126302	140307	161792
18	166045	184841	213732
19	45702	51584	60639
20	89039	100324	117657
21	123872	131353	141031
22	48735	150236	50785
23	73275	115465	177260
24	136187	156878	187218
25	106983	167013	255907
26	181717	256498	384069
27	53168	57213	62451
28	87200	96892	111818
29	92684	104529	122621
30	42052	55162	74974
31	58300	76210	103089
32	31407	41125	55772
33	43926	54782	70915
34	42721	45951	50128
35	87001	97504	113633
36	37794	42472	49667
37	21682	25628	28217
38	38672	41675	45722
39	103772	111697	122316
40	17442	21303	27090
41	49521	53524	58862

ZONE NO.	2003	2011	2021
42	21350	22762	24520
43	20197	21725	23764
44	56230	61806	70418
45	74359	78500	83641
46	37088	39925	43730
47	40745	43973	48370
48	35450	38655	43510
49	53380	58139	65497
50	126748	133800	143042
51	125014	136137	153234
52	47916	52311	59104
53	60179	64079	69298
54	55913	62757	73300
55	82993	91634	104971
56	83010	91703	105120
57	108766	115374	123610
58	39490	61789	107569
59	39330	57680	79938
60	56031	70477	92222
61	15604	20611	28181
62	6188	8087	10956
63	7461	9722	13136
64	25200	27228	30030
65	24875	27110	30047
66	17228	18717	20559
67	30643	33198	36364
68	52626	73442	92899
69	27091	31476	38366
70	38194	43985	52475
71	57570	68899	87433
72	35660	41627	50795
73	41279	47539	56715
74	71731	135115	264925
75	13649	30338	59483
76	14187	21369	41899
77	118976	188200	426563
78	50361	78799	137182
79	59458	83123	133895
80	68394	103014	201983
81	31546	50729	92952
82	16257	26142	47900
83	23223	35104	61184
84	10827	17410	31901
85	23658	38212	67268
86	42848	68903	126252
87	40414	64990	119082

ZONE NO.	2003	2011	2021
88	16773	28789	56449
89	77943	125340	229662
90	31594	47587	93305
91	107211	126410	591213
92	21060	31718	62192
93	31519	57274	88817
94	19004	35309	69231
95	26786	52719	98503
96	25033	52627	99912
97	40464	85068	161501
98	61988	123004	208571
99	55822	127708	218139
100	84660	115895	191286
101	37894	51875	85620
102	119895	132604	253129
103	42769	58549	96636
104	25393	28421	53790
105	22292	34889	68407
106	25169	37908	74331
107	23343	51887	101737
108	81758	90425	172612
109	12315	18550	36372
110	80841	124078	208630
111	45450	68457	134226
112	78793	116152	188508
113	50231	77097	129634
114	134436	189419	245109
115	73944	123841	230195
116	79269	131555	239935
117	145202	238062	425671
118	22349	44210	86686
119	21351	36697	71955
120	52376	93547	183421
121	13879	23452	43993
122	18138	33811	66293
123	4827	9203	18047
124	29941	49272	72008
125	39732	65383	95554
126	44239	74454	145987
127	21500	45203	88633
128	36810	55443	108706
129	39282	58230	137333
Total	**6804741**	**9055184**	**13643431**

Annexure 3.3

ZONE-WISE EMPLOYMENT DISTRIBUTION

ZONE NO.	2003	2011	2021
1	12516	14741	18977
2	8827	10461	13500
3	27205	28406	40321
4	14377	15304	22941
5	10300	11502	18960
6	10891	12001	16165
7	9631	11338	14152
8	8058	9694	12482
9	7117	8757	10332
10	9390	11021	14621
11	4854	5670	7414
12	16374	20483	25546
13	33852	40621	58263
14	7897	9534	11604
15	5714	6527	8648
16	9374	11123	14158
17	20952	25319	34513
18	35884	41518	68351
19	11554	13634	17770
20	20145	24869	30636
21	22506	28986	40803
22	36900	43327	68486
23	12445	14801	23961
24	14543	16141	26402
25	37579	41548	63922
26	65087	76524	114473
27	7316	8955	11285
28	19060	22322	28360
29	24540	30847	39858
30	41956	50130	64679
31	15354	17978	27852
32	14796	16417	21392
33	8844	10477	13623
34	10280	12542	16022
35	16208	19675	26977
36	7911	9548	11642
37	7923	9560	11605
38	12383	14099	18154
39	32437	40858	53496
40	10418	12047	15381
41	23109	28022	32817

ZONE NO.	2003	2011	2021
42	8847	10480	12793
43	6745	7556	9788
44	12036	14960	18486
45	28954	35646	45267
46	12694	15146	18688
47	10654	12282	15596
48	9598	11229	15161
49	7863	9500	12139
50	30475	40569	52368
51	40138	51611	66413
52	21846	25333	37591
53	29129	32573	47657
54	21430	25349	37964
55	13098	16385	20006
56	19451	23199	35305
57	27441	29574	46445
58	6715	8357	10399
59	6122	6935	9707
60	7218	9251	11861
61	5452	6463	9744
62	3952	7380	4923
63	2844	3086	4870
64	5824	7472	8510
65	23934	26363	33656
66	3256	4078	4936
67	4793	5609	7436
68	11470	13096	18604
69	4550	6210	7166
70	3894	7753	9696
71	9381	11012	15188
72	5859	7507	9328
73	6582	8361	10828
74	16171	30754	77048
75	2084	4240	7100
76	3374	4196	5331
77	30027	53576	103336
78	6967	13285	21974
79	17234	34062	54270
80	8279	19639	32227
81	4740	6810	11431
82	3600	4420	5764
83	5141	6794	8020
84	2420	2800	3916
85	4236	6111	10131
86	8114	10538	17350
87	9169	17388	27779

ZONE NO.	2003	2011	2021
88	5126	10541	16849
89	10449	16957	28480
90	4573	7443	12598
91	44697	68868	138235
92	5194	9589	14765
93	6136	16493	29824
94	71235	123909	267829
95	7815	9203	15187
96	8614	10248	13486
97	11054	20488	32759
98	12596	16089	27114
99	12412	22178	36636
100	15889	32129	51618
101	7550	9188	12421
102	19912	21128	35005
103	8283	9918	13273
104	5338	6990	8176
105	4060	7483	14840
106	10909	28494	62102
107	31785	75436	155783
108	12415	14868	19989
109	7016	8657	9937
110	13009	30934	60901
111	13883	35265	52605
112	16960	20674	33565
113	17757	45673	71299
114	27469	28169	46754
115	9263	17862	29620
116	30925	40860	62810
117	26848	37884	61866
118	64680	144536	337323
119	19712	56969	84937
120	16950	47812	75665
121	9573	24827	41144
122	28858	47608	88661
123	2642	5203	7875
124	7087	8727	11292
125	7766	9921	16304
126	10330	15984	26093
127	13531	31048	70293
128	5940	17337	27737
129	10370	21661	34607
Total	**1936922**	**2807515**	**4503000**

Annexure 3.4

Zone-Wise Distribution of Household Sample Size

Zone Number	No. of Samples	Zone Number	No. of Samples	Zone Number	No. of Samples
1	50	46	26	91	61
2	78	47	76	92	19
3	41	48	38	93	27
4	68	49	81	94	22
5	51	50	119	95	54
6	32	51	118	96	20
7	44	52	78	97	43
8	87	53	91	98	36
9	40	54	36	99	31
10	56	55	92	100	80
11	39	56	45	101	36
12	50	57	135	102	117
13	70	58	32	103	40
14	24	59	50	104	26
15	25	60	62	105	20
16	80	61	14	106	24
17	67	62	19	107	20
18	178	63	16	108	71
19	64	64	44	109	37
20	97	65	27	110	75
21	122	66	61	111	42
22	51	67	25	112	80
23	56	68	111	113	60
24	92	69	26	114	128
25	107	70	49	115	46
26	82	71	54	116	78
27	41	72	41	117	93
28	82	73	31	118	20
29	91	74	64	119	20
30	33	75	12	120	47
31	64	76	13	121	13
32	61	77	128	122	36
33	46	78	39	123	4
34	62	79	39	124	41
35	92	80	49	125	23
36	48	81	25	126	40
37	28	82	26	127	14
38	74	83	98	128	34
39	127	84	49	129	37
40	20	85	21	**Grand Total**	**6917**
41	48	86	36		
42	21	87	25		
43	26	88	18		
44	39	89	99		
45	88	90	22		

Annexure 3.5

ACTIVITY AND TRAVEL DIARY FOR ANALYSIS OF VARIOUS TRANSPORT MEASURES TO REDUCE VEHICULAR EMISSIONS IN HYDERABAD

HOUSEHOLD TRAVEL SURVEY BY RITES FOR USEPA

Location / Colony Name:	Day: Date:
Locality Name / No.	Name of Surveyor:
Ward No:	Name of Supervisor:
Traffic Zone No:	Name of Person being Interviewed
Form No:	Address:

How many people live with you in your household? ________________________

Primary Activity or employment might include: Employment, House Wife, Student, and Pensioner etc.

Section 1: Household Demographic Information

Member No.	Name & Relation to Head of Household	Sex (M/F)	Age	Education	Driver's License?	Primary Activity /Employment			Monthly Income (Rs.)	Monthly Expenditure on Transport (Rs.)
						Type of Organization/Business	Type of Activity /Job	Location		
1										
2										
3										
4										
5										
6										
7										
8										
							Total for house Hold			

Section 2. Household Vehicle Characteristics

	Vehicle #1	Vehicle #2	Vehicle #3	Vehicle #4	Vehicle #5	Vehicle #6
VEHICLE TYPE **(car, motorcycle, scooter, bicycle, etc.)**						
VEHICLE MAKE & ENGINE TYPE **(2/4 Stroke)**						
VEHICLE MODEL						
FUEL TYPE (Petrol, diesel, LPG, CNG, etc.)						
VEHICLE USAGE ***(days per week vehicle used)***						
VEHICLE USAGE **(Single (non-return) trips per day vehicle used)**						
VEHICLE ANNUAL MILEAGE **(Mileage accumulated per day)**						
VEHICLE ANNUAL MILEAGE **(mileage accumulated per day)**						
VEHICLE MILEAGE **(Total vehicle lifetime)**						

For motorized 2-wheelers and 3-wheelers (motorcycles, scooters, auto-rickshaws) please also include engine-cycle type (2-stroke or 4-stroke engine). A vehicle generally has a 2-stroke engine if the lubricating oil is mixed directly with the fuel. If no lube oil is mixed in the fuel tank, the vehicle is generally a 4-stroke engine.

Did the weather or any other factors affect what you did, how you traveled, or how you did an activity yesterday?_____________

Section 3: Activity Diary (Complete one sheet regarding yesterday's activities for each member of house hold)

Form No.

HH Member No:

Type of day:

Date:

Interviewer:

Activity No.	What did you do?	Time Activity Began	Time Activity Ended	Where?	List other persons with you	Doing anything else?	For Activities Requiring Displacement		
							How did you travel? (Walk, Bus, Car, etc.); Please include Combination (I.e.5min Walk to bus stop)	Time Travel to Activity Began	Time Travel to Activity Ended
a	d	f	g	h	I	j	k	l	

Section 4: Travel Diary (for travel related activities only from previous page)

Form No.

HH Member No.:

Type of Day:

Date:

Interviewer:

Activity No.	Tour purpose	1st Segment				Transfer location between 1st & 2nd Segment	2nd Segment				Transfer location between 2nd & 3rd Segment	3rd Segment				Transfer location between 3rd & 4th Segment	4th Segment			
		Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	Cost

Now, I would like to ask you some questions about fuel usage and appliance usage in your household.

Section 5: Other Household Characteristics

1. **List total household fuel consumption per month by fuel type:**

Fuel Type	***Consumption***
LPG (cylinder)	
Charcoal(Kg.)	
Kerosene (litre)	
Other*	

2. **List total household electricity / power consumption (watts / units) per month :**

3. **List total household spending is Rupees on electricity and fuels per month (other than spending on transportation):**

Energy Type	Rupees
LPG (cylinder)	
Charcoal(Kg.)	
Kerosene (litre)	
Other*	

4. **Indicate which of the following are used on a frequent basis in your household:**

	YES/NO
Television	
Refrigerator	
Air Conditioner	
Computer	
Microwave Oven	
Water Cooler	

Annexure 3.6

Household Characteristics

Table 1

Usage Of LPG

S No	Description	No Of Houses	Percentage
1	YES	1241	89.54
2	NO	145	10.46
	TOTAL	**1386**	**100**

Table 2

Usage Of Charcoal

S No	Description	No Of Houses	Percentage
1	YES	49	3.54
2	NO	1337	96.46
	TOTAL	**1386**	**100**

Table 3

Usage of Kerosene

S No	Description	No Of Houses	Percentage
1	YES	206	14.86
2	NO	1180	85.14
	TOTAL	**1386**	**100**

Table 4

Usage Of Electricity

S No	Description	No Of Houses	Percentage
1	YES	1323	95.45
2	NO	63	4.55
	TOTAL	**1386**	**100**

Table 5

Usage of Television

S No	Description	No Of Houses	Percentage
1	YES	1327	95.74
2	NO	59	4.26
	TOTAL	**1386**	**100**

Table 6

Usage of Refrigerator

S No	Description	No Of Houses	Percentage
1	YES	768	55.41
2	NO	618	44.59
	TOTAL	**1386**	**100**

Table 7

Usage of Air conditioner

S No	Description	No Of Houses	Percentage
1	YES	64	4.62
2	NO	1322	95.38
	TOTAL	**1386**	**100**

Table 8

Usage of Computer

S No	Description	No Of Houses	Percentage
1	YES	109	7.86
2	NO	1277	92.14
	TOTAL	**1386**	**100**

Table 9

Usage of Microwave

S No	Description	No Of Houses	Percentage
1	YES	23	1.66
2	NO	1363	98.34
	TOTAL	**1386**	**100**

Annexure 3.7

Stated Preference Survey for Analysis of Various Transport Measures to Reduce Vehicular Emissions in Hyderabad

HOUSEHOLD TRAVEL SURVEY BY RITES FOR USEPA

Location / Colony Name:	Day: Date :
Locality Name / No.	Name of Surveyor:
Ward No:	Name of Supervisor:
Traffic Zone No:	Name of Person being Interviewed
Form No:	Address:

How many people live with you in your household?__________________________

Primary Activity or employment might include: Employment, House Wife, Student, and Pensioner, etc.

Section 1: Household Demographic Information

Member No.	Name & Relation to Head of Household	Sex (M/F)	Age	Education	Driver's License?	Primary Activity /Employment			Monthly Income (Rs.)	Monthly Expenditure on Transport (Rs.)
						Type of Organization /Business	Type of Activity /Job	Location		
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
						Total for house Hold				

Section 2: Household Vehicle Characteristics

	Vehicle #1	Vehicle #2	Vehicle #3	Vehicle #4	Vehicle #5	Vehicle #6
VEHICLE TYPE (car, motorcycle, scooter, bicycle, etc.)						
VEHICLE MAKE & ENGINE TYPE (2/4 Stroke)						
VEHICLE MODEL						
FUEL TYPE (Petrol, diesel, LPG, CNG, etc.)						
VEHICLE USAGE (days per week vehicle used)						
V VEHICLE USAGE (Single (non-return) trips per day vehicle used)						
VEHICLE ANNUAL MILEAGE (Mileage accumulated per day)						
VEHICLE ANNUAL MILEAGE (mileage accumulated per day)						
VEHICLE MILEAGE (total vehicle lifetime)						

For motorized 2-wheelers and 3-wheelers (motorcycles, scooters, auto-rickshaws) please also include engine-cycle type (2-stroke or 4-stroke engine). A vehicle generally has a 2-stroke engine if the lubricating oil is mixed directly with the fuel. If no lube oil is mixed in the fuel tank, the vehicle is generally a 4-stroke engine.

Section 3: Trip Information

Collect Data on Yesterday's morning trip characteristics only for the respondent answering the SP Questions)

Now I would like to ask you for some information on your commute (travel from home to work) Yesterday. Please include all trip elements, for example, walking to the bus stop, bus transfer, walking to/from a parking spot to your intended destination, walking between two stores on the same shopping street, etc.

What was your total travel time (in minute) for the morning commute trip that you took yesterday? ______________

How much did it cost you in total (in rupees) for the morning commute trip that you took Yesterday? ____________

What was the primary mode you took (Car, 2-wheeler, bus, walking, 3-seater auto-rickshaw, 7-seater auto-rickshaw, bicycle, or other) for the morning commute trip that you took Yesterday? ______________________

What was your total distance (in Km) for the morning commute trip that you took Yesterday (including of walk)? ______________

Did the weather or any other factors affect what you did, how you traveled, or how you did an activity Yesterday? ________________

Household member (member Number) responding:_________________________

HH Member No:

1st Segment				Transfer location 1st & 2nd Segment	2nd Segment				Transfer location between 2nd & 3rd Segment	3rd Segment				Transfer location between 3rd & 4th Segment	4th Segment			
Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	Cost		Mode	Wait time	Travel time	cost

Annexure 3.8

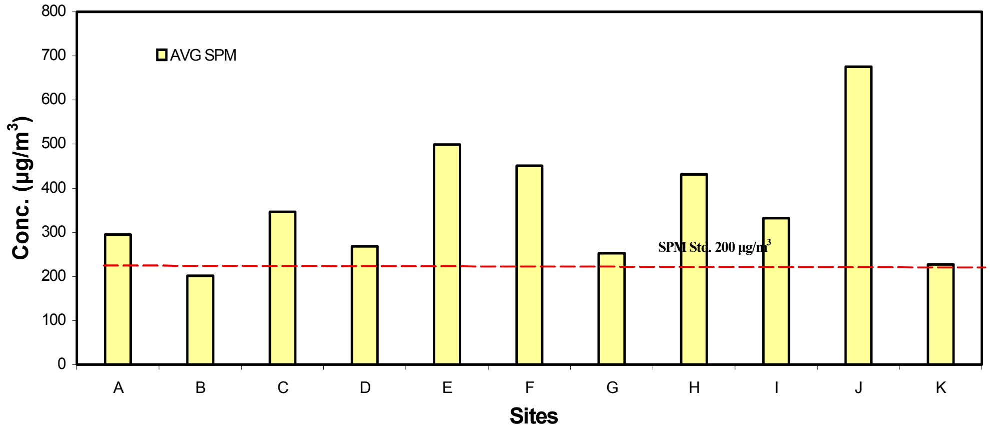
Temperature (^{0}C) Levels in the Study Area

Station Code /Time	A	B	C	D	E	F	G	H	I	J	K
6.00	24.2	24.2	22.6	22.6	23.8	23.8	21.0	21.0	25.5	25.5	25.5
7.00	26.5	26.5	24.7	24.7	24.0	24.0	23.2	23.2	24.6	24.6	24.6
8.00	27.0	27.0	27.6	27.6	27.5	27.5	24.6	24.6	26.7	26.7	26.7
9.00	29.0	29.0	27.9	27.9	27.8	27.8	29.7	29.7	29.2	29.2	29.2
10.00	32.0	32.0	32.5	32.5	32.6	32.6	33.5	33.5	30.0	30.0	30.0
11.00	33.5	33.5	33.8	33.8	33.9	33.9	35.3	35.3	32.2	32.2	32.2
12.00	34.8	34.8	34.3	34.3	34.7	34.7	35.3	35.3	34.1	34.1	34.1
13.00	35.6	35.6	35.4	35.4	35.2	35.2	35.8	35.8	34.8	34.8	34.8
14.00	35.2	35.2	35.6	35.6	35.7	35.7	35.7	35.7	35.4	35.4	35.4
15.00	35.0	35.0	34.9	34.9	34.9	34.9	36.1	36.1	34.5	34.5	34.5
16.00	33.6	33.6	33.1	33.1	33.2	33.2	35.4	35.4	33.2	33.2	33.2
17.00	32.9	32.9	31.7	31.7	31.8	31.8	33.2	33.2	32.8	32.8	32.8
18.00	32.6	32.6	30.8	30.8	30.6	30.6	31.8	31.8	31.7	31.7	31.7
19.00	31.4	31.4	28.7	28.7	28.6	28.6	30.9	30.9	31.2	31.2	31.2
20.00	30.3	30.3	26.1	26.1	26.0	26.0	30.1	30.1	30.4	30.4	30.4
21.00	29.4	29.4	23.5	23.5	23.6	23.6	29.8	29.8	26.7	26.7	26.7
22.00	28.6	28.6	21.3	21.3	21.2	21.2	26.9	26.9	25.0	25.0	25.0
23.00	27.5	27.5	21.1	21.1	21.0	21.0	26.5	26.5	23.2	23.2	23.2
24.00	25.8	25.8	21.9	21.9	21.0	21.0	26.4	26.4	22.1	22.1	22.1
1.00	23.1	23.1	21.5	21.5	21.5	21.5	26.5	26.5	21.7	21.7	21.7
2.00	22.8	22.8	20.6	20.6	21.6	21.6	26.3	26.3	20.6	20.6	20.6
3.00	22.7	22.7	20.3	20.3	21.0	21.0	26.1	26.1	21.4	21.4	21.4
4.00	22.9	22.9	21.2	21.2	21.2	21.2	26.1	26.1	22.4	22.4	22.4
5.00	23.7	23.7	22.2	22.2	22.2	22.2	25.5	25.5	22.3	22.3	22.3

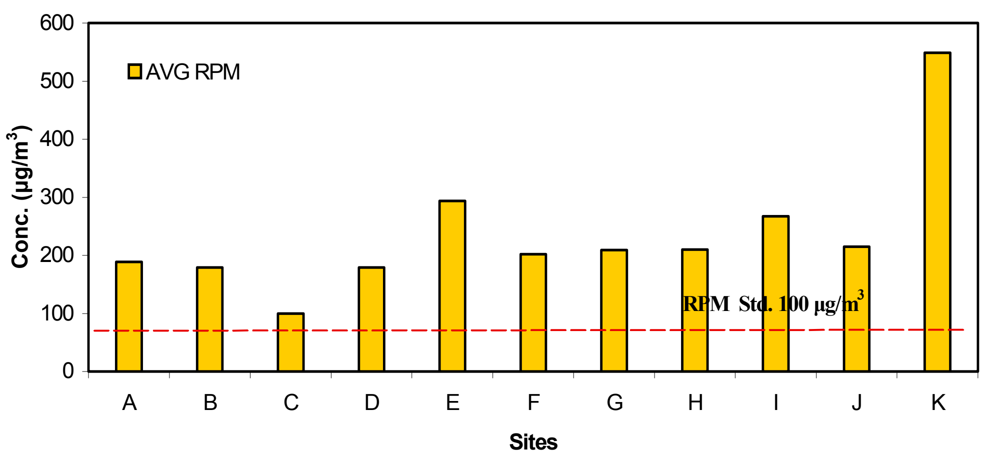
Wind Speed (KMPH) in the Study Area

Station Code /Time	A	B	C	D	E	F	G	H	I	J	K
6.00	4.2	4.8	6.2	4.8	4.2	5.3	7.3	7.3	3.3	4.8	4.3
7.00	3.6	3.8	6.8	6.6	4.8	6.0	8.1	6.3	3.8	5.6	4.6
8.00	1.8	2.6	4.2	3.2	5.2	4.0	6.3	4.2	4.2	5.8	6.2
9.00	1.6	1.9	3.1	2.8	3.1	2.0	4.8	3.6	6.1	2.1	3.2
10.00	1.3	1.9	2.6	2.9	3.6	2.3	2.2	2.5	5.4	2.0	2.1
11.00	1.1	1.2	2.2	2.7	2.8	2.5	1.8	2.0	4.8	1.5	1.1
12.00	1.2	0.8	1.3	3.9	1.3	3.6	1.2	1.0	3.3	1.3	1.3
13.00	0.8	0.9	1.0	3.7	0.8	2.3	1.1	0.9	1.1	1.1	0.3
14.00	2.1	1.5	0.8	3.1	0.9	2.2	0.9	0.8	1.1	0.9	1.2
15.00	2.6	1.9	0.9	3.0	1.1	2.0	0.6	2.2	0.8	3.6	3.3
16.00	7.1	6.8	2.1	3.0	3.3	0.7	0.3	3.9	2.7	4.1	4.2
17.00	7.5	7.0	6.3	2.8	8.4	5.0	1.8	4.6	5.5	6.8	7.2
18.00	8.6	8.9	8.1	4.4	7.6	8.8	4.3	8.2	9.6	7.5	8.1
19.00	4.9	5.1	9.2	9.5	6.5	7.0	6.6	7.1	8.7	8.8	9.6
20.00	4.6	4.1	5.3	8.1	7.1	4.2	8.8	5.5	9.2	4.2	4.7
21.00	2.2	2.0	3.4	6.2	4.8	2.6	5.4	4.3	6.1	2.6	3.1
22.00	2.9	3.2	2.6	4.6	2.1	1.8	2.9	2.8	7.2	2.2	2.0
23.00	1.3	1.1	2.8	2.7	1.3	1.2	1.4	1.2	4.8	1.0	1.1
24.00	1.1	0.9	1.0	1.1	0.9	0.4	1.0	1.0	2.2	1.8	1.2
1.00	0.8	0.7	0.8	0.9	0.8	0.2	0.7	0.9	1.2	0.8	0.5
2.00	0.5	0.6	0.7	0.7	0.9	0.2	0.6	0.8	0.9	1.1	1.0
3.00	1.6	1.8	0.3	1.1	1.4	0.5	1.3	0.9	0.6	0.9	0.5
4.00	3.4	3.7	1.4	2.6	2.9	6.0	3.8	1.9	1.9	2.6	2.4
5.00	5.9	6.7	5.7	3.6	3.7	8.1	4.4	4.6	2.8	3.2	3.1

Annexure 3.9

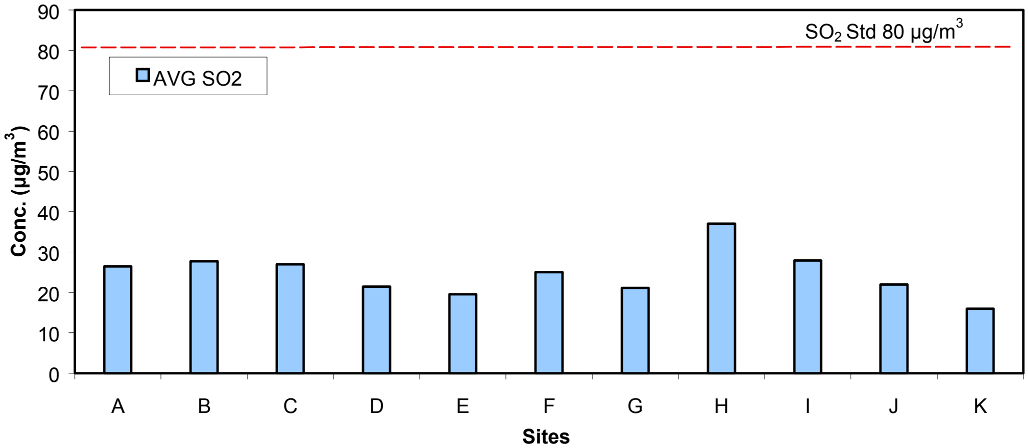


Average (24 hrly) SPM Concentrations in the Study Area

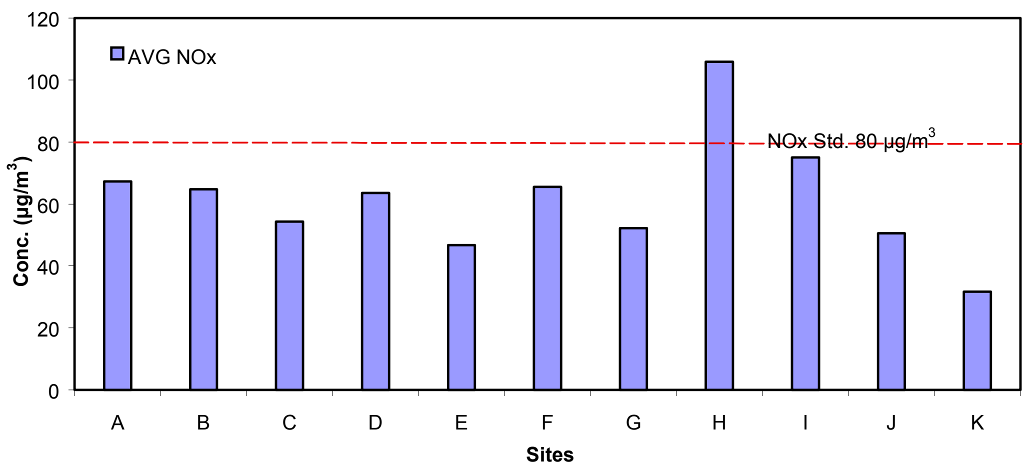


Average (24 hrly) RSPM Concentrations in the Study Area

Annexure 3.10

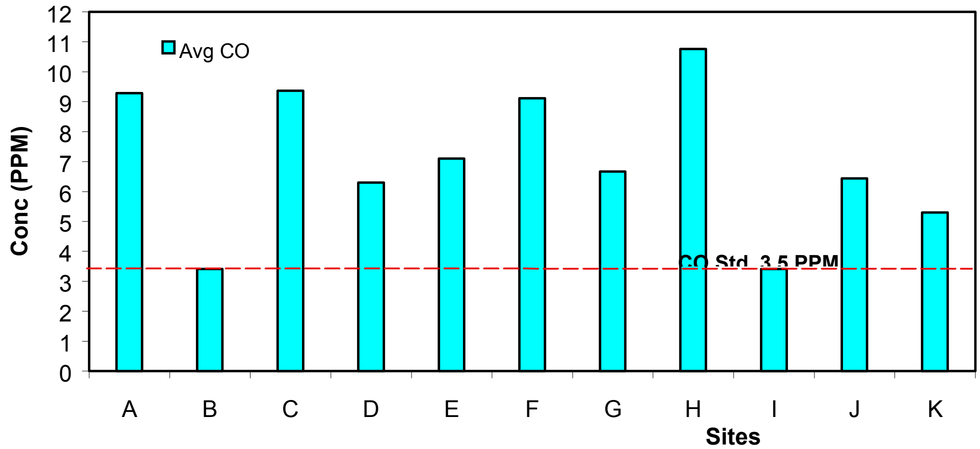


Average (24 hrly) SO_2 Concentrations in the Study Area

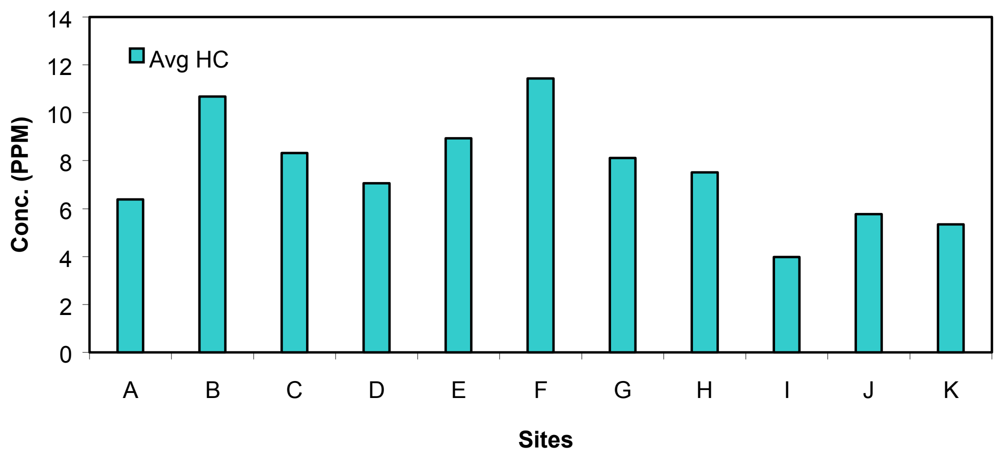


Average (24 hrly) NOx Concentrations in the Study Area

Annexure 3.11



Hourly CO (PPM) Concentrations in the Study Area



Hourly HC (PPM) Concentrations in the Study Area

Annexure 3.12

National Ambient Air Quality Standards (NAAQS)

		Sensitive of Area	Industrial Area	Residential, Rural & Other areas	Testing Method
Sulphur Dioxide (SO_2)	Annual Average*	15 µg/m^3	80 µg/m^3	60 µg/m^3	Improved West and Geake Method
	24 hours**	30 µg/m^3	120 µg/m^3	80 µg/m^3	Ultraviolet Fluorescence
Oxides of Nitrogen (NO_x)	Annual*	15 µg/m^3	80 µg/m^3	60 µg/m^3	Modified Jacob & Hochheiser (Na - Arsenite) Method
	24 hours**	30 µg/m^3	120 µg/m^3	80 µg/m^3	Gas Phase Chemiluminescence
Suspended Particulate Matter (SPM)	Annual 24 hours**	70 µg/m^3 100 µg/m^3	360 µg/m^3 500 µg/m^3	140µg/m^3 200µg/m^3	High volume sampling. (Average flow rate not less than 1.1m^3/min).
Respirable Particulate Matter (RSPM), (size less than 10 µm)	Annual * 24 hours**	50 µg/m^3 75 µg/m^3	120 µg/m^3 150 µg/m^3	60 µg/m^3 100µg/m^3	Respirable particulate matter sampler
Lead (Pb)	Annual* 24 hours**	0.50µg/m^3 0.75µg/m^3	1.0 µg/m^3 1.5 µg/m^3	0.75µg/m^3 1.00µg/m^3	ASS Method after sampling using EPM 2000 or equivalent Filter paper
Carbon Monoxide (CO)	8 hours** 1hour	1.0 mg/m^3 2.0 mg/m^3	5.0 mg/m^3 10.0 mg/m^3	2.0 mg/m^3 4.0 mg/m^3	Non dispersive infra red Spectroscopy

*Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

**24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

NOTE:

1. National Ambient Air Quality Standard: The levels of air quality with an adequate margin of safety, to protect the public health, vegetation and property.
2. Whenever and wherever two consecutive values exceeds the limit specified above for the respective category, it would be considered adequate reason to institute regular / continuous monitoring and further investigations.

Annexure 3.13

Hyderabad City Region Bus Operations and Performance Characteristics

S. No	Parameters	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003*
1	No. of Depots	19	19	19	21	21	21	21
2	No.of Bus stations	12	12	12	12	16	16	18
3	No.of passenger shelters	700	720	740	800	864	1004	1239
4	No. of Employees at Hyderabad Branch (H.C.R)	15162	15342	15676	16160	15729	16095	16203
5	No.of Buses (Avg. Held)	2122	2217	2328	2425	2480	2605	2600
6	No.of Schedules (As on last day)	1969	2066	2163	2253	2306	2421	2414
7	No.of Trips a Day	27808	29027	30488	31536	31803	34694	14455
8	Km. covered a day	504877	536784	559153	597470	602740	606956	643686
9	Avg. annual OR % Load factor	75	69	70	63	58	59	61
10	Avg. annual EPK in Rs (P&L annual account)	10.55	11.49	11.58	12.48	13.47	13.18	13.86
11	Avg. annual CPK in Rs (P&L annual account)	11.19	12.19	12.65	13.19	14.62	15.35	15.37#
12	Avg.Fleet age (kms in million)	0	0	0	0.697	0.611	0.609	0.643
13	Total Revenue (Rs. In million) (as per P&L)	1944.47	2251.82	2363.74	2729.26	2961.48	2919.64	1365.02
14	Total subsidy given(in million)	69.490	113.136	85.242	92.330	104.541	108.611	-
15	Total subsidy received from Govt. (in million)	69.490	113.136	85.242	92.330	104.541	108.611	-
16	Profit (Loss)(in million)	-118.528	-137.456	-218.79	-156.09	-241.47	-415.19	-86.231#
17	Profit & Loss Paise per Km	-64	-70	-107	-71	-106	-206	-110#
18	Vehicle utilization (kms)	238	242	240	246	243	233	247
19	Fleet Utilization (%)	98.68	99.68	98.71	99.71	99.68	97.31	99.46
20	Breakdown rate (Per 10,000km)	0.35	0.35	0.28	0.22	0.46	0.32	0.42
21	Accident rate (per 1,00,000 km)	0.17	0.13	0.14	0.12	0.08	0.10	-
22	Fuel consumption (Total)	39339860	41463825	42647197	45442767	44475858	37752609	-

S. No	Parameters	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003*
23	HSD KMPL	4.73	4.79	4.86	4.87	4.80	4.86	4.85
24	LUB KMPL	1459	1596	1806	1890	1813	1965	1993
25	Average Tire life	1.63	1.68	1.67	1.75	1.93	2.03	2.09
26	Staff per bus	7.48	7.26	7.21	7.09	7.29	6.68	7.11
27	No. of Passengers carried per day on Avg(in Lakhs)	3.177	3.054	3.253	3.050	2.872	3.068	-

Source: APSRTC, Hyderabad City Region

* Up to Aug. 2002

Up to July 2002

Abbreviations:

OR-Occupancy Rate

HCR-Hyderabad City Region

EPK-Earning Per Km

CPK-Cost per Km

P&L- Profit & Loss

HSD-Diesel

LUB-Lubricant Engine Oil

Annexure 3.14

Comparative Fare Structure For Urban/Town Services Of Various STUs

S.No	Name of STUs	Type of Service	Fare Structure per Passenger Km	
			Distance (KM)	Fare (Rs)
1	APSRTC (Andhra Pradesh State Road Transport Corporation)	Ordinary	2	2.50
			4	3.00
			6	3.50
			8	4.00
			10	4.50
			12	5.00
			14	5.50
			16	6.00
			18	6.50
			20	7.00
			22	7.50
			24	8.00
			26	8.50
			28	9.00
			30	9.50
			32	10.00
			34	10.50
			36	11.00
			38	11.50
			40	12.00
		Suburban	The above fares applicable to City/Town services	
		Express	50 Ps more per passenger over the fare applicable to City Ordinary services	
		Metro/City Express	Rs. 3.50 for first stage of 2 kms and 50 Ps. for every subsequent stage of 2 kms thereafter.	
		Metro Liner	2	5.00
			4	5.50
			6	6.00
			8	6.50
			10	7.00
			12	8.00
			14	9.00
			16	10.00
			18	11.00
			20	11.50
			22	12.50

S.No	Name of STUs	Type of Service	Fare Structure per Passenger Km				
			Distance (KM)	Fare (Rs)			
			24	13.00			
			26	14.00			
			28	14.50			
			30	15.50			
			32	16.00			
			34	16.50			
			36	17.00			
			38	17.50			
			40	18.00			
2	BEST (Brihan Mumbai Electric Supply & Transport Undertaking)	Ordinary	Dist (in Kms)	Ordinary Fare	Limited Fare	A/C Fare	Point to Point Fare
			3	3.0	3.5	11.0	5.0
			5	4.0	4.5	15.0	6.0
			7	5.0	6.0	19.0	7.0
			10	6.0	7.0	23.0	8.0
			15	9.0	10.0	27.0	9.0
			20	10.0	11.0	31.0	10.0
			25	11.0	13.0	35.0	12.0
			30	12.0	14.0	39.0	13.0
			35	13.0	16.0	43.0	14.0
			>35	Rs. 2.00 for every additional 5km or part thereof		Rs. 4.00& Rs. 2.00 for every additional 5km or part thereof in respectively for A/C & Point to Point	
3	DTC (Delhi Transport Corporation)	Ordinary	4	2.0			
			4-8	5.0			
			8-12	7.0			
			>12	10.0			
4	BMTC (Bangalore Metropolitan Transport Corporation)	Ordinary	Kms	City Services		Sub-Urban	
				Ordinary	Express	Ordinary	Express
			2	1.0	2.0	2.5	3.0
			4	2.0	2.5	3.5	4.0
			6	3.0	3.5	4.0	4.5
			8	3.0	3.5	4.5	5.0
			10	3.5	4.0	5.0	5.5
			12	3.5	4.0	5.5	6.0

S.No	Name of STUs	Type of Service	Fare Structure per Passenger Km				
			Distance (KM)	Fare (Rs)			
			14	3.5	4.0	6.0	6.5
			16	4.0	4.5	6.5	7.0
			18	4.0	4.5	6.5	7.0
			20	4.0	4.5	7.0	7.5
			22	4.5	5.0	7.0	7.5
			24	4.5	5.0	7.5	8.0
			26	5.0	5.0	7.5	8.0
			28	5.0	5.5	8.0	8.5
			30	5.5	5.5	8.0	8.5
			32	5.5	6.0		
			34	6.0	6.5		
			36	6.0	6.5		
			38	6.5	7.0		
			40	6.5	7.0		
			42	7.0	7.5		
			44	7.0	7.5		
			46	7.5	8.0		
		Pushpak	Upto 3	3.0			
			4-8	5.0			
			9	7.0			
			10-16	8.0			
			17-19	9.0			
			20-25	10.0			
5	South Bengal STC	Ordinary	6	2.0			
			8	2.5			
			12	2.8			
			16	3.0			
			18	3.3			
			22	3.8			
6	Navi Mumbai MT (Navi Mumbai Municipal Transport)	Ordinary	3	3.0			
			6	4.0			
			9	5.0			
			12	6.0			
			15	7.0			
			18	8.0			
			21	9.0			

S.No	Name of STUs	Type of Service	Fare Structure per Passenger Km	
			Distance (KM)	Fare (Rs)
			24	10.0
			27	11.0
			30	12.0
7	Tamil Nadu	Ordinary	2	1.5
			4	1.8
			6	2.0
			8	2.3
			10	2.3
			12	2.8
			14	3.0
			16	3.3
			18	3.3
			20	3.5
			22	3.8
			24	4.0
			26	4.0
			28	4.0
			30	4.3
			32	4.3
			34	4.3
			36	4.5
			38	4.5
			40	4.5
			42	4.8
			44	5.0
			46	5.0
		Express	Express fare 50% extra	
		Limited Stop	25Ps. Extra on above fare	
		Night Services	Two times of the above express fare	
8	PMT/PCMT (Pune Municipal Transport/Pimpri Chinchwad Municipal Transport)	Ordinary	2	2.5
			4	3.5
			6	5.0
			8	6.0
			10	7.0
			12	8.0
			14	9.0

S.No	Name of STUs	Type of Service	Fare Structure per Passenger Km	
			Distance (KM)	Fare (Rs)
			16	10.0
			18	10.5
			20	11.0
			22	11.5
			24	12.0
			26	12.5
			28	12.5
			30	13.0
			32	13.0
			34	14.0
			36	14.0
			38	15.0
			40	15.0
			42	16.0
			44	16.0
			46	17.0
			48	18.0
			50	19.0
			52	20.0
			54	21.0
			56	22.0
			58	23.0
			60	24.0
9	CSTC(Calcutta State Transport Corporation)	Ordinary	4.0	3.0
			8.0	3.5
			12.0	4.0
			16.0	4.5
			20.0	5.0

Source: Association of State Transport Undertakings: Profile & Performance 2000-01,

Annexure 3.15

COMPARATIVE STATEMENT OF MOTOR VEHICLE TAX FOR STAGE CARRIAGES (as on March 2001)

MAHARASTRA (MSRTC & BEST)	KARNATAKA	KERALA (KSRTC)	TAMILNADU	DELHI (DTC)	ANDHRA PRADESH (APSRTC)	WEST BENGAL	
						CSTC	NBTC
(a) Rs.71/- per seat per annum and Rs.18/- per standee per year. Annual Rate of MV Tax comes to Rs. 4068	(a) KnSTRC & BMTC: Rural =6% on Traffic revenue; City = 3% on Traffic revenue	(a) City / Ordinary: Rs. 400/-+ per seat for a quarter	(a) CNI-I&II: City Services: Rs. 60/- per seat and authorized standee per quarter	Annual Tax Rs. 1951/- for first 18 passenger +Rs. 280/- for every additional passenger the bus is allowed to carry conductor and driver excluded from the number licensed to carry.	(1) *Ordinary: Slab* If the distance covered by the bus per day (a) Does not exceed 100km- Rs. 191 Per quarter per seat (b) Exceeds 100kms, but does not exceed 160km- Rs. 267 Per quarter per seat © Exceeds 160kms, but does not exceed 240km-Rs. 342 Per quarter per seat (d) Exceeds 240km but does not exceed 320km- Rs. 401 Per quarter per seat (e) Exceeds 320km-Rs. 438 Per quarter per seat	*(a) City & Mofussil:*The Govt. of West Bengal has exempted totally all State Carriages buses belonging to CSTC from payment of M.V.Tax from their respective dates or registration	(a) Seating Capacity (50+1)-Rs.799 per Year(b) Seating Capacity(40+1)-Rs.699 per Year© Seating Capacity(37+1)-Rs.669 per Year(d) Seating Capacity(30+1)-Rs. 580per Year(e) Seating Capacity(20+1)-Rs. 431 per Year
(b) For buses plying solely with in municipal limits, only 2/3rd of annual tax as worked out above need be paid	(b) NWKnRTC: Rural = 8% on Traffic revenue; City= 5% on Traffic revenue	(b) Fast Pas/Express: Rs. 460/- per seat for a quarter	(b) Others: (1) Mofussil - Rs. 450/- seat/quarter (2) Town - Rs. 302.50 seat/quarter (3) Spare - Rs. 337.50 seat/quarter (4) Ghat - Rs. 50/- seat/quarter		*(2) Express:*(a) Does not exceed 320km-Rs.504 Per quarter per seat(b) Exceed 320 km-Rs.656 Per quarter per seat	*(b) Inter-State Operation:* In case of Inter-State Operation, rates of taxation paid by CSTC to the Bihar Govt. as follows; Road Tax-@Rs. 375/- per bus per month & additional M.V.Tax-@Rs. 1664/- per bus per month	

© For buses plying with in Bombay City Corporation limits a wheel tax @ Rs. 260/- per bus per annum has to be paid to the Municipal Corporation		© Reserve/Spare bus: Rs 25/- per seat for a quarter			© *Spare Vehicles:* Rs. 144/- for every passenger which the vehicle is permitted to carry		
(d) Bus having seating capacity 49+22 standees may MV Tax per year Rs. 2937/-		(d) Standees: Rs. 100/- for quarter					

Source: *Association of State Transport Undertakings: Profile & Performance 2000-01*.

Abbreviations:

MSTRC-Maharastra State Road Transport Corporation

BEST-Brihan Mumbai Electric Supply & Transport Undertaking

KSRTC-Kerala State Road Transport Corporation

DTC- Delhi Transport Corporation

APSRTC-Andhra Pradesh State Road Transport Corporation

KnSRTC-Karnataka State Road Transport Corporation

BMTC-Bangalore Metropolitan Transport Corporation

NWKnRTC-North West Karnataka Road Transport Corporation

CNI-I&II-Metropolitan Transport Corp.Ltd(Chennai Div I&II)

CSTC-Calcutta State Transport Corporation

NBSTC-North Bengal State Transport Corporation

Annexure 4.1

Zone Wise Daily Trip Productions & Attractions (2003) - Including Walk

ZONE NO.	TRIP PRODUCTIONS			TRIP ATTRACTIONS		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
1	13142	15581	4336	75462	29101	16565
2	11750	9739	2858	18230	5718	2435
3	10734	7098	3982	11057	7252	2106
4	18304	13898	10508	5271	8144	9090
5	12897	11139	1172	4109	6418	781
6	13122	15571	3674	7580	7147	2269
7	14275	7739	2064	17865	11227	2410
8	19399	16368	5001	4450	7407	3924
9	8808	11806	2061	3316	3716	2716
10	16015	20269	6006	10046	20224	3540
11	11629	5881	3743	9156	4365	2687
12	14194	8236	1227	6238	3591	1477
13	26712	15604	11901	14194	9415	8728
14	14124	4598	4927	7176	5096	2151
15	10875	6920	1483	3988	1847	736
16	15837	13174	561	3720	4892	280
17	38312	30312	6315	11123	16321	3119
18	59290	39755	7882	45699	24759	5294
19	14674	8101	7490	22188	16038	5400
20	27564	12295	4759	23086	18261	3757
21	35361	34933	9644	30368	39717	8268
22	10522	4246	2215	6498	2536	1975
23	22916	14429	2829	16889	8425	1242
24	38549	18852	8160	27106	12989	8474
25	28175	24296	4696	19858	11539	7197
26	51108	36911	3245	34198	19754	2276
27	13152	8675	3918	16894	10631	4767
28	25260	8566	4393	60347	53007	8887
29	24345	19647	6193	8373	8774	4604
30	16403	5368	4175	14891	5987	4202
31	26023	10692	2622	55147	33205	6620
32	11392	6814	852	34490	9879	419
33	14914	7151	3882	35434	7942	6473
34	11679	8606	2305	10398	13783	1570
35	28353	15342	4078	10210	7123	2202
36	12017	7141	174	7832	2986	174
37	19445	19273	2925	51182	40494	4660

ZONE NO.	TRIP PRODUCTIONS			TRIP ATTRACTIONS		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
38	7941	5775	412	6620	7357	1084
39	35338	24133	8102	35286	11019	10017
40	4774	6426	2020	24697	11277	1614
41	13882	10774	5387	62652	39437	15442
42	6312	4641	743	5251	2382	1137
43	7389	5254	2299	24105	4412	2492
44	12291	12905	1844	7734	4734	922
45	31043	18590	2707	69752	88641	9436
46	24725	10302	11126	74866	44261	20007
47	10392	8025	514	15256	6604	1658
48	11008	6530	1306	6004	2607	1494
49	15651	10480	3913	10800	10193	3719
50	38645	36242	17821	15756	18656	16286
51	37889	33432	10536	33103	28945	8615
52	11743	10798	4049	17537	14414	5321
53	19032	13671	3753	26209	34560	2684
54	16293	13701	4443	6363	4066	2962
55	19681	17824	4456	14379	10965	4431
56	25411	23717	2372	8299	11041	2033
57	29525	25283	14423	37232	32585	9655
58	11552	16656	4836	17342	27582	5418
59	10135	9379	3328	7966	11389	4161
60	22792	9877	5128	35171	14062	5577
61	4176	4176	659	2925	2544	659
62	1392	3017	0	6614	5071	361
63	1892	2417	105	3173	3065	702
64	9712	5775	1181	11036	3415	3490
65	17526	6784	4334	169571	78795	33933
66	5743	2960	2131	8401	12815	1071
67	9946	5107	3763	2616	1906	1873
68	15885	13400	4755	12644	8688	4846
69	2007	1003	201	6891	3348	671
70	12288	6808	2325	7186	4438	901
71	15252	12889	6230	8899	13269	3411
72	12303	6419	3744	1531	4551	1605
73	13112	10198	8013	5571	3089	3642
74	22226	8689	4243	13109	7632	2252
75	5783	1851	1388	1552	1619	1337
76	5573	1773	2027	1719	3166	1013
77	37466	27701	9566	27280	18483	5999
78	18024	11662	10602	10255	7689	10736
79	14951	11474	4520	17328	5553	4537
80	20914	13848	10457	18543	13280	6262

ZONE NO.	TRIP PRODUCTIONS			TRIP ATTRACTIONS		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
81	7960	5897	1179	3129	1948	884
82	4589	4982	1180	11297	7104	7824
83	5920	6375	1265	2844	2325	300
84	3733	3033	3127	38656	57869	15054
85	6795	4782	1762	6869	3928	3323
86	13419	12242	8475	4534	5415	3061
87	9547	4455	10183	4825	2120	6297
88	5920	1579	3552	2763	395	2174
89	25451	25451	19884	12044	18378	15886
90	6319	8517	6319	1509	2473	2473
91	36647	33528	8577	29210	24227	1229
92	6845	4475	0	2347	2171	180
93	10346	8180	962	4480	5774	722
94	6848	5136	1712	11717	3177	2458
95	6383	6487	1779	2275	5117	1965
96	6069	3287	2781	3500	134	2276
97	12835	11965	4786	5404	7202	4351
98	18352	12234	2447	23009	9030	2659
99	18875	4418	1606	5792	2008	0
100	23407	18813	5907	6502	6344	1313
101	10379	5793	7241	6509	2869	6975
102	34830	36169	7368	13106	19817	5371
103	13871	7398	6011	6063	2081	5506
104	11479	7131	174	40485	20244	6683
105	6130	9195	557	4276	3809	1076
106	8303	4670	519	704	578	0
107	7225	3335	2779	862	834	557
108	22684	16777	6616	14472	5798	6147
109	3289	3568	1679	4281	4397	1199
110	21470	13364	5258	6314	5546	4942
111	10575	13950	2250	1938	3601	2025
112	21059	25791	6625	11673	18875	4895
113	12275	17373	944	4364	12264	378
114	40905	38909	9228	10152	23934	7163
115	22997	13798	4599	5734	7788	4304
116	27621	19761	3368	47427	13607	4493
117	43244	37970	12305	25074	33012	12171
118	6417	7523	2213	3037	4204	1106
119	5132	4517	2053	3546	4138	1096
120	19296	9272	3508	9421	1422	1253
121	3036	4771	651	3557	5693	651
122	8493	1296	432	4878	2021	0
123	1536	439	0	728	0	0

ZONE NO.	TRIP PRODUCTIONS			TRIP ATTRACTIONS		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
124	10547	7655	2041	12328	6985	1373
125	7946	6863	3973	1445	2528	1445
126	14504	10153	5077	3626	6527	4593
127	7976	347	1040	7995	2077	1040
128	10382	1133	378	6622	9545	577
129	10611	9256	7224	4744	6763	7224
TOTAL	2091356	1541409	547615	2091356	1541409	547615

Annexure 4.2

Daily Trip Productions (Including Walk)

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
1	13702	15131	3431	17488	16579	3704
2	16365	11765	3467	21555	13325	3857
3	12913	12848	3185	16132	13733	3364
4	21783	19439	4980	28507	22094	5578
5	19018	12497	4138	24801	14367	4666
6	11695	8367	2756	14474	9197	2972
7	13958	10142	3191	16711	10561	3301
8	22133	15498	4724	27557	16028	4867
9	13328	9049	3177	16159	9690	3358
10	22232	17045	5399	27453	18684	5858
11	14070	8726	2718	17156	9080	2805
12	14483	10551	3557	18210	11501	3824
13	34393	33207	7695	42649	36327	8357
14	15646	10635	3597	19959	12391	4106
15	13011	9621	2872	16656	11177	3242
16	20803	11854	4210	26161	12682	4466
17	43125	37860	9729	54990	43560	11094
18	64704	44697	12626	83737	51584	14463
19	20381	12368	4261	26708	14428	4836
20	31025	15858	7145	40853	18488	8247
21	45311	26489	9178	55680	28393	9793
22	36275	15559	10415	15705	5681	4090
23	39555	24076	8149	65287	36621	12078
24	36393	31945	10758	48409	38000	12688
25	48841	32285	11391	80052	49130	17044
26	76646	47446	17010	124531	70727	25123
27	14161	13290	4276	17228	14449	4608
28	28616	13945	6867	37555	15996	7815
29	28096	22319	7371	37076	26072	8522
30	20108	7807	4277	29078	10382	5537
31	29393	13252	5568	43012	17702	7277
32	16227	10174	3289	23544	13571	4220
33	20388	9861	4097	28487	12577	5123
34	14632	7960	3524	18731	8626	3789
35	30021	20049	6874	39816	23260	7900
36	13234	8707	3398	17252	10074	3855
37	11453	4593	2207	13960	4993	2371
38	15129	10989	3264	19310	11994	3520

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
39	35092	25254	7746	44333	27594	8421
40	8484	6397	1956	11264	7961	2324
41	15747	9637	3945	19618	10535	4284
42	9064	6404	2061	10732	6849	2172
43	7609	4278	2019	9072	4620	2148
44	13294	13338	4544	16980	15108	5091
45	30862	16522	5582	38442	17563	5908
46	13047	14631	3157	15632	15965	3399
47	17560	8575	3482	22467	9369	3761
48	13296	8788	3108	16884	9812	3416
49	20852	9290	4335	27618	10385	4802
50	43010	37905	9231	54023	40480	9818
51	38014	35404	9343	49132	39770	10430
52	16051	5413	3964	20684	6033	4396
53	24744	12549	4717	31531	13519	5049
54	18233	17167	4669	23348	19944	5339
55	21125	18197	6561	27949	20753	7409
56	27171	30257	6575	34585	34590	7428
57	37301	26410	8131	46902	28249	8654
58	21362	17479	4711	38140	29957	7622
59	19638	15289	4485	29403	20944	5901
60	26871	12990	5215	38106	16801	6598
61	5504	6850	2008	7672	9133	2489
62	4544	2872	1211	5880	3665	1393
63	5131	2549	1327	6750	3221	1544
64	10300	6579	2429	13023	7190	2606
65	10159	5263	2457	12429	5765	2643
66	13649	4034	1959	18793	4369	2076
67	11216	5635	2892	13449	6112	3093
68	25465	12748	5536	35787	15956	6773
69	10109	9620	2838	13395	11587	3276
70	15877	9420	3602	21078	11115	4142
71	20825	15361	5439	28853	19322	6617
72	17002	7670	3548	22996	9219	4131
73	16365	10551	3852	21513	12464	4436
74	40193	34870	9710	82461	67759	17966
75	12368	6236	2866	24455	11616	4720
76	9216	3015	2308	17931	5301	3613
77	53109	42905	12918	125034	96439	28078
78	24728	13271	5977	45319	22631	9690
79	20388	17565	6171	34957	27905	9399
80	32689	24521	7561	67190	47468	13855
81	14727	10252	4163	27759	18256	6848

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
82	9935	6946	2540	17424	12197	3923
83	11516	8269	3074	20003	13940	4732
84	9903	3172	1939	16350	5283	2860
85	9365	6331	3396	16510	10660	5243
86	20472	20385	5341	39456	36822	8988
87	16964	12036	5178	32394	21523	8618
88	9944	4071	3020	19574	7371	4779
89	37170	27817	9041	71013	50440	15675
90	14234	14327	4239	28624	27480	7147
91	34257	25433	9444	161175	116608	39005
92	9696	7723	3014	18803	14531	4952
93	16379	11902	4927	26773	18107	6933
94	9672	11306	3578	18749	21556	5735
95	16312	9855	4458	30247	17861	7369
96	14630	11440	4524	28269	21146	7531
97	28780	19342	6575	57148	36148	11436
98	29773	23437	8748	53794	39299	14190
99	42843	25036	9191	78847	42313	14942
100	33022	26675	8356	57860	43613	13150
101	12829	8492	4152	21692	13602	6298
102	43532	29312	9503	86323	55376	17167
103	20138	10015	4769	34896	16116	7190
104	12525	10541	2733	22791	19381	4345
105	8966	9447	3576	17315	17911	5707
106	12918	7946	3888	25600	14969	6204
107	15321	9082	4441	31072	17197	7611
108	24335	8077	6731	47930	14839	11958
109	7648	5342	2681	13771	9863	3813
110	38858	32392	9104	69572	54032	14481
111	18881	16342	5711	37996	31431	9893
112	28940	27212	8336	50066	43767	12938
113	22116	19563	6008	38942	32461	9349
114	55439	40835	12996	78851	52654	16537
115	33571	30705	8933	66228	56528	15697
116	40278	32731	9414	77517	59172	16307
117	55380	51928	16070	105808	92349	28002
118	12059	13789	4169	23994	26427	6870
119	10430	10404	3667	20654	19788	5909
120	24047	20673	7258	49003	39923	12974
121	5575	8343	2580	9884	15093	3886
122	8697	4395	3291	16656	8006	5357
123	4217	2114	1846	7443	3534	2408
124	16002	9562	4011	24829	13680	5456

ZONE NO.	2011			2021		
	WORK	**EDUCATION**	**OTHERS**	**WORK**	**EDUCATION**	**OTHERS**
125	16777	13185	5021	26075	18976	6939
126	25186	13776	6236	51291	26400	10785
127	11955	8849	4030	24049	16740	6792
128	14191	16012	4643	28607	30782	8030
129	16487	8189	5036	38502	18450	10067
TOTAL	2807403	2006622.9	690497	4486568	2983366	982248

Daily Trip Attractions (Including Walk)

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
1	18474	20334	6044	25577	31186	7812
2	16469	22879	4213	22369	35476	5451
3	24876	24803	5285	38078	38721	7440
4	18738	18707	4502	27899	28442	6152
5	16957	13109	4275	25567	19002	5856
6	17190	19743	5880	23929	30188	7604
7	16880	9205	5841	22751	12418	7454
8	16110	12675	5743	21773	18269	7330
9	15671	10338	5686	20513	14329	7172
10	16732	22967	5822	23025	35625	7489
11	14224	15730	5502	18805	23422	6954
12	21164	19061	4811	29424	29038	6345
13	30598	21170	6015	48585	32594	8770
14	16035	13362	5733	21258	19429	7265
15	14626	14612	3978	19528	21538	5092
16	16779	8254	4252	22754	10814	5500
17	23430	17629	5101	34675	26623	7009
18	31018	13373	6069	54494	19448	9519
19	17956	9813	5978	24870	13446	7723
20	23219	64966	6650	32406	106444	8676
21	25147	30926	6896	38360	49046	9431
22	31865	9834	6177	54573	13480	9528
23	18503	16176	4472	28496	24174	6227
24	19130	38612	4552	29925	62007	6408
25	31033	37332	7646	51900	59847	11145
26	47418	23687	8162	81507	36839	12938
27	15764	5466	5699	21071	6114	7242
28	22025	34874	6497	31072	55701	8508
29	26020	15403	5431	37806	22869	7406
30	35053	27897	8159	52343	43938	11201
31	19991	39258	6238	30774	63094	8470
32	19259	18274	6145	26991	27713	7991
33	16477	38411	5789	22441	61666	7416
34	17444	44138	4337	23846	71324	5639
35	20785	22286	4763	30263	34476	6451
36	16042	19127	4158	21281	29149	5313
37	16047	43815	5735	21259	70779	7266
38	18173	36548	4430	25095	58526	5796
39	30709	10376	6029	45795	14392	8417
40	17212	5466	5883	23481	6114	7545

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
41	24696	17641	6838	33700	26644	8839
42	16478	14638	5789	21956	21579	7353
43	15109	16993	5615	20194	25551	7131
44	18577	10521	4482	25289	14636	5820
45	28268	75252	7294	40974	123787	9762
46	18664	42295	6069	25408	68216	7790
47	17322	12486	5898	23596	17951	7562
48	16829	25746	4259	23342	40309	5575
49	16019	26481	4155	21572	41550	5350
50	30574	45134	6012	45133	73003	8334
51	35746	50345	6672	53358	81790	9374
52	23436	21442	6678	36478	33055	9193
53	26828	34103	7110	42374	54402	9938
54	23443	5466	6679	36697	6114	9220
55	19244	37041	4567	26180	59357	5934
56	22436	5934	4974	35139	6902	7068
57	25423	9630	5356	41665	13136	7894
58	15484	17867	5663	20553	27025	7177
59	14817	9435	4001	20148	12808	5170
60	15902	30631	5716	21409	48547	7284
61	14596	6678	3974	20170	8159	5172
62	15026	6276	5604	17346	7481	6770
63	13014	7419	5347	17315	9406	6766
64	15069	6894	4034	19446	8522	5082
65	23919	66692	6738	34174	109355	8900
66	13479	25339	3831	17354	39626	4817
67	14196	18870	3923	18818	28718	5002
68	17703	14628	4370	25358	21562	5829
69	14478	9763	3958	18660	13360	4982
70	15200	5513	4051	20141	6193	5170
71	16727	12430	4246	23358	17857	5576
72	15086	11659	4036	19926	16557	5142
73	15485	11001	4087	20804	15447	5253
74	25976	5466	5426	59588	6114	10163
75	13555	6999	3841	18621	8700	4977
76	13534	5466	3839	17585	6114	4845
77	36667	5828	6790	74984	6725	12113
78	17792	5466	4382	27333	6114	6080
79	27525	5466	5623	46247	6114	8474
80	20769	5466	4761	33336	6114	6839
81	14759	9572	3994	21158	13037	5298
82	13639	7286	5428	17839	9183	6833
83	14751	14695	3993	19159	21675	5044

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
84	12880	26577	5331	16756	41714	6695
85	14431	5466	3953	20395	6114	5202
86	16506	5466	4217	24624	6114	5737
87	19714	5466	4627	30732	6114	6509
88	16507	5466	4218	24330	6114	5699
89	19513	10057	4601	31143	13856	6562
90	15056	5466	4032	21841	6114	5384
91	43831	7926	9280	95424	10263	16655
92	16060	11245	4160	23110	15859	5546
93	19295	5648	4573	31929	6421	6662
94	69616	5804	10993	171323	6684	24308
95	15880	5466	4137	23357	6114	5576
96	16369	8824	4200	22360	11776	5450
97	21166	5466	4812	33649	6114	6879
98	19105	8578	4549	30343	11360	6461
99	21959	5466	4913	35920	6114	7167
100	26620	5466	5508	44694	6114	8277
101	15873	6048	4136	21737	7095	5372
102	21466	5466	4851	34964	6114	7046
103	16215	6409	4180	22237	7705	5434
104	14843	17130	5581	19251	25781	7012
105	15074	5466	4034	23154	6114	5551
106	24916	5466	5291	50835	6114	9055
107	46908	5466	8097	105700	6114	16001
108	18534	5466	4476	26169	6114	5933
109	15624	5481	4104	20282	6138	5188
110	26060	5466	5436	50130	6114	8965
111	28089	5466	5696	45272	6114	8350
112	21254	7594	4823	34121	9705	6939
113	32965	5466	6317	56221	6114	9737
114	24765	13751	5271	41844	20084	7917
115	19937	6052	4655	31810	7101	6646
116	30710	5466	6029	51250	6114	9107
117	29316	15533	5852	50695	23119	9037
118	79279	5466	12253	212025	6114	29461
119	38256	5466	6992	64208	6114	10749
120	33967	5466	6445	58777	6114	10061
121	23199	5466	5071	38560	6114	7501
122	33871	7913	6432	66390	10225	11025
123	14006	6185	3898	19075	7329	5034
124	15657	7281	4119	21076	9175	5287
125	16217	5466	4181	24011	6114	5659
126	19056	5466	4542	29745	6114	6385

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
127	26113	5719	5443	55631	6542	9662
128	19691	5466	4624	30708	6113	6507
129	21716	5629	4883	34731	6390	7012
TOTAL	2807568	2006623	690497	4502983	2983366	982248

Annexure 4.3

Daily Trip Productions (Excluding Walk)

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
1	9591	10591	2402	12242	11606	2593
2	11456	8236	2427	15089	9328	2700
3	9039	8994	2230	11292	9613	2355
4	15248	13607	3486	19955	15466	3905
5	13313	8748	2897	17361	10057	3266
6	8187	5857	1929	10132	6438	2080
7	9771	7100	2234	11698	7393	2310
8	15493	10848	3307	19290	11220	3407
9	9330	6334	2224	11311	6783	2350
10	15562	11932	3779	19217	13079	4100
11	9849	6108	1903	12009	6356	1964
12	10138	7386	2490	12747	8051	2677
13	24075	23245	5387	29854	25429	5850
14	10952	7445	2518	13971	8673	2874
15	9108	6735	2010	11659	7824	2270
16	14562	8298	2947	18313	8878	3126
17	30188	26502	6810	38493	30492	7766
18	45293	31288	8838	58616	36109	10124
19	14267	8658	2983	18696	10099	3385
20	21718	11101	5002	28597	12941	5773
21	31718	18542	6425	38976	19875	6855
22	25393	10891	7291	10994	3977	2863
23	27689	16853	5704	45701	25635	8455
24	25475	22362	7531	33886	26600	8881
25	34189	22600	7974	56036	34391	11931
26	53652	33212	11907	87172	49509	17586
27	9913	9303	2993	12060	10114	3226
28	20031	9762	4807	26289	11197	5471
29	19667	15623	5160	25953	18250	5965
30	14076	5465	2994	20355	7268	3876
31	20575	9277	3898	30108	12391	5094
32	11359	7122	2302	16481	9500	2954
33	14272	6903	2868	19941	8804	3586
34	10242	5572	2467	13112	6038	2652
35	21015	14034	4812	27871	16282	5530
36	9264	6095	2379	12076	7052	2699
37	8017	3215	1545	9772	3495	1660
38	10590	7692	2285	13517	8396	2464

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
39	24564	17677	5422	31033	19316	5894
40	5939	4478	1369	7885	5573	1626
41	11023	6746	2762	13733	7374	2999
42	6345	4483	1443	7512	4794	1520
43	5326	2994	1413	6350	3234	1504
44	9306	9337	3181	11886	10576	3564
45	21603	11566	3907	26909	12294	4136
46	9133	10242	2210	10942	11175	2379
47	12292	6003	2437	15727	6559	2633
48	9307	6152	2176	11819	6869	2391
49	14596	6503	3035	19333	7270	3362
50	30107	26534	6462	37816	28336	6873
51	26610	24783	6540	34392	27839	7301
52	11236	3789	2775	14479	4223	3077
53	17321	8784	3302	22072	9463	3534
54	12763	12017	3268	16344	13961	3737
55	14788	12738	4593	19564	14527	5186
56	19020	21180	4603	24210	24213	5199
57	26111	18487	5692	32831	19775	6058
58	14953	12235	3298	26698	20970	5335
59	13747	10703	3140	20582	14661	4130
60	18810	9093	3651	26674	11761	4619
61	3853	4795	1406	5370	6393	1742
62	3181	2010	848	4116	2565	975
63	3592	1784	929	4725	2254	1081
64	7210	4605	1700	9116	5033	1825
65	7111	3684	1720	8700	4035	1850
66	9554	2824	1371	13155	3058	1453
67	7851	3944	2024	9414	4278	2165
68	17826	8923	3875	25051	11169	4741
69	7076	6734	1987	9377	8111	2293
70	11114	6594	2521	14755	7781	2899
71	14578	10752	3807	20197	13525	4632
72	11901	5369	2484	16097	6453	2892
73	11456	7385	2696	15059	8725	3105
74	28135	24409	6797	57723	47432	12576
75	8658	4365	2006	17119	8131	3304
76	6451	2111	1616	12552	3711	2529
77	37176	30033	9043	87524	67508	19655
78	17310	9289	4184	31723	15842	6783
79	14272	12295	4320	24470	19534	6580
80	22882	17165	5293	47033	33228	9698
81	10309	7177	2914	19431	12779	4794

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
82	6955	4862	1778	12197	8538	2746
83	8061	5788	2152	14002	9758	3312
84	6932	2221	1357	11445	3698	2002
85	6556	4431	2377	11557	7462	3670
86	14330	14269	3739	27619	25775	6291
87	11875	8425	3625	22676	15066	6033
88	6961	2850	2114	13702	5160	3345
89	26019	19472	6329	49709	35308	10972
90	9964	10029	2967	20037	19236	5003
91	23980	17803	6611	112823	81626	27304
92	6787	5406	2110	13162	10172	3466
93	11465	8331	3449	18741	12675	4853
94	6770	7914	2505	13124	15089	4015
95	11418	6899	3121	21173	12503	5158
96	10241	8008	3167	19788	14802	5272
97	20146	13539	4603	40004	25304	8005
98	20841	16406	6124	37656	27509	9933
99	29990	17525	6434	55193	29619	10459
100	23115	18672	5849	40502	30529	9205
101	8980	5944	2906	15184	9521	4409
102	30472	20519	6652	60426	38763	12017
103	14097	7010	3338	24427	11281	5033
104	8768	7378	1913	15954	13567	3042
105	6276	6613	2503	12121	12537	3995
106	9043	5562	2722	17920	10478	4343
107	10725	6358	3109	21750	12038	5328
108	17035	5654	4712	33551	10388	8370
109	5354	3739	1877	9640	6904	2669
110	27201	22675	6373	48700	37822	10137
111	13217	11439	3998	26597	22002	6925
112	20258	19049	5835	35046	30637	9056
113	15481	13694	4206	27259	22722	6544
114	38807	28585	9097	55196	36858	11576
115	23500	21494	6253	46360	39570	10988
116	28195	22912	6590	54262	41420	11415
117	38766	36349	11249	74066	64644	19601
118	8441	9653	2918	16796	18499	4809
119	7301	7283	2567	14458	13852	4136
120	16833	14471	5081	34302	27946	9082
121	3903	5840	1806	6919	10565	2720
122	6088	3077	2304	11659	5604	3750
123	2952	1480	1292	5210	2474	1686
124	11201	6693	2808	17380	9576	3819

ZONE NO.	2011			2021		
	WORK	**EDUCATION**	**OTHERS**	**WORK**	**EDUCATION**	**OTHERS**
125	11744	9230	3515	18253	13283	4858
126	17630	9643	4365	35904	18480	7550
127	8369	6195	2821	16834	11718	4754
128	9934	11208	3250	20025	21548	5621
129	11541	5733	3525	26951	12915	7047
TOTAL	1965182	1404636	483348	3140598	2088356	687574

Daily Trip Attractions (Excluding Walk)

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
1	12932	14234	4231	17904	21830	5468
2	11528	16015	2949	15658	24833	3816
3	17413	17362	3700	26655	27105	5208
4	13117	13095	3151	19529	19909	4306
5	11870	9176	2993	17897	13301	4099
6	12033	13820	4116	16750	21132	5323
7	11816	6444	4089	15926	8693	5218
8	11277	8873	4020	15241	12788	5131
9	10970	7237	3980	14359	10030	5020
10	11712	16077	4075	16118	24938	5242
11	9957	11011	3851	13164	16395	4868
12	14815	13343	3368	20597	20327	4442
13	21419	14819	4211	34010	22816	6139
14	11225	9353	4013	14881	13600	5086
15	10238	10228	2785	13670	15077	3564
16	11745	5778	2976	15928	7570	3850
17	16401	12340	3571	24273	18636	4906
18	21713	9361	4248	38146	13614	6663
19	12569	6869	4185	17409	9412	5406
20	16253	45476	4655	22684	74511	6073
21	17603	21648	4827	26852	34332	6602
22	22306	6884	4324	38201	9436	6670
23	12952	11323	3130	19947	16922	4359
24	13391	27028	3186	20948	43405	4486
25	21723	26132	5352	36330	41893	7802
26	33193	16581	5713	57055	25787	9057
27	11035	3826	3989	14750	4280	5069
28	15418	24412	4548	21750	38991	5956
29	18214	10782	3802	26464	16008	5184
30	24537	19528	5711	36640	30757	7841
31	13994	27481	4367	21542	44166	5929
32	13481	12792	4302	18894	19399	5594
33	11534	26888	4052	15709	43166	5191
34	12211	30897	3036	16692	49927	3947
35	14550	15600	3334	21184	24133	4516
36	11229	13389	2911	14897	20404	3719
37	11233	30671	4015	14881	49545	5086
38	12721	25584	3101	17567	40968	4057
39	21496	7263	4220	32057	10074	5892
40	12048	3826	4118	16437	4280	5282

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
41	17287	12349	4787	23590	18651	6187
42	11535	10247	4052	15369	15105	5147
43	10576	11895	3931	14136	17886	4992
44	13004	7365	3137	17702	10245	4074
45	19788	52676	5106	28682	86651	6833
46	13065	29607	4248	17786	47751	5453
47	12125	8740	4129	16517	12566	5293
48	11780	18022	2981	16339	28216	3903
49	11213	18537	2909	15100	29085	3745
50	21402	31594	4208	31593	51102	5834
51	25022	35242	4670	37351	57253	6562
52	16405	15009	4675	25535	23139	6435
53	18780	23872	4977	29662	38081	6957
54	16410	3826	4675	25688	4280	6454
55	13471	25929	3197	18326	41550	4154
56	15705	4154	3482	24597	4831	4948
57	17796	6741	3749	29166	9195	5526
58	10839	12507	3964	14387	18918	5024
59	10372	6605	2801	14104	8966	3619
60	11131	21442	4001	14986	33983	5099
61	10217	4675	2782	14119	5711	3620
62	10518	4393	3923	12142	5237	4739
63	9110	5193	3743	12121	6584	4736
64	10548	4826	2824	13612	5965	3557
65	16743	46684	4717	23922	76549	6230
66	9435	17737	2682	12148	27738	3372
67	9937	13209	2746	13173	20103	3501
68	12392	10240	3059	17751	15093	4080
69	10135	6834	2771	13062	9352	3487
70	10640	3859	2836	14099	4335	3619
71	11709	8701	2972	16351	12500	3903
72	10560	8161	2825	13948	11590	3599
73	10840	7701	2861	14563	10813	3677
74	18183	3826	3798	41712	4280	7114
75	9489	4899	2689	13035	6090	3484
76	9474	3826	2687	12310	4280	3392
77	25667	4080	4753	52489	4708	8479
78	12454	3826	3067	19133	4280	4256
79	19268	3826	3936	32373	4280	5932
80	14538	3826	3333	23335	4280	4787
81	10331	6700	2796	14811	9126	3709
82	9547	5100	3800	12487	6428	4783
83	10326	10287	2795	13411	15173	3531

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
84	9016	18604	3732	11729	29200	4687
85	10102	3826	2767	14277	4280	3641
86	11554	3826	2952	17237	4280	4016
87	13800	3826	3239	21512	4280	4556
88	11555	3826	2953	17031	4280	3989
89	13659	7040	3221	21800	9699	4593
90	10539	3826	2822	15289	4280	3769
91	30682	5548	6496	66797	7184	11659
92	11242	7872	2912	16177	11101	3882
93	13507	3954	3201	22350	4495	4663
94	48731	4063	7695	119926	4679	17016
95	11116	3826	2896	16350	4280	3903
96	11458	6177	2940	15652	8243	3815
97	14816	3826	3368	23554	4280	4815
98	13374	6005	3184	21240	7952	4523
99	15371	3826	3439	25144	4280	5017
100	18634	3826	3856	31286	4280	5794
101	11111	4234	2895	15216	4967	3760
102	15026	3826	3396	24475	4280	4932
103	11351	4486	2926	15566	5394	3804
104	10390	11991	3907	13476	18047	4908
105	10552	3826	2824	16208	4280	3886
106	17441	3826	3704	35585	4280	6339
107	32836	3826	5668	73990	4280	11201
108	12974	3826	3133	18318	4280	4153
109	10937	3837	2873	14197	4297	3632
110	18242	3826	3805	35091	4280	6276
111	19662	3826	3987	31690	4280	5845
112	14878	5316	3376	23885	6794	4857
113	23076	3826	4422	39355	4280	6816
114	17336	9626	3690	29291	14059	5542
115	13956	4236	3259	22267	4971	4652
116	21497	3826	4220	35875	4280	6375
117	20521	10873	4096	35487	16183	6326
118	55495	3826	8577	148418	4280	20623
119	26779	3826	4894	44946	4280	7524
120	23777	3826	4512	41144	4280	7043
121	16239	3826	3550	26992	4280	5251
122	23710	5539	4502	46473	7158	7718
123	9804	4330	2729	13353	5130	3524
124	10960	5097	2883	14753	6423	3701
125	11352	3826	2927	16808	4280	3961
126	13339	3826	3179	20822	4280	4470

ZONE NO.	2011			2021		
	WORK	EDUCATION	OTHERS	WORK	EDUCATION	OTHERS
127	18279	4003	3810	38942	4579	6763
128	13784	3826	3237	21496	4279	4555
129	15201	3940	3418	24312	4473	4908
TOTAL	1965298	1404636	483347.9	3152088	2088356	687574

Annexure 7.1

TWO-WHEELER USERS' OPINION SURVEY &

AUTO (3&7-SEATER) DRIVERS/PASSENGERS' OPINION SURVEY

(1) TWO-WHEELER USERS' OPINION SURVEY

The information collected from two wheeler users at petrol pumps are presented in the following tables.

Share of Two/Four Stroke Vehicles

Engine Type	Sample	%
2-stroke	1143	80
4-stroke	285	20
Grand Total	**1428**	**100**

Type of Two wheeler Models on Road

S.No	Model/Year	Sample	%
1	<=1990	133	9.3
2	1991-1995	202	14.1
3	>1995 & <=2000	762	53.4
4	>2000	331	23.2
	Total	1428	100.0

Average Two Wheeler Fuel Mileage

Engine Type	Avg. Mileage (km/Lt)
2-Stroke	44
4-Stroke	54
Average	**50**

Average Distance Traveled by Two Wheeler per day

Engine Type	Avg. Km Traveled Per Day (km)
2-Stroke	23
4-Stroke	25
Average	**24**

Two wheeler passengers' opinion to control pollution in the Hyderabad

	Measures to control Pollution*											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Grand Total**
Total	124	325	102	150	127	119	111	85	125	77	83	1428
%	9	23	7	11	9	8	8	6	9	5	6	100

1-Ban on old vehicles, 2- Avoid use of mixed oil, 3- Ban on use of kerosene as a fuel, 4-plantation of trees, 5- Regular vehicle maintenance 6- Regular Clean and Green program, 7-Ban on 2-stroke vehicles, 8- Use of Gas vehicles, 9-Implementation of Metro, 10-Exclusive lanes, 11-Segregation of Fast & slow moving vehicles

(2) AUTO (3&7-SEATER) DRIVERS/PASSENGERS' OPINION SURVEY

The information collected from Auto (3&7-seater) drivers/passenger's at petrol pumps are presented in the following tables.

No. of 3&7-seater Autos

SEATERTYPE	Sample	%
3-seater	868	97
7-seater	23	3
Grand Total	**891**	**100**

Type of auto models on road

S.No	Model/Year	3-Seater	7-Seater	Total	%
1	<=1990	15	0	15	1.7
2	1991-1995	115	1	116	13.0
3	>1995 & <=2000	548	18	566	63.5
4	>2000	190	4	194	21.8
	Total	868	23	891	100.0

Auto Mileage

	3-seater	7-seater	Avg. Mileage (km/Lt)
Avg. Mileage	31	22	26

Average Distance Traveled by Auto per day

SEATER TYPE	Average Distance Traveled per day (km)
3-seater 7-seater	91 98
Average	**95**

Number of autos having Pollution under Control Certificate (PUC)

SEATERTYPE	PUC-YES	PUC-NO	Grand Total
3-seater	792	76	868
7-seater	23	0	23
Grand Total	**815**	**76**	**891**
%	**91**	**9**	**100**

Auto passengers' opinion to attract bus transport from Pvt. Modes

SEATERTYPE	More Frequency	Less Fare	Grand Total
3-seater	687	181	868
7-seater	15	8	23
Grand Total	**702**	**189**	**891**
%	**79**	**21**	**100**

Auto Passengers' opinion for choosing auto

SEATERTYPE	1	2	3	4	5	6	Grand Total
3-seater	345	89	154	123	93	64	868
7-seater	3	2	2	10	2	4	23
Grand Total	**348**	**91**	**156**	**133**	**95**	**68**	**891**
%	**39**	**10**	**18**	**15**	**11**	**8**	**100**

1-Convinience, 2-Low Cost, 3-Safety, 4-Comfort, 5- Compulsory, 6- Others

Auto Passengers' opinion to control pollution in the Hyderabad

SEATER TYPE	1	2	3	4	5	6	7	8	9	10	11	Grand Total
3-seater	364	68	43	158	53	7	26	17	20	95	17	868
7-seater	2	1	1	6	1	1			1	9	1	23
Grand Total	**366**	**69**	**44**	**164**	**54**	**8**	**26**	**17**	**21**	**104**	**18**	**891**
%	**41**	**8**	**5**	**18**	**6**	**1**	**3**	**2**	**2**	**12**	**2**	**100**

1-Ban on old vehicles, 2- Avoid use of mixed oil, 3- Ban on use of kerosene as a fuel, 4-plantation of trees, 5- Regular maintenance 6- Regular Clean and Green program, 7-Ban on 2-stroke vehicles, 8- Use of Gas vehicles, 9-Implementation of Metro, 10-Exclusive lanes, 11- Segregation of Fast & slow moving vehicles

(3) CAR USERS' OPINION SURVEY

The information collected from Car users at petrol pumps are presented in the following tables.

Type of Car models on road

S.No	Model/Year	Sample	%
1	<=1990	3	3.7
2	1991-1995	10	11.2
3	>1995 & <=2000	67	75.3
4	>2000	9	10.1
	Total	89	100.0

Average Car Mileage

	Avg. mileage (km/lit)
Car Avg. Mileage	12

Average Distance Traveled by Car per day

	Average Distance Traveled per day (km)
Car	55

No. of Cars having Pollution under Control Certificate (PUC)

Car	PUC-YES	PUC-NO	Grand Total
Total	88	1	89
%	99	1	100

Car Passengers' Opinion to attract Bus Transport from Pvt. Modes

	More Frequency	Less Fare	Grand Total
Total	60	29	89
%	67	33	100

Auto Passengers' opinion for choosing own mode

Reasons	1	2	3	4	5	6	Grand Total
Total	46	11	8	17	3	4	89
%	52	12	9	19	3	4	100

1-Convinience, 2-Low Cost, 3-Safety, 4-Comfort, 5- Compulsory, 6- Others

Car Passengers' opinion to control pollution in the Hyderabad.

Measures to Control Pollution	1	2	3	4	5	6	8	9	Grand Total
Total	18	6	1	29	8	7	3	17	89
%	20	7	1	33	9	8	3	19	100

1-Ban on old vehicles, 2- Avoid use of mixed oil, 3- Ban on use of kerosene as a fuel, 4-plantation of trees, 5- Regular vehicle maintenance 6- Regular Clean and Green program, 7-Ban on 2-stroke vehicles, 8- Use of Gas vehicles, 9-Implementation of Metro

(4) BUS PASSENGERS' OPINION SURVEY

The information collected from Bus passengers at bus stops are presented in the following tables.

Bus passengers' opinion for choosing bus mode

Reasons for Choosing Mode	Pass Holder	Convenience	Low Fare	Safety	Comfort	Reliability	Others	Grand Total
Sample	851	388	345	214	138	24	31	1991
%	43	19	17	11	7	1	2	100

Bus Passengers' opinion to attract bus transport from Pvt. Modes

Measures for attracting Bus from Pvt. Modes	More Frequency	Less Fare	Grand Total
Sample	1435	556	1991
%	72	28	100

Bus Passengers' opinion to control pollution in the Hyderabad

	Measures to control Pollution*											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Grand Total**
Sample	88	177	198	65	128	286	372	150	400	57	70	1991
%	4	9	10	3	6	14	19	8	20	3	4	100

1-Ban on old vehicles, 2- Avoid use of mixed oil, 3- Ban on use of kerosene as a fuel, 4-plantation of trees, 5- Regular vehicle maintenance 6- Regular Clean and Green program, 7-Ban on 2-stroke vehicles, 8- Use of Gas vehicles, 9- Implementation of Metro, 10-Exclusive lanes, 11- Segregation of Fast & slow moving vehicles

Annexure 7.2

DRIVING HABITS OF TWO WHEELERS & AUTO RICKSHAW OPERATORS

Observations were made at few intersections during peak as well as non-peak hours. The following Intersections were observed during the reconnaissance survey:

1. The Ameerpet Cross Roads Intersection
2. The Srinagar Colony T Junction
3. The Panjagutta Cross Roads Intersection
4. The Green lands Rotary

The problems associated with these intersections are of two categories:

- Those arising due to improper Intersection/Signal cycle design and inadequate signboards to discipline the drivers
- Those associated with poor driving habits and lack of traffic awareness.

At intersection numbers 1 and 2 of above, it was observed that the right turning traffic was blocking the free straight moving traffic during peak hours. This is so because the green light for the right turn has a longer time cycle. Similarly at these junctions the straight and right turning traffic blocks the free left turn traffic leading to unnecessary congestion at these points.

During non-peak hours, the 2 and 3 wheeler drivers do not follow the traffic signals and signals are violated even during peak hours leading to chaos on some occasions. These observations are valid even for the 4 wheelers and city transport buses.

The 3-wheeler drivers lacked knowledge about the proper use of gears. They changed the gears too quickly while starting from rest at the intersections, resulting in inadequate speeds. This leads to obstruction for the faster moving vehicles, which are behind the 3-wheelers. Many vehicles do not switch off their engines even when stoppage time is quite high. This idling stage adds to emissions problem.

Another common problem associated with the drivers concerns the wrong choice of lanes while waiting at the intersections. Drivers maneuvering their vehicles from the straight or left turn lane to take a right turn is a common sight.

Majority of the drivers are ignorant about the rules of using a rotary. They take a right turn from the median end instead of going around the rotary purpose. This leads to obstruction of the traffic within the rotary. This is observed in particular at the Green Lands rotary.

Improper tuning of the engine leads to a condition where the drivers are found to accelerate their vehicles continuously at the intersections. The drivers are so habituated to this practice that even the four stroke vehicle drivers, whose engines are well tuned, are found to indulge in it frequently.

The drivers are very often ignorant about the traffic rules and signal cycles. The amber light, one of the important components of the signal cycle is absent at most of the signals. This has been done because the drivers did not know the significance of the amber light and hence continued to cross the stop line even on amber.

ANNEX – D

MITIGATION OF PM10 AND GHG FROM ALTERNATIVE INDUSTRIAL SCENARIOS FOR IES-INDIA PROJECT

ANNEX - D

MITIGATION OF PM_{10} AND GHG FROM ALTERNATIVE INDUSTRIAL SCENARIOS FOR IES-INDIA PROJECT

1.0 INTRODUCTION

Alternative industrial scenarios have been proposed for the reduction of particulate matter less than 10 microns in diameter (PM_{10}) and green-house gas (GHG) emissions in the Hyderabad Urban Development Area (HUDA). These scenarios have been selected based on relevance and acceptability to study area, as well as having maximum impacts on pollutant reductions. The following is the list of the four alternative industrial mitigation scenarios proposed for the IES- India program.

1) Use of additives to improve combustion for heavy fuel oils (furnace oil) in oil fired boilers.
2) Particulate controls to be made mandatory for all existing uncontrolled, solid-fuel (coal, wood and agricultural waste) fired boilers. For existing coal, wood and agricultural waste fired boiler with PM_{10} emissions below 10 tons per year (tpy) (primarily boilers with a steam generation capacity less than 5 tons/hour (tph)), cyclone controls will be assumed. For existing particulate emissions above 10 tpy, (primarily boilers with capacity larger than 5 tph), baghouse (fabric filter) controls will be assumed.
3) Introducing use of natural gas as primary combustion fuel for industry.
4) Use of energy efficiency and renewable energy for industry.

These four scenarios were selected because they can be readily implemented and are cost effective solutions to pollution reduction in the Indian context. The Andhra Pradesh Pollution Control Board (APPCB) is currently promoting cleaner production and waste minimization for industries. These mitigation measures could be part of this promotion.

2.0 METHODOLOGY

The industrial database for base year (CY 2001) was used as the starting point. It was assumed that the industrial growth rate up to CY 2021 would be fixed at 6.5% per annum (source: CII, Hyderabad). It was also assumed that industrial fuel use would increase at the same rate. Using this compounded growth rate, the increase in fuel used would be 188% by CY 2011 and 352% by CY 2021. For each scenario, the fuel usage in CY 2001 was multiplied by these percentages to estimate fuel usage in CYs 2011 and 2021, respectively.

Details for each industrial mitigation scenario are given below:

3.0 USE OF ADDITIVES TO IMPROVE COMBUSTION IN FUEL OIL BOILERS

Efficient liquid fuel combustion is a process that takes place when fuel is vaporized and ignited. The rate of vaporization depends on the surface area, which in turn, depends on the droplet size of the fuel. Even with the use of air and steam atomization burners, the fuel droplet size is not small enough to ensure complete combustion in the limited fuel residence time. As a result, there is some loss of energy in the form of unburnt hydrocarbons in the exhaust gas, as well as soot formation on boiler walls/pipes and other heat transfer surfaces. Carbonaceous deposits are also formed, which causes a reduction in heat transfer efficiency. Addition of chemical catalysts to fuel oil has been found to be the most effective solution to mitigate these combustion problems. Considering the heavy fuel oil used in India, containing high metal content and asphaltines, the preferred dosage of additives for optimum combustion results is usually 500 ppm (ie., 1 liter additive per 2,000 liters of fuel oil).

Several additives are available and currently being used (eg. Pennar ELF 13S) for improving furnace oil (heavy fuel oil) combustion in oil-fired boilers. These additives are usually aromatic solvents readily soluble in fuel oil and which act as catalysts by increasing speed of oxidation of unburnt hydrocarbons during the process of heavy fuel oil combustion. These additives have the following properties:

- Significantly reduce significantly the amount of soot and unburnt hydrocarbons formed during the combustion of heavy fuel oils.
- Reduction in excess air used during the combustion process.
- Improvement of flame homogeneity, resulting in more stable yield of combustion with time.
- Reduction of deposits on heat transfer surfaces, consequently having more efficient heat transfer in the convection zone.

As a consequence of the above, there is a reduction in fuel consumption and also reduction of particulate emissions. It should be noted that the additive can be used in most liquid fuels used in boilers, with the exception of diesel fuel.

This measure requires very little infrastructure change and can be implemented for the study area by 2011.

3.1 PARTICULATE EMISSIONS REDUCTION

The catalyst additive acts by forming fuels that burn easily and results in elimination or reduction of unburnt hydrocarbons. Boiler tests using a 1.16MW boiler with 500 kg of fuel oil (measured oxygen concentration in stack gases was 4.5%), showed 50-60% reduction of total particulates due to chemical reaction initiated by catalyst additive (ref: Pennar Elf AC 13S document).

For purposes of the IES study, a 50% reduction in total particulate emissions will be conservatively assumed for boilers currently using furnace oil. This will result in a 50% reduction in PM_{10} emissions from fuel oil combustion. In addition, there will be a further reduction in particulate emissions because of the reduction in fuel oil consumption (refer below). Use of additives to fuel oil will, therefore, cause considerable reduction in PM_{10} emissions.

3.2 SAMPLE CALCULATION

PM_{10} Mitigation Emissions (CY 2011/2021) (tpy)= PM_{10} Emissions (CY 2011/2021) x 0.5 (PM reduction factor)x 0.96 (fuel reduction factor).

3.3 GHG REDUCTION

Use of additives will result in a very slight (0.5%) increase in CO_2 emissions due to better combustion (ref: Pennar Elf document). However, due to greater stability of yield of combustion with time and better efficiency of heat transfer in the convection zone, the use of additives results in reduction of fuel oil consumption. Boiler tests (ref: Pennar Elf AC 13S document) have shown reduction of fuel oil consumption to the extent of 3-4% (4% reduction will be assumed for the IES-India study).

This reduction in fuel usage will result in lower emissions of GHG gases. For example, using the emission factor for CO_2 of 3.14E-03 tons CO_2 per liter of heavy fuel oil, a 4% reduction (or 157, 419 liters) in fuel oil usage in the Jeedimetla industrial area (one of the Industrial Development Areas in HUDA) would result in CO_2 decrease of 495 tons. The other GHGs (N_2O and CH_4) would also show a decrease, but to a much lesser extent. (The increase in CO_2 due to improved combustion has not been considered since it is negligible).

3.4 SAMPLE CALCULATION

eCO_2 (CY 2011/2021) (tpy)= Fuel Usage (CY 2011/2021)x Emission Factors

Please refer to Tables 1 and 1(a) below for PM_{10} and GHG mitigation impacts from the above scenario.

4.0 CONTROLS FOR COAL, WOOD AND AGRICULTURAL WASTE- FIRED BOILERS

For this mitigation scenario, particulate controls will be made mandatory for all uncontrolled solid fuel fired boilers (using coal, wood or agricultural waste as fuel). For existing coal, wood or agricultural waste fired boiler with particulate matter (PM_{10}) emissions below 10 tons per year (tpy) or for boilers with capacity less than 5 tph, cyclone controls will be required. For existing coal, wood or agricultural waste fired boilers with PM_{10} emissions above 10 tpy or boilers with capacity over 5 tph, installation of baghouse (fabric) filters would be required. Baghouses and cyclones are the most commonly used control equipment in the study area. While the collection efficiency of the baghouse is much higher, it is also much more expensive. Therefore, it has been assumed that cyclones will be used for smaller boilers, and baghouses for the larger boilers. These measures should result in significant decrease of PM_{10} emissions from all uncontrolled coal and agricultural waste fired boilers.

This measure can be implemented in the study area by 2011, provided the proper regulatory and policy support structures are in place.

4.1 PM_{10} EMISSIONS REDUCTIONS

Cyclones provide a low-cost, low maintenance method of removing particulate matter from gas streams. A cyclone control reduces dust loading and removes larger abrasive particles. Multiple-tube cyclone arrangements are usually used on fossil fuel boilers, where they can handle large volumes of air flow. Overall multiple-tube cyclone collection efficiencies for PM_{10} ranges from 60% to 90%, depending on cyclone diameter, collection temperature, etc. (ref: Air Pollution Engineering Manual, AWMA). For purposes of the IES- India study, it has been conservatively assumed that cyclone collection efficiency for PM_{10} is 60%.

Baghouses or fabric filters remove dust from the boiler exhaust by passing the heated exhaust through a porous fabric. Dust particles form a more or less porous cake on the surface of the fabric. It is normally this cake that actually does the filtration. The manner in which the dust is removed from the fabric is a crucial factor in the performance of the fabric filter system. If the dust cake is not adequately removed, the pressure drop across the system will increase to an excessive amount. If too much of the cake is removed, excessive dust leakage will occur while fresh cake develops. The selection of design parameters and proper operation and maintenance is crucial for optimal performance of the fabric filter system.

Well designed and operated baghouses have been shown to be capable of reducing overall particulate emissions to less than 0.1 gr/dscf (ref: Air Pollution Engineering Manual, AWMA). This translates to overall particulate removal efficiency of greater than 99%. However, for IES-India study, it has been assumed that baghouse collection efficiency is 99%.

4.2 SAMPLE CALCULATION:

PM_{10} Emissions (CY 2011/2021)= TSPM Emissions x (1- Control Efficiency/ 100).

4.3 GHG REDUCTION

Cyclone separators provide low-cost, low maintenance method of removing particulates from gas streams. Cyclones usually use a fan for booster/suction purposes. This may cause a negligible increase in CO_2 emissions. It is estimated that during power generation, very small quantities of CO_2 are formed for each KWh generated, which is insignificant when compared to GHGs released from fuel combustion from boilers/furnaces.

Fabric filters, or baghouses, use fans to force gas through the filter system. Fan power depends on gas flow rate and pressure drop. This will also cause a very slight increase in CO_2 emissions. It has been estimated that insignificant quantities of CO_2 are released per KWh used (ref: National Productivity Council). Therefore, it can be seen that increase in GHG emissions due to baghouse installation is negligible as compared to total GHGs from fuel combustion.

It can therefore be assumed that installation of cyclones and baghouses will have a negligible net effect on GHG emissions.

Please refer to Table 2 below for PM_{10} mitigation results for this scenario. For this scenario, there is no GHG mitigation.

5.0 INTRODUCING USE OF NATURAL GAS

Natural gas is emerging as the preferred fuel of the future in view of it being environmentally friendly and economically attractive to industry. The Government of India (GoI) has developed a policy framework (Hydrocarbon Vision- 2025) which guides policies relating to the hydrocarbon sector for the next 25 years. With regards to natural gas, the objectives of this policy are:

a) To encourage use of natural gas, which is considered a relatively “clean” fuel,
b) To ensure adequate availability by a mix of domestic gas imports through pipelines and import of LNG,
c) To tap unconventional sources of natural gas like coal bed methane, natural gas hydrates, underground coal gasification, etc.

Medium and long term objectives have been formulated by GoI to achieve these objectives. The total estimated reserves of natural gas in India are about 763 billion cubic meters (BCM), the bulk of which are in the Western Offshore region and the balance spread over northeast India, and the Western and Southern regions. The present annual production in India is around 30 BCM (ref: Gas Authority of India Limited (GAIL)).

While there currently is no piped gas in the Hyderabad region, GAIL (India) is in the process of developing a “green” quadrilateral of clean energy corridors in India, connecting the major consumption centers with the major gas fields. This pipeline will pass through the Hyderabad region, providing piped natural gas to industrial, commercial and residential users. The estimated completion date for this pipeline through Hyderabad is 2006-2007 (ref: GAIL, India, Ltd.).

The percentage of natural gas as a share of total energy supply in India by 2010-11 is estimated to be about 14%-15% and by 2020-2021, approximately 18%-20% (ref: Hydrocarbon Vision-2025). For the IES-India study, it has been assumed that industry in the study area will switch to natural gas in the same percentages, ie., 15% and 20% of industrial fuel use will be natural gas by 2011 and 2021, respectively. Since 15-20% replacement of total fuel by natural gas will involve a fuel switch of a relatively small number of boilers (out of the total number of boilers in the study area), for purposes of this study, it will be assumed that initially, an appropriate number of only coal-fired boilers will be replaced by natural gas-fired boilers. For purposes of mitigation calculations, it has been assumed that the coal will be replaced by an equivalent amount of natural gas (in terms of kilocalories). Please refer to Table 5 below for heating value equivalents.

5.1 PARTICULATE EMISSIONS REDUCTION

Natural gas is considered as a clean fuel with no appreciable particulate matter emissions at normal operating conditions. The particulate emissions factor used for natural gas for the IES- India study is 0.061 kg PM_{10}/ton natural gas (ref: Rapid Inventory Techniques, WHO), with heat value of natural gas approximately 10,000 Kcal/m^3. For coal, the emission factor used for particulates is 3.1 Kg PM_{10}/ton coal (ref: USEPA-AP42 document), and useful heat value for Indian coal is about 4,500 Kcal/kg. For furnace oil, the particulate emissions factor is 12 kg

PM_{10}/ton fuel oil (ref: Rapid Assessment Method, World Bank Study), with heat value approximately 10,200 Kcal/kg. Since natural gas has higher heating value and a much lower particulate emissions factor, it can be seen that particulate emissions from natural gas are much lower than solid or liquid fuels when adjusted for heating values.

5.2 SAMPLE CALCULATION:

PM_{10} Emissions from Natural Gas (tpy) = Amount of Natural Gas Introduced (tpy) x Natural Gas Emission Factor.

5.3 GHG REDUCTION

Since heating value for natural gas is much higher as compared to heating value for coal, there will be a decrease in GHG emissions (primarily CO_2) from natural gas combustion. This also holds true for furnace oil. Therefore, use of natural gas for combustion in place of coal or fuel oil will result in decrease of total GHGs from fuel combustion.

5.4 SAMPLE CALCULATION:

eCO2 (CY 2011/2021) (tpy) = Quantity of natural gas (CY 2011/2021) (tpy) x Emission Factors.

Please refer to Tables 3 and 3a below for PM_{10} and GHG mitigation results for this scenario.

6.0 USE OF ALTERNATIVE ENERGY

India has an abundance of sunlight, water and bio-mass and is today at the forefront in harnessing renewable energy resources and has one of the largest/broad based programs in non-conventional energy. The

Ministry of Non-Conventional Energy Sources (MNES) has been entrusted to provide a thrust and importance to the renewable energy sector. The future requirement may necessitate distributed generation and demand side management. Renewable energy is emerging as an effective option for ensuring green house gas (GHG) abatement and to provide a certain degree of national energy security. Realizing the potential and importance of new and renewable sources of energy (NRSE) in national development, the Government of India established the Indian Renewable Energy Development Agency (IREDA) in 1956 as one of the instruments for promoting, developing and financing NRSE technologies, as well accelerating development and assistance in large-scale utilization of renewable energy resources. In India, renewable energy sources have the following potential:

Sector	Potential
Wind Energy	45,000 MW
Small Hydro (< 25MW)	15,000 MW
Biomass/Co-generation	19,500 MW
Solar Energy	20 MW/sq.km.
Bio Gas Plants	12 million plants

It can be seen that renewable energy has huge potential in all sectors. Additionally, major industries have at least 1,500 MW of demand side energy savings potential. Currently, the renewable energy constitutes about 3.5% of total grid capacity in India (ref: IREDA). The Renewable Energy Policy sets medium term goal of 10% of total power capacity from renewable energy sources by 2012 (ref: IREDA). IREDA has also fixed target to sanction an additional capacity of 1500 MW and thermal energy saving projects/systems equivalent to 120,000 tons of coal replacement during this period (ref: IREDA).

For purposes of the IES- India study, it has been assumed that 5% of industrial energy (fuel use) in the study area will be from renewable energy sources by 2011, with this number increasing to 10% by 2021. Since 5-10% replacement of total fuel by biogas will involve a fuel switch of a relatively small number of boilers (compared to the total number of boilers in the study area), for purposes of this study, it will be assumed that initially, an appropriate number of only fuel oil fired boilers will be replaced by biogas. It has also been assumed that wood from sustainable sources will be the fuel used for biogas generation. For purposes of mitigation calculation, it has been assumed that the fuel oil will be replaced by an equivalent amount of wood (in terms of kilocalories). Please refer to Table 5 below for heating value equivalents.

It should be noted that there are only a few biogas units presently operating in the study area. Therefore, the assumption of 5-10% replacement of total fuel by biogas by 2011 and 2021, respectively, is quite optimistic, but it is illustrative of the benefits of switching to renewable energy. The other renewable energy sources such as solar, wind and hydro are not economically viable for the small and medium scale industries in the study area.

6.1 PARTICULATE EMISSIONS REDUCTION

None of the major renewable energy technologies (wind, hydro, biomass, solar) contribute to particulate emissions (PM_{10}). Therefore, replacement of 5%-10% of fuel used in industry by renewable energy will result in a significant decrease in PM_{10} emissions.

6.2 SAMPLE CALCULATION:

For Biogas Units (using wood) PM_{10} Emissions= 0.

6.3 GHG REDUCTION

For wind energy, hydro-power and solar energy generation, GHGs are not formed. Since the majority of biomass plants use wood or agricultural waste as fuel, there is no net CO_2 generation (assuming sustainable sources for these fuels, which do not cause non-sustainable deforestation). There may be emissions of other GHGs (N_20, CH_4) from wood/agricultural wastes, but these will be small because emission factors are small (ie., 3.38E-03 tons eCO_2/ton wood for N_2O, and 6.87E-02 tons eCO_2 /ton wood for CH_4). Therefore, it can be seen that replacement of 5%-10% of industrial fuel use by renewable energy will result in considerable GHG abatement.

6.4 SAMPLE CALCULATION:

GHG Emissions (tons eCO2) = Amount of Wood Used (tons) x Emissions Factors

Please refer to Tables 4 and 4a below for PM_{10} and GHG abatement results for the biogas scenario.

Table: 1 PM_{10} Emissions

	Fuel Additive Scenario			
Area :	CY 2011 PM10 Emissions (Tons.)		CY 2021 PM10 Emissions Tons.)	
	(BAU)	(Mitigation)	(BAU)	(Mitigation)
MCH	175.35	154.22	328.31	288.75
NMDC	448.13	371.36	839.06	695.31
JEEDIMETLA :	1070.03	996.97	2003.45	1866.68
SANGA REDDY :	238.16	187.88	445.92	351.78
R.C. PURAM	299.83	249.47	561.38	467.1
TOTAL :	2231.5	1959.9	4178.12	3669.62
Mitigation (tons.)		271.6		508.5

Table: 1a GHG Emissions

Fuel Additive Scenario				
CY 2011 GHG Emissions (Tons. eCO_2		CY 2021 GHG Emissions (Tons. eCO_2)		
(BAU)	(Mitigation)	(BAU)	(Mitigation)	
1487602	1469186	2770365	2735884	Total (tons eCO_2)
18416		34481		Mitigation (tons eCO_2)

Table: 2 PM_{10} Emissions

Area :	Control Scenario			
	CY 2011 PM_{10} Emissions (Tons.)		CY 2021 PM_{10} Emissions (Tons.)	
	Boilers (BAU)	Boilers (mitigation)	Boilers (BAU)	Boilers (mitigation)
MCH	175.35	128.47	328.31	245.68
NMDC	448.13	372.24	839.06	696.96
JEEDIMETLA :	1070.03	709.28	2003.45	1328.01
SANGA REDDY :	238.16	201.57	445.92	377.42
R.C. PURAM	299.83	214.63	561.38	401.87
TOTAL :	2231.5	1626.19	4178.12	3049.94
Mitigation (tons.)	605.31		1128.18	

Table: 3 PM_{10} Emissions

Area :		NG Scenario			
		CY 2011		CY 2021	
		PM_{10} Emissions (Tons.)		PM_{10} Emissions (Tons.)	
		Boilers (BAU)	Boilers (Mitigation)	Boilers (BAU)	Boilers (Mitigation)
MCH		175.35	146.95	328.31	274.25
NMDC		446.98	400.34	828.76	703.72
JEEDIMETLA :		1072.82	1047.46	2008.68	1917.12
SANGA REDDY :		237.93	203.79	445.48	365.82
R.C. PURAM		299.83	193.24	561.38	318.06
TOTAL :		2232.91	1991.78	4172.61	3578.97
Mitigation (tons.)		241.13		593.64	

Table: 3a GHG Emissions

NG Scenario				
CY 2011		CY 2021		
GHG Emissions (Tons. eCO_2		GHG Emissions (Tons. eCO_2)		
(BAU)	(Mitigation)	(BAU)	(Mitigation)	
1487602	1454319	2770364	2682163	Total (tons eCO_2)
33283		88201		Mitigation (tons eCO_2)

Table: 4 PM_{10}

	Biogas Scenario			
	CY 2011		CY 2021	
	PM_{10} Emissions (Tons.)		PM_{10} Emissions (Tons.)	
	Boilers	Boilers	Boilers	Boilers
Area	(BAU)	(mitigation)	(BAU)	(mitigation)
MCH	175.35	166.73	328.31	252.25
NMDC	446.98	386	828.76	604.65
JEEDIMETLA :	1072.82	1025.86	2008.68	1877.5
SANGA REDDY :	237.93	214.48	445.48	364.44
R.C. PURAM	299.83	255.63	561.38	476.02
TOTAL :	2232.91	2048.7	4172.61	3574.86
Mitigation (tons.)	184.21		597.75	

Table: 4a GHG Emissions

Biogas Scenario				
CY 2011		**CY 2021**		
GHG Emissions (Tons. eCO_2		**GHG Emissions (Tons. eCO_2)**		
(BAU)	**(Mitigation)**	**(BAU)**	**(Mitigation)**	
1488339	1391079	2771745	2490683	Total (tons eCO_2)
97260		281062		Mitigation (tons eCO_2)

Table: 5 Heating Values

Coal:	4,400	K.Cal/Kg.
Wood:	3500	K.Cal/Kg.
Fuel Oil:	9486	K.Cal/lt.
Light Diesel Oil	9328	K.Cal/lt.
Diesel/Low Sulfur Heavy Stock	9200	K.Cal/lt.
Coke	6500	K.Cal/Kg.
Husk	3000	K.Cal/Kg.
Natural Gas	14000	K.Cal/Kg.

ANNEX – E

MITIGATION SCENARIOS MODELING FOR IES-INDIA PROJECT

ANNEX - E

MITIGATION SCENARIOS MODELING FOR IES-INDIA PROJECT

1.0 INTRODUCTION

The emissions from transport and industrial sectors for base year (CY 2001) are used as the base emissions in the study area (refer to Annex B for further details). For the industrial sector, it was assumed that the industrial growth rate to CY 2021 would be 6.5% per annum (source: CII, Hyderabad).

In the transportation studies, the Transportation Demand Modeling (TDM) exercise was carried out to estimate transport demand that would be satisfied by various modes of transport such as motorized two-wheelers, cars, auto rickshaws, buses and non-motorized transport through 2021 for BAU-2011 and BAU-2021 scenarios. For business-as-usual (BAU) scenarios, the share of the buses is expected to fall from 42% of total motorized trips in 2003 to 31% by 2021 and the 3 wheeler's share is expected to increase from 9% in 2003 to 33% by 2021. This will result in rapid increase in PM_{10} and hydrocarbon air emissions from the transport sector. Due to lack of available field data, appropriate assumptions have been made to estimate vehicular emissions (refer to Annex C for further details of transportation study).

The following are the four of alternative mitigation scenarios (one transportation scenario and three industrial scenarios) selected for the Air Quality Modeling studies of the IES- India program. Air Quality Modeling was carried out for BAU-2011 with these four alternative mitigation scenarios. The transportation emissions were estimated with feedback loop methodology. The same procedure was adopted for BAU-2021 for the four identified alternative mitigation scenarios. The following are the selected four alternative mitigations scenarios.

2.0 TRANSPORTATION SECTOR

The alternative transportation mitigation scenarios are:

i) More Effective Bus Transit System

ii) Traffic system management measures

iii) Vehicle technology/training for two-stroke vehicles.

The Effective Bus Transit System was selected as the most suitable transport mitigation measure in the study area for air quality modeling.

2.1 EFFECTIVE BUS TRANSIT SCENARIO

In any developing city, the public transport system plays crucial role in developing a clean and effective transportation sector. The availability of a good public transport system with inexpensive rates can deliver better environmental conditions, faster travel speeds, better mobility, and economic growth. After evaluating the different modes of existing systems of transport, the Effective Bus Transit System has been considered as most appropriate and suitable system in the study area for air quality modeling because particulate matter (PM_{10}) reduction potential is greatest for this mitigation scenario. The bus system can be made faster and more reliable by providing exclusive bus lanes, provision of adequate and well-designed bus bays, bus route rationalization, high frequency buses, etc. If bus travel can be made faster, these will induce/shift passengers from other transport modes (refer to Annex C for further details).

3.0 INDUSTRIAL SECTOR

To reduce industrial emissions for BAU-2011and BAU-2021, some feasible alternative industrial mitigation scenarios have been proposed. These mitigation measures are useful for reduction of particulate matter less than 10 microns in diameter (PM_{10}) and greenhouse gas (GHG) emissions. These mitigation scenarios have been chosen based on suitability to the existing industries in the region, their cost implications and pollutant load reduction (refer to Annex D for more details of the Industrial Mitigation Scenarios).

3.1 COMBINED NATURAL GAS AND BIOGAS SCENARIO:

Natural Gas is a mixture of hydrocarbon gases. It consists primarily of methane, ethane, propane, butane and pentane. The other minor constituents of natural gas are carbon dioxide, oxygen, nitrogen, hydrogen sulfide and trace rare gases. Natural Gas is rapidly emerging as the preferred transportation fuel in several parts of the world, including India, since it is more environmentally friendly than traditional fossil fuels, convenient to transport and use, and has several techno-economic advantages. Natural gas is considered as a clean fuel with no appreciable particulate matter emissions at normal operating conditions. Since the heating value for natural gas is much higher as compared to heating value for coal, there will be a decrease in GHG (primarily CO_2) emissions from natural gas combustion. However, the IES team acknowledges that there will be a slight increase in CH_4 emissions (also a GHG).

India has an abundance of Biogas which is largely produced from wood and agriculture residues and is today at the forefront in harnessing renewable energy resources and has one of the largest/broad based programs in non-conventional energy. Biomass gasification is basically conversion of solid biomass/agricultural residue into a combustible gas mixture. Future requirements may necessitate distributed generation and demand side management. Biogas is emerging as an effective option for ensuring greenhouse gas (GHG) abatement and PM_{10} reduction.

For this mitigation scenario, it has been assumed that a small number of coal and fuel oil fired boilers in the study area will switch over to natural gas and biogas, respectively. For the natural gas scenario, it has been assumed that 10% and 15% of total industrial fuel usage will be replaced by natural gas by CYs 2011 and 2021, respectively. For the biogas scenario, it has been assumed that 5% and 10% of total fuel usage will be replaced by biogas by CYs 2011 and 2021, respectively (refer to Annex D for further details).

3.2 CONTROL SCENARIO

For this mitigation scenario, particulate controls would be made mandatory for all uncontrolled solid fuel (coal, wood and agricultural waste) fired boilers. For existing coal, wood and agricultural waste fired boilers with particulate (PM_{10}) emissions below 10 tons per year (tpy) (primarily boilers with capacity less than 5 tons/hour (tph)), cyclone controls will be assumed to be installed; for existing coal, wood, and agricultural waste fired boilers with PM_{10} emissions above 10 tpy (primarily boilers with capacity greater than 5 tph), installation of bag house (fabric) filters will be assumed. Bag houses and cyclones are the most commonly used control equipment in the study area. It has been assumed that cyclones will be used for smaller boilers, and bag houses for the larger boilers. These measures would result in significant decrease of PM_{10} emissions from all uncontrolled coal and agricultural waste fired boilers.

3.3 FUEL ADDITIVES SCENARIO

Addition of chemical catalysts to fuel oil has been found to be the one of the most effective solutions to mitigate particulate emissions from boilers. Several additives are available and currently in use. These additives are usually aromatic solvents readily soluble in fuel oil, which act as catalysts by increasing speed of oxidation of unburnt hydrocarbons during the process of heavy fuel-oil combustion. As a consequence of the above, there is a reduction in fuel consumption and also reduction of particulate and GHG emissions.

3.4 RESULTS AND CONCLUSIONS

The following are the Air Quality Modeling results obtained with the mitigation scenarios described above. Tables 1 and 2 below present the spatial distribution of average annual PM_{10} concentrations, with mitigation scenarios for BAU-2011 and BAU-2021. From Tables 1 and 2 and Figures (1), (2) and (3), (4), it is observed that effective bus transit mitigation scenario is the most effective mitigation scenario, when compared to other recommended scenarios for reducing emissions for CYs 2011 and 2021. With the Effective Bus Transit scenario, ambient pollutant concentrations are reduced to about 1/3 of corresponding BAU levels. Industrial mitigation scenarios do not show significant PM_{10} reductions in the Municipal Corporation of Hyderabad (MCH) area, but they do show significant reductions of ground-level concentrations (GLCs) of PM_{10} in some industrial areas such as Rajendranagar, Gaddiannaram, Patancheru, Qutbullapur, etc., because most of the air polluting industries are located in the Industrial Development Areas (IDAs) of neighboring municipalities.

Table 1: Predicted Ground Level Concentrations of PM_{10} for HUDA Area with Alternative Mitigation Scenarios-2011

(Annual Avg. Concentrations)

S. No.	Locality	BAU-2011 PM_{10} ($\mu g/m^3$)	Transp. Mitig. Bus transit Scenario. PM_{10} ($\mu g/m^3$)	Ind. Mitig. NG+BG Scenario. PM_{10} ($\mu g/m^3$)	Ind. Mitig. Control Scenario. PM_{10} ($\mu g/m^3$)	Ind. Mitig. Fuel Additive Scenario. PM_{10} ($\mu g/m^3$)
1	MCH Area	420	260	420	420	420
2	Rajendra nagar	120	50	119	109	99
3	L B Nagar	130	70	120	120	130
4	Uppal	110	60	100	110	110
5	Kapra	70	30	40	40	50
6	Malkajgiri	50	30	40	40	50
7	Alwal	140	70	130	130	120
8	Qutbullap ur	220	110	210	210	210
9	Kukatpall y	70	40	70	70	70
10	Serlingam pally	70	40	70	80	70
11	Patancher u	190	100	140	190	190
12	Ghatkesa r	50	40	40	40	40
13	Gaddiann aram	230	100	170	180	170

Figure 1: Predicted GLCs of PM_{10}

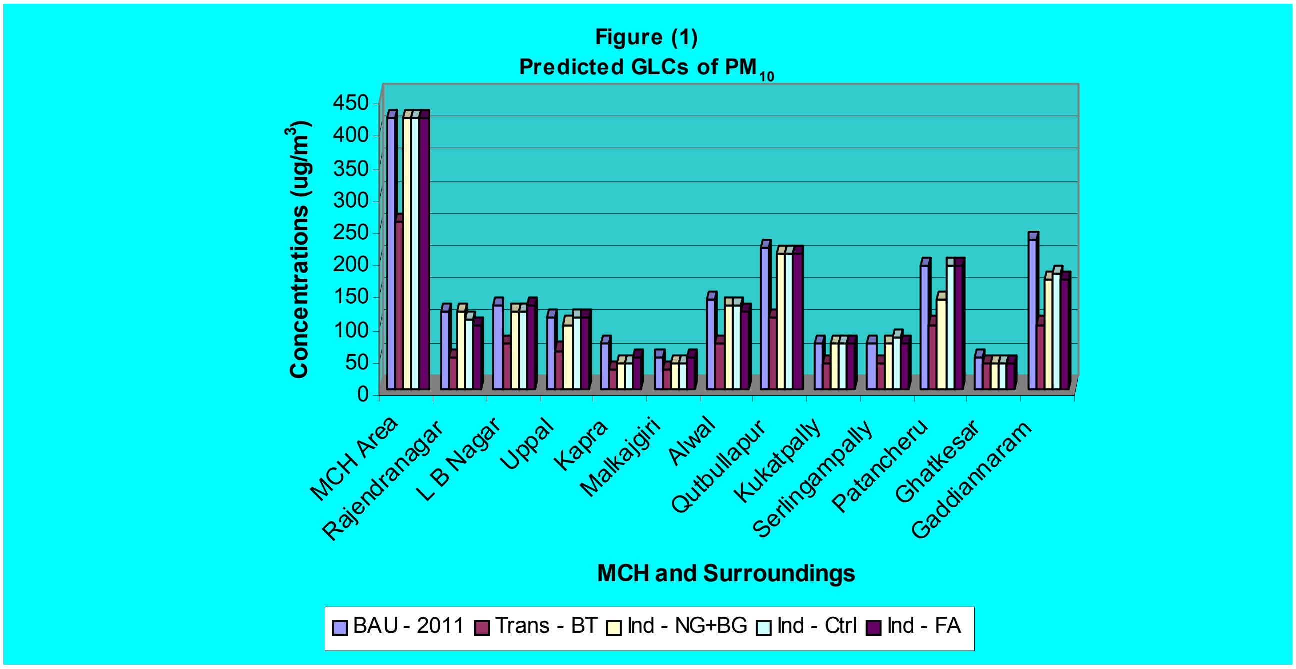


Figure 2: Predicted GLCs of PM_{10}

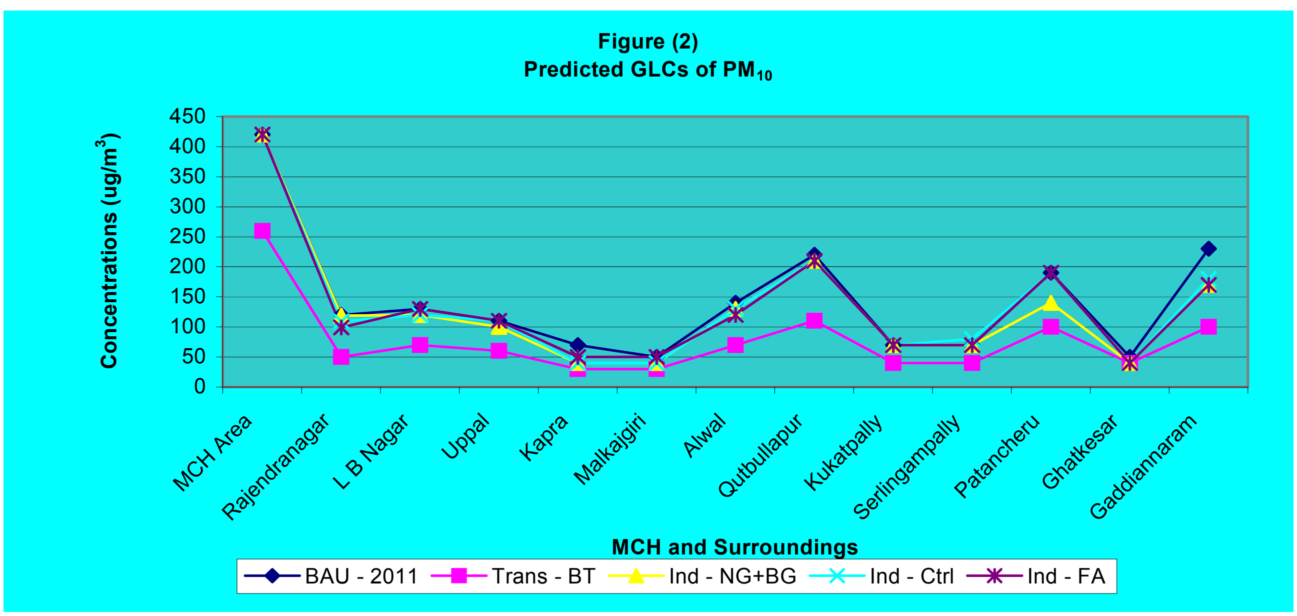


Table 2: Predicted Ground Level Concentrations of PM_{10} For HUDA area With Alternative Mitigation Scenarios-2021

(Annual Avg. Concentrations)

S. No.	Locality	BAU-2021 PM10 (μg/m3)	Transp. Mitigation Bus Transit Scenario PM10 (μg/m3)	Ind.Mitigation-NG+BG Scenario PM10 (μg/m3)	Ind. Mitigation-Control Scenario PM10 (μg/m3)	Ind.Mitigation-Fuel Additive Scenario PM10 (μg/m3)
1	MCH Area	1010	490	1009	1009	1009
2	Rajendranagar	360	50	219	244	246
3	L B Nagar	310	100	260	260	260
4	Uppal	260	100	260	260	260
5	Kapra	110	40	110	110	110
6	Malkajgiri	60	40	110	60	110
7	Alwal	285	90	285	285	285
8	Qutbullapur	560	180	510	510	485
9	Kukatpally	210	60	185	210	210
10	Serlingampally	210	60	210	210	210
11	Patancheru	560	180	485	535	535
12	Ghatkesar	160	50	135	160	160
13	Gaddiannaram	310	140	310	310	310

Figure 3: Predicted GLCs of PM_{10}

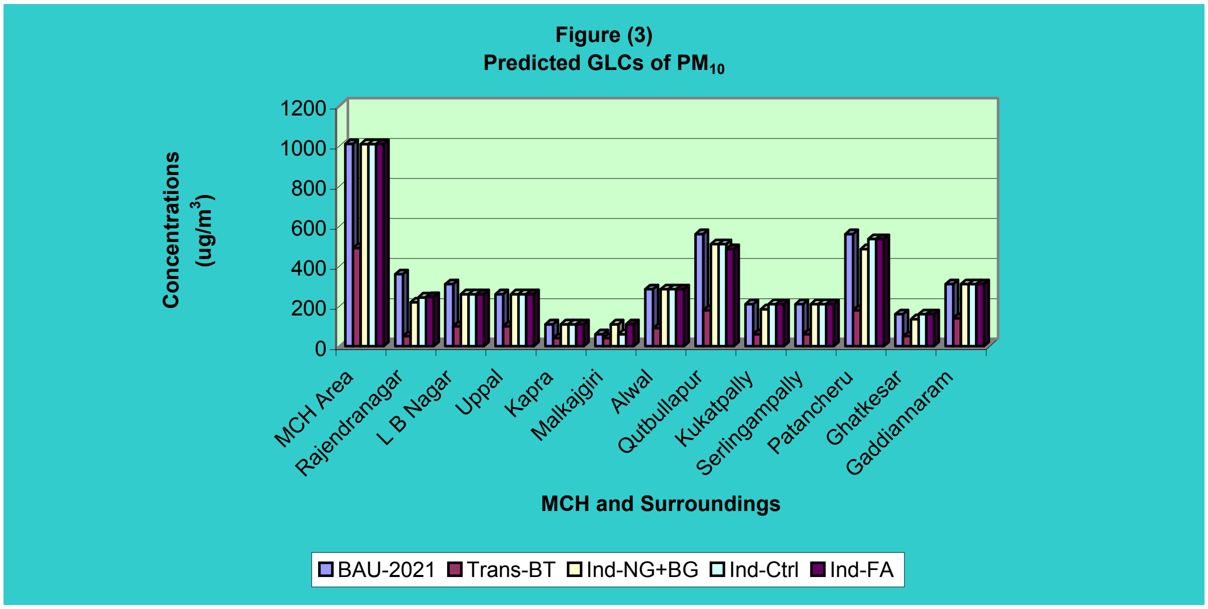
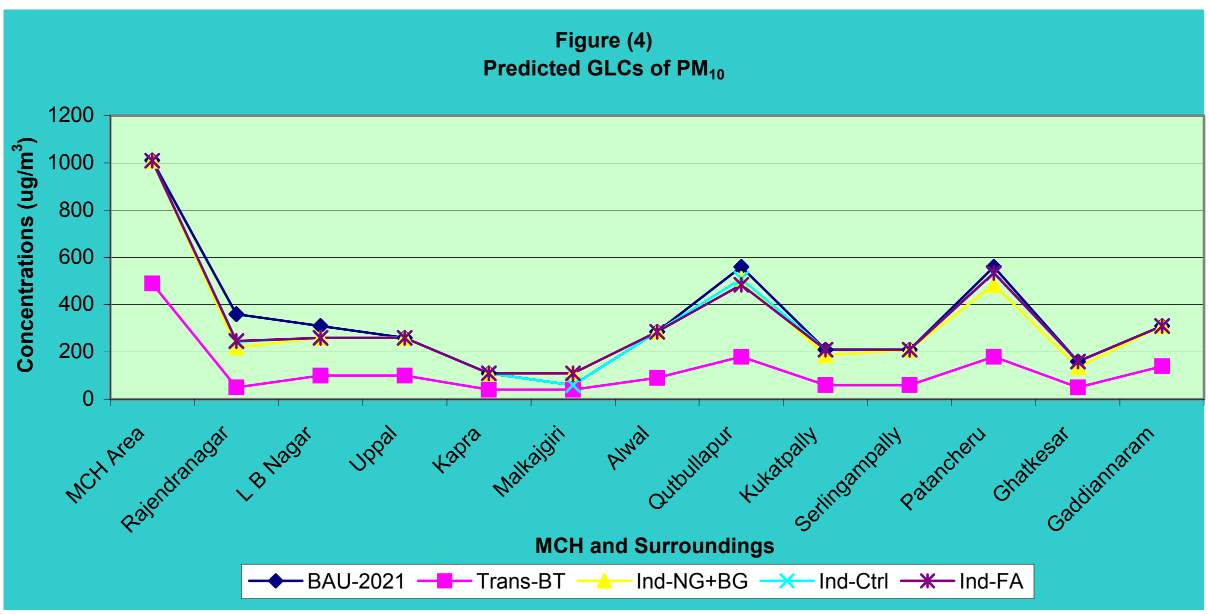


Figure 4: Predicted GLCs of PM_{10}



For BAU-2011, maximum PM_{10} concentrations occur in the MCH area where emissions from transportation sector are maximum. However, with more effective bus transit scenario, about 38% of pollutant concentrations can be reduced. For BAU-2021, with the more effective bus transit scenario, about 51% of pollutant concentrations can be reduced.

For the both BAU scenarios, industrial mitigation scenarios are effective in the neighboring municipal areas such as Rajendranagar, Gaddiannaram, Patancheru, and Qutbullapur. This may be because most of the industries are located in these municipal areas.

3.5 LIMITATIONS AND ASSUMPTIONS OF THE IES AIR QUALITY MODELING (AQM) STUDY

The following assumptions were made during preparation of the AQM study:

1. The AQM exercise has been carried out based on point source emissions and line source emissions from industrial and transportation sectors. Emissions from domestic (household fuel combustion) activities were not included in the present study as the most of urban population uses LPG as their cooking fuel. Emissions from commercial activities and unpaved roads were also not considered in this iteration of the IES study.

2. Micro-meteorological information was collected from Indian Meteorological Department (IMD), which is a Government of India (GoI) Department, and provides information on region-wise weather conditions in the country. It should be noted that hourly

observations are not available, as IMD generates only three hourly wind speed observations. Based on the information available with IMD, Compiled Daily values of the micro-met parameters were considered for the study. While compiling the data, the following approach was used:

- ❖ Daily Wind speed - average of three hourly observations.
- ❖ Daily Wind direction- based on monthly wind rose diagrams.
- ❖ Daily Ambient temperatures- average of daily maximum and minimum values.

3. Industries which have greater than or equal to10 tons per year (tpy) PM_{10} emissions have been considered and modeled as point sources.
4. Industries which have less than 10 tpy PM_{10} load have been considered and modeled as area sources.
5. All area sources are located at the center of the region (except for line sources).
6. For transportation emissions modeling, emissions from nine major corridors were considered as line sources in the study. It is estimated that 1.69 tons per day (tpd) of PM_{10} is being emitted from transportation sources for the selected nine corridors, but the total load from transportation sources in the HUDA area is 5 tpd. It is assumed that 60% of the remaining load, 2.31 tpd (not included in the line sources), is emanating from Municipal Corporation of Hyderabad (MCH) area, since the vast majority of traffic in the study area is in the MCH area.

ANNEX – F

HEALTH EFFECTS ANALYSIS FOR THE IES-INDIA PROJECT

ANNEX – F

HEALTH EFFECTS ANALYSIS FOR THE IES - INDIA PROJECT

1.0 INTRODUCTION

Adverse health effects attributable to air pollution are an important public health problem in Hyderabad, India and throughout much of the world. Air pollutants such as particulate matter have damaging effects on human health. Estimates of the health damages associated with air pollution, namely particulate matter concentrations, are required to assess the size of the problem and to evaluate the impact of specific pollution control measures.

Worldwide, the World Health Organization (WHO) estimates that as many as 1.4 billion urban residents breathe air exceeding the WHO air guidelines[7]. On a global basis, an estimated 800,000 people die prematurely from illnesses caused by air pollution. Approximately 150,000 of these deaths are estimated to occur in South Asia alone[8]. Air pollution has also been associated with a variety of cardiopulmonary illnesses.

2.0 PARTICULATE MATTER AND HEALTH

Particulate matter, or PM, is the term for particles found suspended in the air, including dust, dirt, soot, pollen, smoke, and liquid droplets.

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[7] World Health Organization (1997). Health and Environment in Sustainable Development: Five years After the Earth summit. Geneva: World Health Organization.

[8] A. Cohen, R. Anderson, B. Ostro, K.D. Pandey, M. Kryzanowski, N. Kunzli, K. Gutschmidt, A. Pope, I. Romieu, J. Samet and K. Smith. (2003). Mortality Impacts of Air Pollution in the Urban Environment. In M. Ezzati, A.D. Lopez, A.D. Rodgers and C.J.L. Murray, ed., Comparative Quantification of Health Risks: Global and Regional Burden of Diseases due to Selected Major Risk Factors. Geneva: World Health Organization.

Particulate matter (PM) appears to be associated with adverse health outcomes ranging from acute respiratory symptoms to premature mortality. Particles in the air are classified by aerodynamic diameter and chemical composition. Particulate matter is classified into two basic categories based on the chemical composition and formation, primary and secondary particles. Primary particles are composed of particles that are emitted directly into the atmosphere from sea spray, wind blown soil, road traffic, coal burning, incomplete combustion of transportation fuels, and HCL and ammonium compounds under atmospheric conditions. Airborne particles are referred to as Suspended Particulate Matter (SPM), and the term Total Suspended Particulate (TSP) implies that a gravimetric procedure was used to determine suspended particulate matter. Particulate matter is classified into course, fine and ultra-fine particles based on aerodynamic diameter. PM_{10} and coarse particles are synonymous terms, with an aerodynamic diameter of 10 microns or less. $PM_{2.5}$ are fine particles with a diameter of 2.5 micron, ultra fine particles are those with a diameter of <1.0 micron.

Health effects due to PM_{10} exposure can be immediate and acute (short-term effects) or delayed and chronic (long-term effects). Extensive epidemiological evidence has demonstrated that increase in ambient particulate concentrations are associated with increase in total mortality from respiratory and cardiac diseases, increases in daily respiratory symptoms and decreases in pulmonary functions. Sensitive groups including the elderly, children and individuals with pulmonary and cardiovascular diseases such as asthma and Chronic Obstructive Pulmonary Disease (COPD) are at a higher risk of developing adverse health effects from particulate matter exposure.

In India, millions of people breathe air with high concentration of pollutants. This leads to a greater incidence of associated health effects on the population, manifested in the form of sub-clinical effects, impaired pulmonary functions, increased demand for medications, reduced physical performance, frequent medical consultations, and increased hospital admissions.

3.0 GEOGRAPHIC SCOPE

The health effects analysis for the Integrated Environmental Strategies (IES) Program was carried out in the Hyderabad Urban Development Area (HUDA). The IES health effects study aimed at developing an initial estimation of the health impacts of air pollution in Hyderabad, based on available secondary data and ambient air quality modeling.

4.0 POLLUTANT CONSIDERED

Since PM_{10}, particulate matter <10 microns in diameter, is most strongly associated (and documented) with respiratory morbidity and premature mortality, PM_{10} was identified by the IES team as the criteria pollutant for health effects analysis in Hyderabad. The base year for the health effects analysis, and the entire IES project was Calendar Year (CY) 2001.

5.0 AGE GROUPS CONSIDERED

For the health effects analysis, the following age groups were considered:

- Children: 0 to 17 yrs;
- Adults: 18 to 64 yrs;
- Elder: Greater than 65 yrs.;
- All: All ages (the whole population).

6.0 STATEMENT OF OBJECTIVES

1) Develop an initial estimation of the health impacts of air pollution in Hyderabad and the social costs of air pollution, based on available secondary data.
2) Identify the most relevant health and social welfare impacts.
3) Identify data gaps and research needs for future assessments.

7.0 DATA COLLECTION PROCESS

7.1 POPULATION DATA

Age-wise and sex-wise population data **of the study area** were obtained from the Census of India 2001.

7.2 MORTALITY DATA

Data on all cause and cause specific deaths, from non-external causes, excluding the trauma deaths, age and sex-wise for the year 2001 were obtained from the Directorate of Health / Municipal Health Offices falling under the MCH area and 10 municipalities of Ranga Reddy Districts.

7.3 MORBIDITY DATA

Cause-specific morbidity data for the selected health endpoints were collected from Health Care Institutions (HCI), these institutes were selected using APHIDB (Andhra Pradesh Health Institutions Database) an electronic database maintained by IHS. The selection of hospitals was considered to be representative of the study area. Initial surveys of all major hospitals and health posts within the study area revealed that record keeping, particularly with respect to retrospective data was very poor. Hence, data was collected from available medical records at only 28 hospitals (Table 1) out of a total of 68 hospitals visited in and around HUDA area.

Table 1: List of Hospitals that provided cause-specific morbidity data

Sr. No.	Name of the Hospital	Type of Management	Bed strength
1	Osmania General Hospital	Government	1,168
2	Gandhi General Hospital	Government	1,012
3	Nizam's Institute of Medical Sciences	Government	735
4	A.P. General and Chest Hospital	Government	670
5	Sir Ronald Institute of Tropical & Communicable Disease Hospital	Government	330
6	ESI Hospital	Government	334
7	Niloufer Hospital	Government	300
8	King Koti District Hospital	Government	200
9	Vanasthalipuram Area Hospital	Government	100
10	Nampally Area Hospital	Government	100
11	Malakpet Area Hospital	Government	100
12	Golconda Area Hospital	Government	100
13	Rajendranagar CHC	Government	30
14	Dr. R. Vijay Kumar Clinic	Private	NA
15	Apollo Hospital	Private	350
16	Mediciti Hospital	Private	NA
17	Indo-American Cancer Hospital and Research Centre	Non-profit Registered trust	125
18	APVVP Government Dispensary	Government	NA
19	Balanagar PHC	Government	6
20	Government Unani Dispensary	Government	NA
21	Uppal PHC	Government	NA
22	Gatkesar PHC	Government	NA
23	Ramchandrapuram PHC	Government	NA
24	Kesara PHC	Government	NA
25	Serilingampally PHC	Government	NA
26	Alwal CHC	Government	NA
27	Quthbullapur PHC	Government	NA
28	Malkajgiri GVH	Government	NA
NA: Data not available			

8.0 Health Effects Quantification

The magnitude of health impacts in relation to PM_{10} exposure was calculated using both a health risk assessment approach and percent increase of mortality or morbidity per unit increase of air pollutant concentration.

Since most of the epidemiological studies linking air pollution and health endpoints are based on a relative risk model in the form of Poisson regression, the number of health effects at a given concentration C, is given by the following Equation:

$$\text{Effects (C)} = \exp(\beta \times (C - C_0)) \times R_0 \times Pop$$

In the above Equation, β is the slope of the CR function, C and C_0 are concentrations of the air pollutants in one specific scenario and baseline scenario respectively, R_0 refers to the base rate of effects at concentration C_0, and *Pop* is the exposed population.

8.1 APHEBA Model

The Air Pollution Health Effects Benefits Analysis (APHEBA) Model was selected for the health effect analysis component of the IES - India Project. The APHEBA model is an integrated assessment model designed to evaluate the benefits or costs associated with changes in atmospheric pollutant concentrations in a given location and time period. It allows comparison of a base case and study case for a selected pollutant. This model has been developed by Dr. Luis Cifuentes (IES, Chile Project), and is coded in Analytica software. Analytica is an object oriented health effects modeling language. It incorporates Uncertainty Propagation and Analysis through Montecarlo Simulation. APHEBA makes it possible to manage complex multidimensional objects as simple objects. The APHEBA Model also enables easy visualization of results by scenarios, using different metrics. Progressive refinement of the model is possible by defining interconnecting models.

The following is the summary of data sources and assumptions that were used for the health effects analysis.

Parameter	Time and Geographical Resolution	Observations
Demographic Data		
Population	For 2001, 2011 and 2021 For each municipality	
Health data		
Mortality Rate (All cause, CVD, RSP)	For 2001 only For each municipality	Rates extrapolated for other years
Incidence Rate for Hospital admissions (CVD, RSP, COPD, Asthma) and Outpatient visits	For 2001 only For each municipality	Rates extrapolated for other years
Incidence Rate for morbidity endpoints	USA data only	Rates extrapolated for other years and locations
Average length of stay for hospital admissions (CVD, RSP, COPD, Asthma)	For 2001 only For the whole area	Rates extrapolated for other years and locations
C-R for short-term exposure mortality	HEI meta-analysis from Asian studies	
C-R for long-term exposure mortality	USA data	
C-R for morbidity endpoints	USA data	
Economics data		
VSL	USA data transferred using PCI	
Human Capital Value	Computed for Hyderabad	
Unit values for morbidity endpoints	USA data transferred using PCI	

9.0 ENDPOINTS CONSIDERED

The endpoints considered for the study are as follows:

Endpoint
Mortality (long-term exp) Mortality All Hosp Adm CVD (Cardiovascular Disease) (ICD 390-429) Hosp Adm RSP (Respiratory Ailment) (ICD 460-519) Hosp Adm COPD (Chronic Obstructive Pulmonary Disease) (ICD 490-496)
Hosp Adm Asthma (ICD 493)
Outpatient visits (internal medicine)

10. DEMOGRAPHIC DATA

The population data for the different localities falling under the study area are given in **Table-2**. The population figures for the analysis years of 2011 & 2021 were projected using the population growth rates corresponding to the base year 2001.

Table- 2: Hyderabad localities and their population for the analysis years

MUNICIPALITY	Population		
	2001	2011	2021
HYDERABAD (MCH)	3,655,983	4,196,979	4,818,029
RAJENDRANAGAR	162,114	301,539	560,876
LB NAGAR	286,177	588,814	1,211,495
MALKAJGIRI	192,810	280,818	408,996
ALWAL	110,576	201,422	366,905
QUTHBULLAPUR	229,322	701,785	3,147,645
SERILINGAMPALLY	151,101	445,567	1,313,891
GADDIANARAM	53,622	90,546	152,896
UPPAL KALAN	118,747	210,923	374,651
KAPRA	159,176	359,247	810,791
KUKATPALLY	291,256	506,902	882,375
PATANCHERU	64,189	73,732	84,693
GHATKESAR	19,449	22,340	25,662
TOTAL	5,494,531	7,980,614	14,158,905

Notes: Patancheruvu and Ghatkesar are not municipalities. Patancheruvu is an industrial outgrowth, and Ghatkesar is the rural area selected from HUDA area for health data collection, to be able to extrapolate health effects analysis to the outlying rural areas of HUDA as it is a predominantly urban area.

11.0 HEALTH DATA

The baseline mortality rates for the base year 2001 for the different localities are given in **Table-3**.

Table 3: Baseline mortality rate by municipalities for the year 2001 (cases/100,000)/year)

Mun.Corporation/ Municipality	All	Children	Adult	Elder
HYDERABAD (MCH)	433.78	184.43	430.72	4106.91
RAJENDRANAGAR	133.85	2.92	139.36	2240.48
LB NAGAR	288.63	15.73	315.14	4342.31
MALKAJGIRI	272.29	2.46	256.84	5210.30
ALWAL	260.45	184.43*	233.74	5290.04
QUTHBULLAPUR	175.30	5.17	210.40	2287.52
SERILINGAMPALLY	140.30	10.98	154.30	2029.37
GADDIANARAM	201.40	13.26	681.67	3386.00
UPPAL KALAN	176.85	184.43 *	319.63	3160.04
KAPRA	159.57	1.49	172.59	2560.20
KUKATPALLY	185.09	15.46	209.78	2521.82
PATANCHERU	433.78*	184.43*	430.72*	4106.90*
GHATKESAR	433.78*	184.43*	430.72*	4106.90*

* Data gaps completed with data from Municipal Corporation of Hyderabad (MCH) Area due to geographical and population similarities.

The baseline incidence rate data for morbidity endpoints for Municipal Corporation of Hyderabad (MCH) area for the year 2001 is given in **Table-4**.

Table 4: MCH incidence rate data for morbidity end points

Endpoint	All	Children	Adult	Elder
Hosp Adm CVD (ICD 390-429)	100.62	3.14	139.75	788.22
Hosp Adm RSP (ICD 460-519)	118.11	89.27	136.52	194.47
Hosp Adm COPD	47.84	1.43	57.28	546.17
Hosp Adm Asthma (ICD 493)	33.15	19.25	40.01	107.58
Outpatient visits (internal medicine)	2996.5	3990.4	2250.8	2422.6

The average length of stay for different morbidity endpoints, were computed based on the date of admission and date of discharge recorded in the case sheets of public hospitals of HUDA area. The same is shown in **Table-5**.

Table 5: Average Length of Hospital Stay for Hospital Admissions Endpoints (days per event)

Age Group	Asthma	CVD	RSP	COPD
0-17	5.33	8.07	8.24	11.42
17-64	7.27	8.24	8.92	10.41
64+	6.66	9.34	9.02	8.79
All Ages	6.76	8.43	8.80	10.29
Source: Health records of public hospitals in HUDA area				

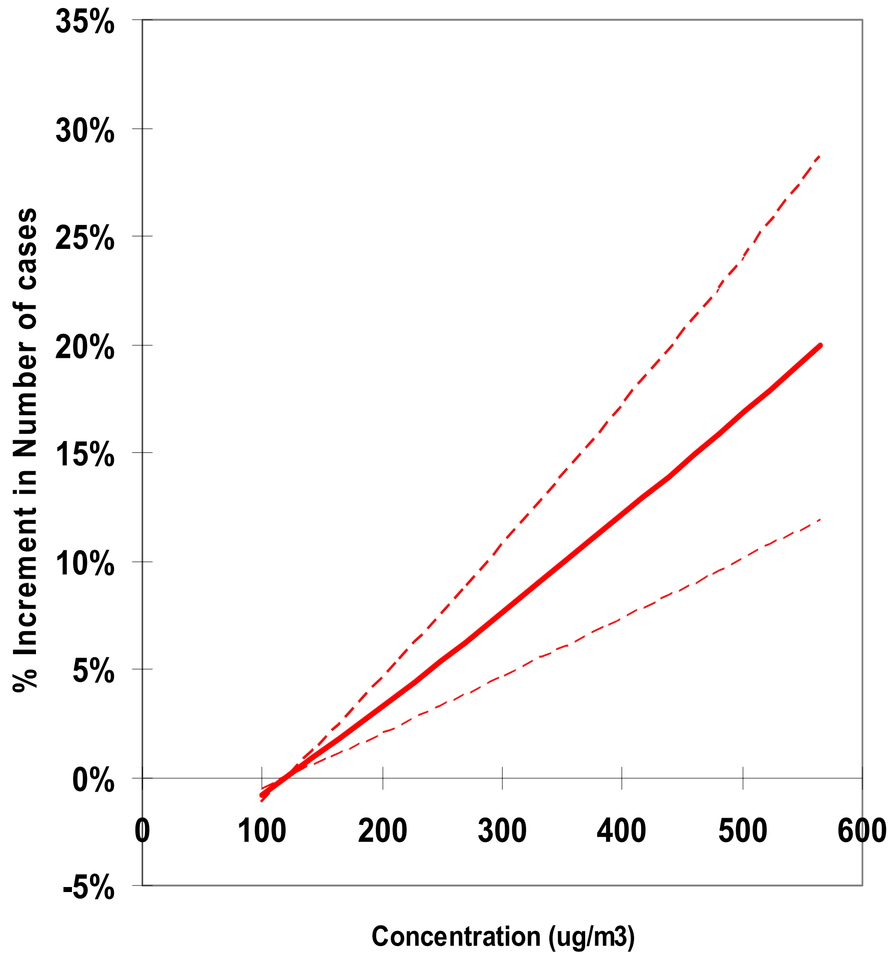
12.0 CONCENTRATION-RESPONSE FUNCTIONS

Concentration-Response (C-R) functions are one of the most critical areas. Unfortunately, there are few studies conducted in India. However, a recent meta-analysis has been conducted on Asian studies[9]. The results of the meta-analysis give a beta of 0.0004 and a Std. Dev. of 0.00008 for all cause mortality. These were used in the IES health effects analysis.

The following figure shows the C-R function in the relevant range of concentrations observed in the municipalities. We have assumed a base concentration of 121 $\mu g/m^3$, the population weighted mean of all localities.

[9] HEI International Scientific Oversight Committee (2004). Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Boston, MA, Health Effects Institute. Available at http://www.healtheffects.org/Pubs/SpecialReport15.pdf

Figure 1: C-R function for All-cause mortality (mid value and 95% CI)



Note: Lower and upper dotted lines in the above graph represent low and high values, and solid line represents mid value respectively of the CR coefficient for all-cause mortality.

For the other endpoints, C-R functions were used with the following relative risks:

Table 6: Estimated % increase in effects per 10 μg/m3 of PM_{10} for different endpoints

Endpoint	All	Children	Adult	Elder
Mortality (long-term exp)	3.40%	-	-	-
Mortality All	0.40%	4.00%	-	-
Hosp Adm CVD (ICD 390-429)	2.30%	-	-	1.20%
Hosp Adm RSP (ICD 460-519)	0.02%	-	-	1.70%
Hosp Adm COPD (ICD 490-496)	-	-	-	2.6%

13.0 LONG-TERM EFFECTS OF PARTICULATE MATTER

Long term effects of Particulate Matter pollution are more difficult to consider. The risk coefficient for long-term mortality is much higher (see above Table-6, the coefficient is 8 times more) than that for short-term effects. That means that at higher concentrations, the risk is bigger. Also, there are problems with extrapolation outside the range of the original studies, which is about 10-30 $\mu g/m^3$ of $PM_{2.5}$. To apply the $PM_{2.5}$ coefficients to PM_{10} concentrations, the criteria pollutant in the current IES study, a ratio of $PM_{2.5}$ to PM_{10} of 0.60 was assumed[10,11].

Since there are no Asian studies at higher concentrations (all of them have been performed in the US), one should make some assumptions

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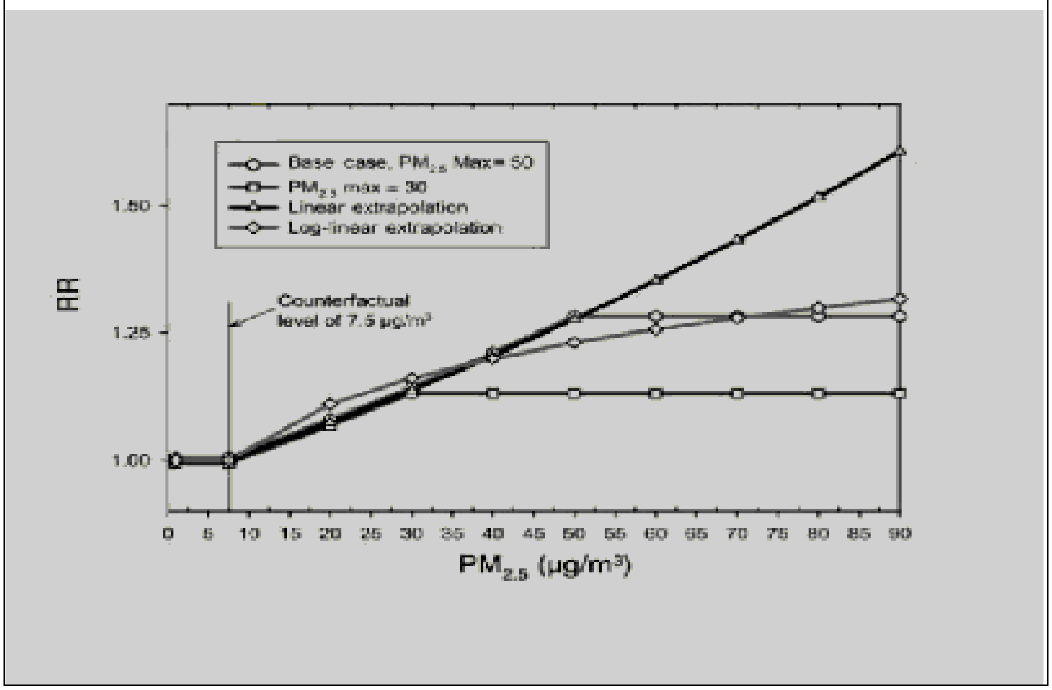
[4] Jorquera. H (2002). Air Quality at Santiago, Chile: A Box Modeling Approach II. $PM_{2.5}$ and PM_{10} Particulate Matter Fractions. Atmospheric Environment (**36)** 331-334.

[5] H. Bogo, M. Otero, P. Castro, M. Ozafrán, A.J. Kreiner, E.J. Calvo y R. Martín Negri (2003). Study of Particulate Matter in the Atmosphere of Buenos Aires City. Atmospheric Environment (**37)** 1135-1147.

about the shape of the C-R function outside the range of the original study. The next figure shows some of such assumptions, proposed by the group that performed the Global Burden of Disease calculation for the WHO.

Figure 2: Alternative concentration-response curves for mortality from cardiopulmonary disease, using different scenarios



Source: Figure 17.7 Cohen, A. J., H. R. Anderson, et al. (2004). Chapter 17: Urban air pollution. Comparative Quantification of Health Risks.

In this analysis we assumed a linear C-R function for long-term mortality. It must be noted that this probably results in an overestimation of the long-term exposure effects. Also, the original studies considered an exposure that lasted 18 or so years. If the pollution levels are growing rapidly, then the annual average will be higher than the moving average for the past years, also resulting in an overestimation of the impacts. Therefore, for the calculation of the impacts of the long-term exposure, we computed the average exposure during the last 20 years. For 2021, this corresponds to the average of 2001, 2011 and 2021 levels. For 2011, this corresponds to the averages of 1991, 2001, and 2011. For 1991 value, we assumed the same value as for 2001.

14.0 MITIGATION SCENARIOS

The health effects analysis was conducted for Business as Usual (BAU) years: 2001, 2011, 2021 and four identified alternative mitigation scenarios (refer to Annexes C & D for details of mitigation scenarios). The scenarios considered are as follows:

Scenario		**Definition**
Base	Base Case	BAU for years 2001, 2011, 2021
C1	Control 1	Alternative – Transport – Bus Transit Mitigation Scenario
C2	Control 2	Combined Industrial (NG+BG) Mitigation Scenario
C3	Control 3	Industrial (Fuel Additives) Mitigation Scenario
C4	Control 4	Industrial Control Mitigation Scenario

15.0 POLLUTANT CONCENTRATIONS

The PM_{10} concentrations municipality–wise and for the baseline and alternative scenarios are given in **Table-7**.

Table- 7: Concentrations for each scenario (μg/m3)

Locality	Base			C1 Alternative - Transport - Bus Transit Mitigation Scenario		C2 Combined Industrial (NG+BG) Mitigation Scenario		C3 Industrial (Fuel Additives) Mitigation Scenario		C4 Industrial Control Mitigation Scenario	
	2001	2011	2021	2011	2021	2011	2021	2011	2021	2011	2021
HYDERABAD (MCH)	160	420	1010	260	490	420	1009	420	1009	420	1009
RAJENDRANAGAR	30	120	360	50	50	119	219	99	246	109	244
LB NAGAR	70	130	310	70	100	120	260	130	260	120	260
MALKAJGIRI	20	50	60	30	40	40	110	50	110	40	60
ALWAL	60	140	285	70	90	130	285	120	285	130	285
QUTHBULLAPUR	80	220	560	110	180	210	510	210	485	210	510
SERILINGAMPALLY	30	70	210	40	60	70	210	70	210	80	210
GADDIANARAM	70	230	310	100	140	170	310	170	310	180	310
UPPAL KALAN	40	110	260	60	100	100	260	110	260	110	260
KAPRA	20	70	110	30	40	40	110	50	110	40	110
KUKATPALLY	30	70	210	40	60	70	185	70	210	70	210
PATANCHERU	90	190	560	100	180	140	485	190	535	190	535
GHATKESAR	30	50	160	40	50	40	135	40	160	40	160

Table–8 below presents population weighted average concentrations that were computed to have a sense of the changes in PM_{10} concentration:

Table-8: Population Weighted average Concentrations for each scenario (μg/m3)

Case	**2001**	**2011**	**2021**
Base	121	279	571
C1-Alternative – Transport – Bus Transit Mitigation Scenario	-	166	238
C2-Combined Industrial (NG+BG)	-	274	549
C3-Industrial (Fuel Additives)	-	275	546
C4-Industrial Control	-	275	550

16.0 RESULTS

16.1 CHANGE IN AMBIENT CONCENTRATIONS

Table-9 below shows the reductions in annual average PM_{10} concentrations for each scenario.

Table- 9: Concentration reductions for control scenarios with respect to base scenario (μg/m3)

Locality	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
HYDERABAD (MCH)	160	0		0	520	1	1	1
RAJENDRANAGAR	70	1	21	11	310	141	114	116
LB NAGAR	60	10	0	10	210	50	50	50
MALKAJGIRI	20	10	0	10	20	-50	-50	0
ALWAL	70	10	20	10	195	0	0	0
QUTHBULLAPUR	110	10	10	10	380	50	75	50
SERILINGAMPALLY	30	0	0	-10	150	0	0	0
GADDIANARAM	130	60	60	50	170	0	0	0
UPPAL KALAN	50	10		0	160	0	0	0
KAPRA	40	30	20	30	70	0	0	0
KUKATPALLY	30	0	0	0	150	25	0	0
PATANCHERU	90	50	0	0	380	75	25	25
GHATKESAR	10	10	10	10	110	25	0	0

16.2 CHANGE IN HEALTH EFFECTS

The change in health effects is computed using the formula based on the Poisson CR functions. The excess cases in each scenario with respect to base case scenario are computed based on the change of population exposure levels to PM_{10} under each scenario, CR functions, and baseline rates for the health outcomes. The baseline for 2001 corresponds to the population multiplied by the mortality rate. For the years 2011 and 2021, the mortality rate was increased corresponding to the increase in air pollution levels.

The baseline number of deaths (cases per year) municipality-wise is shown in **Table-10**.

Table-10: Baseline number of deaths by municipality (cases per year)

Municipality	2001	2011	2021
HYDERABAD (MCH)	15,859	20,254	29,614
RAJENDRANAGAR	217	418	859
LB NAGAR	826	1,741	3,858
MALKAJGIRI	525	774	1,132
ALWAL	288	542	1048
QUTHBULLAPUR	402	1303	6,718
SERILINGAMPALLY	212	625	1,985
GADDIANARAM	108	138	160
UPPAL KALAN	210	384	725
KAPRA	254	585	1,342
KUKATPALLY	539	954	1,758
PATANCHERU	521	333	445
GHATKESAR	158	98	117
TOTAL	20,119	26,130	39,083

The total number of mortality / morbidity cases for all localities for the base and projection years is summarized in **Table-11**.

Table 11: Baseline number of mortality & morbidity cases (Total for all localities, cases per year)

End point	All Population			Elder		
	2001	**2011**	**2021**	**2001**	**2011**	**2021**
Mortality	19,702	28,035	49,625	6,006	8,107	12,052
Hosp Adm CVD (ICD 390-429)	6,500	8,676	13,007	1,324	1,742	2,513
Hosp Adm RSP (ICD 460-519)	5,188	6,691	9,957	670	973	1,518
Hosp Adm COPD (ICD 490-496)	2,128	2,745	4,072	134	170	229

The number of cases of short-term mortality avoided in the projection years of 2011 and 2021 municipality-wise and scenario-wise is presented in **Table-12**.

Table–12: Change in short-term mortality by municipality (cases avoided in each year)

Locality	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
Hyderabad (MCH)	1,286	0	0	0	5,686	12	12	12
Rajendranagar	12	0	4	2	103	48	39	40
LB Nagar	42	7	0	7	318	78	78	78
Malkajgiri	6	3	0	3	9	23	23	0
Alwal	15	2	4	2	81	0	0	0
Quthbullapur	57	5	5	5	969	136	203	136
Serilingampally	8	0	0	3	118	0	0	0
Gaddiannaram	1	0	0	0	2	0	0	0
Uppal Kalan	8	2	0	0	46	0	0	0
Kapra	10	7	5	7	38	0	0	0
Kukatpally	12	0	0	0	105	18	0	0
Patancheruvu	12	7	0	0	64	13	5	5
Ghatkesar	1	1	1	1	5	1	0	0
Total	1,470	34	20	30	7,544	329	360	271

The avoided cases of mortality and morbidity by scenarios and projection years are presented in **Table-13**.

Table–13: Change in health effects by scenarios - Total for All localities (cases avoided per year)

(a) All Population								
End point	**2011**				**2021**			
	C1	**C2**	**C2**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure)	3699	90	49	65	21552	847	845	780
Mortality (short -term exposure)	1469	34	19	25	7544	284	314	271
Hosp Adm CVD (ICD 390-429)	2320	304	196	173	17401	821	683	582
Hosp Adm RSP (ICD 460-519)	56	13	9	8	181	20	14	16
Hosp Adm COPD (ICD 490-496)	0	0	0	0	0	0	0	0

(b) Elder Population								
End point	**2011**				**2021**			
	C1	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure	771	28	17	20	4052	179	161	163
Mortality (short -term exposure	0	0	0	0	0	0	0	0
Hosp Adm CVD (ICD 390-429)	301	27	14	13	1922	90	77	68
Hosp Adm RSP (ICD 460-519)	278	43	39	28	2553	471	360	357
Hosp Adm COPD (ICD 490-496)	70	15	7	6	667	46	24	22

Table-13 shows the heath benefits in different scenarios in Hyderabad in the years 2011 and 2021. It is clear from the results that **C1** Scenario (i.e., Alternative-Transport-Bus Transit-Mitigation Scenario) could have significant impact on the health status for Hyderabad residents in the future. Implementation of Alternative-Transport-Bus Transit-Mitigation Scenarios in Hyderabad would prevent **3,699** and **21,552** long-term mortality, and **1,469** and **7,544** short-term mortality deaths in 2011 and 2021 respectively.

With regards to the morbidity endpoints, **2,320** and **17,401** cardiovascular hospital admission would be avoided in 2011 and 2021 respectively. In elderly population, **4,052** long-term mortality, **1,922** CVD and **2,553** RSP hospital admissions will be avoided in 2021. The most significant reductions in PM_{10} concentrations were also observed in this scenario. Transportation sector is the largest contributor to air emissions (approx. 70% of the total load) in Hyderabad (MCH area). The effective bus transit mitigation measures resulted in 1/3rd reduction of PM_{10} concentrations compared to BAU levels.

17.0 BENEFITS CALCULATIONS

Valuation of health effects is a crucial component in assessing the social costs of air pollution, since it allows the performance of cost-benefit analysis of pollution control measures and provides a basis for setting priorities for actions. In order to perform the economic valuation of health effects of air pollution, we need to know first the unit cost of valuation to translate health impacts into economic values. Benefits were computed using values derived from local data and values transferred from the USA.

17.1 HUMAN CAPITAL APPROACH (HCA)

Human Capital Approach (HCA) was followed for mortality valuation. Premature deaths were valued using the value of a statistical life (VSL), which is estimated as the discounted value of expected future income at the average age. The VSL was computed using a life expectancy at birth of 62.5 years, and an average age of the population of 27.5 years. The average annual wage considered was US$357.55 using an annual discount rate of 5%.The VSL for Hyderabad was estimated at US$ 6, 212.

17.2 WILLINGNESS TO PAY (WTP)

There are no Indian studies of WTP to reduce risks of death. Therefore, the US values were transferred to India. The current value used in the US is 5.5M US$. The annual per capita income for USA is US$ 35,060. For India the per capita income (PCI) is US$ 480, while expressed in purchase power parity (PPP) it is $2570[12]. For PCI however, we used the value computed for India, that is $357. The following table shows the VSL values (US $ per case) transferred from USA to India for the present analysis.

Income Type	USA	India	Eta = 0	Eta = 0.4	Eta = 1.0
PPP	35,060	2,570	5,500,000	1,933,798	403,166
PCI	35,060	357	5,500,000	878,562	56,090

Eta = Income Elasticity

Note: The unit values were not increased for projection years, assuming a growth in the per capita income, which is a limitation of the analysis

17.3 COST OF ILLNESS (COI)

The Cost of Illness (COI) Approach was used for valuing morbidity. The cost of illnesses includes both direct (medical) and indirect (lost work days) costs. The medical costs were estimated based on local information on costs of hospital visits, and treatment, after taking expert opinion of General Practitioners, Consultant Pulmonologists and Consultant Cardiologists.

[12] World Development Report, 2002. Building Institutions for Markets. The World Bank. Washington, D.C. www.worldbank.org

The Unit values for morbidity endpoints derived locally for Hyderabad for the base year 2001(US$ per case) is given below:

Endpoint	Age Group	Type of value	
		Medical Costs	**Lost Productivity**
Hosp Adm COPD	All	122.23	14.30
Hosp Adm CVD (ICD 390-429)	All	119.22	11.44
Hosp Adm RSP (ICD 460-519)	All	74.76	12.87
Hosp Adm Asthma (ICD 493)	All	87.31	10.01
OP Visits IM	All	8.26	1.43

18.0 BENEFITS ESTIMATION

The following table presents the total benefits by endpoint in Millions of US$ per year, for two transfer scenarios: using PPP and Eta=0.4, and using PCI and Eta = 1.0. These two scenarios are the upper and lower bound values of benefits. The values shown are the total values, i.e. COI and WTP.

Total Benefits by Endpoint, COI plus WTP (Millions of US$ per year)								
(a) PCI and 1.0								
End point	**2011**				**2021**			
	C1	**C2**	**C2**	**C4**	**C1**	**C2**	C3	**C4**
Mortality (Long–term exposure)	207.46	5.02	2.77	3.66	1,208.9	47.53	47.40	43.73
Mortality (short –term exposure)	82.41	1.92	1.06	1.407	423.15	15.94	17.62	15.21
Hosp Adm CVD (ICD 390-429)	0.303	0.04	0.026	0.023	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.042	0.006	0.006	0.004	0.378	0.079	0.062	0.061
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.001	0.0009	0.0911	0.0063	0.0033	0.003

(b) PPP and 0.4								
End point	**2011**				**2021**			
	C1	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
Mortality (Long-term exposure	7,152.3	173.1	95.5	126.2	41,678	1,639	1,634	1,508
Mortality (short –term exposure	2,841.0	66.2	36.4	48.2	14,589	550	608	524
Hosp Adm CVD (ICD 390-429)	0.3032	0.0397	0.0256	0.0230	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.0420	0.006	0.0061	0.0044	0.3776	0.079	0.0619	0.0613
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.0010	0.0009	0.0911	0.0063	0.0033	0.0030

19.0 SUMMARY OF HEALTH EFFECTS ANALYSIS RESULTS

The estimated annual health benefits in terms of deaths (long-term mortality) avoided from effective bus transit mitigation measures (C1 Scenario), ranges from 207 million US$ in 2011 to 1,209 million US$ in 2021. The economic benefits of the cardiovascular and other respiratory diseases avoided from the effective bus transit mitigation (C1 Scenario) ranges from 0.0096 million US$ in 2011 to 2.27 million US$ in 2021. The transportation sector was recognized as an area where significant air quality and health benefits could be realized through implementing recommendations from the IES, India Analysis.

ANNEX – G

COST-BENEFIT ANALYSIS FOR IES-INDIA PROJECT

ANNEX G

COST- BENEFIT ANALYSES FOR IES – INDIA PROJECT

1.0 INTRODUCTION

For the IES-India program, alternative transportation and industrial scenarios have been proposed for reduction of particulate matter less than 10 microns in diameter (PM_{10}) and green- house gas (GHG) emissions in the Hyderabad Urban Development Authority (HUDA) Area. Calendar Year (CY) 2001 is considered as the base year, and expected reductions in PM_{10} from the business-as-usual (BAU) scenario, the relative emissions profiles, and the associated health benefits have been considered for the years 2011 and 2021. When preparing the Cost-Benefit Analyses (CBA), one transportation mitigation scenario and three industrial mitigation scenarios were considered (see Annex C & D for additional details on the mitigation scenarios). They are as follows:

1. On the basis of analyses of problems plaguing the bus system, a bus transit scenario has been proposed, which will result in significantly lower emissions.

2. Use of natural gas as primary fuel for some industries currently using coal-fired boilers, and the use of bio-gas as primary fuel for some industries currently using fuel oil (FO) to run their boilers.

3. Use of additives to improve combustion efficiency for heavy fuel oils (furnace oil) in fuel oil fired boilers.

4. Particulate controls to be made mandatory for all existing uncontrolled, solid-fuel (coal, wood and agricultural waste) fired boilers.

It should be noted that all costs and benefits are estimated in CY 2001 prices. These scenarios and their respective analyses are explained in more detail in the following sections.

2.0 C1 ALTERNATIVE: TRANSPORT – BUS TRANSIT MITIGATION SCENARIO

On the basis of analyses of problems plaguing the bus system, an alternative bus transit scenario has been considered to achieve a more effective bus service by making bus system faster and by the rationalization of bus routes, which will result in lower emissions.

There are several road corridors in the HUDA area, where a large number of public buses ply. It is expected that making bus travel faster on these corridors, will induce/shift passengers from other less public modes of transport to that of bus travel. Some of the measures that are proposed to improve the bus system include the creation of exclusive bus lanes/ways on major corridors, provision of adequate and well designed bus stops, assigning priority for buses at traffic signals, and improving road surface on trunk routes (refer to Annex C for details of transportation study).

2.1 NET-COSTS

The IES- India team at RITES has estimated the cost of constructing a more effective bus transit system in their analysis of Hyderabad's transportation sector. The summary of the calculation is as follows:

SI No	Item	Units	Quantity	Unit Rate (Rs)	Amount (Rs) (in millions)
1	Bus Lane markings	Sq.m	190,000	550	104.500
2	Construction of Bus bays	Each	1,500	300,000	450.000
3	Traffic Signs	Each	3,000	3,000	9.000
4	Overhead Signs	Each	190	180,000	34.200
5	Pavement Markings	Km	1,900	15,000	28.500
				Total	626.200

Contingencies @ 5%	Rs	31.31 million
Project Management Consultancy (PMC) @ 10%	Rs	62.62 million
Supervision Cost @ 5%	Rs	31.31 million
GRAND TOTAL (2003 Prices)	*Rs*	751.44 million
		(Approx. Rs 751 million)
GRAND TOTAL (2001 Prices)[13]	*Rs*	***698 million***
GRAND TOTAL OF COSTS in million US $[14]	*US $*	***15 million***

[1] Figure rounded-off. Source of Implicit GDP Deflators used: The World Bank

[2] Figure rounded-off. Conversion Rate used: 1 US $ = 47.1 INR, mid- 2001 rate. Source: The Reserve Bank of India.

2.2 BENEFITS

A. Health Benefits: (Corresponding to a reduction of 1,555 tons PM_{10} from BAU for CY 2011 and 6,555 tons PM_{10} from BAU for CY 2020 over the entire study area.)

((Note: Purchasing Power Parity (PPP) with elasticity (eta) of 0.4 and Per Capita Income (PCI) with eta. 1.0 give upper and lower bounds on health benefits, respectively; please refer to IES Health Benefits Studies Report, Annex F, for further details)).

I. Mid-value of the benefits for C1 Scenario (Bus Transit), considering Short-term exposure mortality (millions of US$ per year).

Year 2011		
Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	9.48	9.48
High	91.89	2,850.50
Year 2021		
Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	49.61	49.61
High	472.75	14,638

II. Mid-value of the benefits for C1 Scenario, considering long-term exposure mortality
(millions of US $ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	23.33	23.33
High	230.79	7,175.67

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	136.63	136.63
High	1,345.50	41,814

B. GHG Reduction[15] (GHG reduction benefits are based on market value of $5/ton eCO_2. It should be noted that this is not the cost of actual climate change benefit, but only the value assigned to a ton of equivalent carbon reduction for trading purposes).

2011: 431,667 tons eCO2/yr of approximate value **US $ 2.16 million** = **Rs. 101.74 million**

2021: 2,167,640 tons eCO2/yr of approximate value **US $ 10.84 million** = **Rs. 510.56 million**

[3] Value of eCO2 taken as $5 per ton. Source: eCO2.com

Total Benefits

Total Benefits = (A) Health Benefits (from air pollution reduction) + (B) GHG Reductions

2011

Lower Bound: A (I) Lowest[16] + B = **<u>US $ 11.64 million</u>** = **<u>Rs. 548.24 million</u>**

Upper Bound: A (II) Highest[17] + B = **<u>US $ 7,177.83 million</u>** = **<u>Rs. 338,075.79 million</u>**

2021

Lower Bound: A (I) Lowest + B = **<u>US $ 60.45 million</u>** = **<u>Rs. 2,847.20 million</u>**

Upper Bound: A (II) Highest + B = **<u>US $ 41,824.84 million</u>** = **<u>Rs. 1,969,949.96 million</u>**

3.0 C2 ALTERNATIVE: COMBINED INDUSTRIAL MITIGATION SCENARIO (NATURAL GAS & BIO GAS)

Natural gas is emerging as the preferred fuel of the future in view of it being environmentally friendly and economically attractive to industry. The Government of India (GoI) has developed a policy framework

[4] 'A (I) Lowest' implies the 'Low' value of Health Benefits using PCI and Eta=1.0, while considering mortality due to short-term exposure (Table I)

[5] 'A (II) Highest' implies the 'High' value of Health Benefits using PPP and Eta=0.4, while considering mortality due to long-term exposure (Table II)

(Hydrocarbon Vision- 2025), which guides policies relating to the hydrocarbon sector for the next 25 years.

The percentage of natural gas as a share of total energy supply in India by 2010-11 is estimated to be about 14%-15% and by 2020-2021, approximately 18%-20% (ref: Hydrocarbon Vision-2025). For the IES-India study, it is assumed that industry in the study area will switch to natural gas in similar percentages, i.e., 15% and 20% of industrial fuel use will be natural gas by 2011 and 2021, respectively. Since 15-20% replacement of total fuel by natural gas will involve a fuel switch of a relatively small number of boilers (out of the total number of boilers in the study area; refer to Net Costs section below), for purposes of this study, it is assumed that, initially, an appropriate number of only coal-fired boilers will be replaced by natural gas. Therefore, it has been assumed that the coal will be replaced by an equivalent amount of natural gas (in terms of kilocalories). (Refer to Annex D for details of this mitigation scenario).

India has an abundance of sunlight, water and bio-mass and is today at the forefront in harnessing renewable energy resources and has one of the largest/broad based programs in non-conventional energy. For purposes of the IES- India study, it is conservatively assumed that 5% of industrial energy (fuel use) in the study area will be from renewable energy sources by 2011, and 10% by 2021. Biogas has been chosen for this study because it is the most cost efficient renewable energy source for industry in the study area, and is presently being used by a few industries. Since 5-10% replacement of total fuel by biogas will involve a fuel switch of a relatively small number of boilers (out of the total number of boilers in the study area; refer to Net Costs section below), for purposes of this study, it is assumed that initially, an appropriate number of only fuel oil fired boilers will be replaced by biogas. It has also been assumed that wood from sustainable sources will be the fuel used for biogas generation. For purposes of mitigation calculation, it has been assumed that the fuel oil will be replaced by an equivalent amount of wood (in terms of kilocalories). (Refer to Annex D for details).

Thus, this combined scenario assumes that natural gas replaces coal and biogas replaces fuel oil in the percentages mentioned above. This assumption makes economic sense due to cost advantages inherent in these substitutions.

3.1 Net-Costs

A. Natural Gas

(i) Boiler Conversion Cost[18] :

2011 >76 boilers * Rs. 6.5 lakhs[19] per boiler: Rs. 9,400,000

2021 > 107 boilers * Rs. 6.5 lakhs per boiler: Rs. 69,550,000

(ii) Amount of Natural Gas Used[20]:

2011 > 62725 tons * Rs. 2880/ton = Rs. 180,648,000

2021 > 166223 tons * Rs. 2880/ton = Rs. 478,722,240

(iii) Amount of Coal Replaced[21]:

2011 > 199581 tons * Rs.1050/ton = Rs. 209,560,050

2021 > 528892 tons *Rs. 1050/ton = Rs. 555,336,600

Total Cost of NG Scenario [(i) + (ii) – (iii)]:

2011: Rs.49,400,000 + Rs.180,648,000 – Rs. 209,560,050 = **Rs. 20,487,950**

2021: Rs. 69,550,000 + Rs.478,722,240 – Rs.555,336,600 = **– Rs. 7,064,360**

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6 Boiler Conversion Cost Source: CII, Hyderabad.

7 1 lakh = 100,000. Therefore Rs 6.5 lakhs = Rs 650,000.

8 Price of NG assumed to be the same as along the existing Hazira-Bijapur-Jagdishpur (HBJ) pipeline.

9 Average price of E&F grade coal, which is used mostly in HUDA region, is taken as Rs. 890 per ton. Transp. cost approximately Rs 160 per ton. Source: SCCL

(Note: a negative cost implies that the fuel savings gained by switching to natural gas is greater than the costs of boiler conversion from coal-fired to natural gas-fired).

B. Biogas

(i) Investment Required for Biogas units[22]:

2011: 100 liters / hr F.O. boiler units replaced by Biogas units: 27 nos = Rs 175,500,000

75 liters / hr F.O. boiler units replaced by
Biogas units: 24 nos = Rs 132,000,000

50 liters / hr F.O. boiler units replaced by
Biogas units: 8 nos = Rs 28,000,000

Total Rs 335,500,000

2021:

100 liters / hr F.O. boiler units replaced by
Biogas units: 103 nos = Rs 669,500,000

75 liters / hr F.O. boiler units replaced
by Biogas units: 40 nos = Rs 220,000,000

50 liters / hr F.O. boiler units replaced by
Biogas units: 11 nos = Rs 38,500,000

Total: Rs 928,000,000

(ii) Quantity of F.O. Replaced in liters and in monetary value[23]:

2011: 33,750,378 liters FO, of value Rs 421,879,725

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[10] The cost of replacing one 50 liter/hr boiler by a Biogas unit is Rs. 35 lakhs, the cost of replacing one 75 l/hr boiler by a Biogas unit is Rs. 55 lakhs and the cost of replacing one 100 l/hr boiler by a Biogas unit is Rs. 65 lakhs Source: Agni Energy Services (P) Ltd.

[11] At current price of F.O. i.e., Rs 12.5 per liter of F.O.

2021: 97,037,863 liters FO, of value Rs 1,212,973,288

(iii) Maintenance Cost[24]:

2011: Rs 16,875,189

2021: Rs 48,518,932

(iv) Quantity of Wood Used in tons and in monetary value[25]:

2011: 90,801 tons, of value Rs 77,180,850

2021: 246,699 tons, of value Rs 209,694,150

Total Cost of BG Scenario [(i) + (iii) + (iv) - (ii)]: (in Rs.)

2011: 335,500,000 + 16,875,189 + 77,180,850 – 421,879,725 = **Rs. 7,676,314**

2021: 928,000,000 + 48,518,932 + 209,694,150 – 1,212,973,288 = **– Rs. 26,760,206** (Note: a negative cost implies that the fuel savings gained by switching to biogas is greater than costs for converting fuel oil boilers to biogas units).

Grand Total: (**A** + **B**) in Indian Rupees and in US Dollars:

2011: Rs. 28,164,264 (**Rs. 28.16 million**) = US $ 597,967.39 (**US $ 0.60 million)**

2021: -Rs. 33,824,566 (**– Rs. 33.82 million)** = -US $ 718,143.65 (**– US $ 0.72 million)** (Note: a negative cost implies that the fuel savings gained by switching to natural gas and biogas is greater than costs for converting coal and fuel oil-fired boilers to natural gas and biogas units, respectively).

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[12] @50 paise per liter replaced. Source: Agni Energy Services (P) Ltd.

[13] @ Rs 850 per ton of wood. Source: Agni Energy Services (P) Ltd.

3.2 BENEFITS

A. Health Benefits (Corresponding to a reduction of 425.3 tons PM_{10} by CY 2011 and 1,191.4 tons PM_{10} by CY 2020 for the entire study area.)

I. Mid-value of the benefits for C2 Scenario, considering Short-term exposure mortality (millions of US$ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.26	0.26
High	2.18	66.42

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	1.96	1.96
High	17.90	551.54

II. Mid-value of the benefits for C2 Scenario, considering long-term exposure mortality
(millions of US $ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.60	0.60
High	5.63	173.72

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	5.46	5.46
High	52.99	1,644.2

B. GHG Reductions[26]

2011: 97,260 tons eCO2/year + 33,283 tons eCO2/year = 130,543 tons eCO2/year of approximate value **US $ .65 million = Rs. 30.62 million**
2021: 281,062 tons eCO2/year + 88,201 tons eCO2/year = 369,263 tons eCO2/year of approximate value **US $ 1.85 million = Rs. 87. 14 million**

Total Benefits

2011

Lower Bound: A (I) lowest + B = **US $ 0.91 million** = **Rs. 42.86 million**
Upper Bound: A (II) Highest + B = **US $ 174.37 million** = **Rs. 8,212.83 million**

2021

Lower Bound: A (I) Lowest + B = **US $ 3.81 million** = **Rs. 179.45 million**
Upper Bound: A (II) Highest+ B = **US $ 1,646.05 million** = **Rs. 77,528.96 million**

[14] BG Scenario + NG Scenario

4.0 C3 ALTERNATIVE: INDUSTRIAL (FUEL ADDITIVES) MITIGATION SCENARIO

The addition of chemical catalysts/additives to fuel oil has been found to be one of the most effective solutions to improve combustion efficiency while mitigating pollution from fuel oil boilers. Several additives are available and currently being used for improving furnace oil (heavy fuel oil) combustion in oil- fired boilers (eg. Pennar ELF 13S). These additives are usually aromatic solvents readily soluble in fuel oil and which act as catalysts by increasing the speed of oxidation of unburned hydrocarbons during the process of heavy fuel oil combustion. As a consequence, there is a reduction in fuel consumption and also reduction of particulate emissions. (Refer to Annex D for further details).

This measure can be implemented for the study area by 2011.

4.1 NET COSTS

(i) Quantity of Fuel Additive added in liters and in monetary value[27]:
2011: 62,000 liters, of approximate value Rs. 18.60 million
2021: 116,500 liters, of approximate value Rs. 34.95 million
(ii) Quantity of Fuel Oil Saved in liters and in monetary value[28]
2011: 4,960,000 liters FO, of approximate value Rs. 62.00 million
2021: 9,320,000 liters FO, of approximate value Rs. 116.50 million

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[15] 1 liter of Additive required per 2 Kilo Liters of F.O. Price of additive (Pennar ELF 13 S) taken as Rs 300 per liter. Source: Pennar

[16] Assuming 4% savings in Fuel Oil consumption.

Net Costs [(i) – (ii)]:

2011: = **<u>– Rs 43.40 million</u> = <u>– US $ 0.92 million</u>**

2021: = **<u>– Rs 81.55 million</u> = <u>– US $ 1.73 million</u>**

(Note: negative costs imply that the cost savings of reduction in fuel oil used are greater than the fuel additive costs).

4.2 BENEFITS

A. Health Benefits (Corresponding to a reduction of 271.6 tons PM_{10} by CY 2011 and 508.5 tons PM_{10} by CY 2020 for the entire study area.)

I. Mid-value of the benefits for C3 Scenario, considering Short-term exposure mortality (millions of US$ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.15	0.15
High	1.21	36.58

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	2.11	2.11
High	19.73	609.72

II. Mid-value of the benefits for C3 Scenario, considering long-term exposure mortality
(millions of US $ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.34	0.34

High	3.11	95.87
Year 2021		
Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	5.41	5.41
High	52.81	1,639.5

B. GHG Reductions

2011: 18,416 tons eCO2/yr of approximate value **US $ 0.09 million** = **Rs. 4.24 million**

2021: 34,481 tons eCO2/yr of approximate value **US $ 0.17 million** = **Rs. 8.01 million**

Total Benefits

2011

Lower Bound: A (I) Lowest + B = **US $ 0.24 million** = **Rs. 11.30 million**

Upper Bound: A (II) Highest + B = **US $ 95.96 million** = **Rs. 4,519.72 million**

2021

Lower Bound: A (I) Lowest + B = **US $ 2.28 million** = **Rs. 07.39 million**

Upper Bound: A (II) Highest + B = **US $ 1,639.67 million** = **Rs. 77,228.46 million**

5.0 C4 ALTERNATIVE: INDUSTRIAL CONTROL MITIGATION SCENARIO

For this mitigation scenario, particulate controls are assumed to be made mandatory for all uncontrolled solid fuel fired boilers (using coal, wood or agricultural waste as fuel). For existing coal, wood or agricultural waste fired boiler with particulate (PM_{10}) emissions below 10 tons per year (tpy) (primarily boilers with capacity less than 5 tons/hour), cyclone controls will be required. For existing coal, wood or agricultural waste fired boilers with PM_{10} emissions above 10 tpy (primarily boilers with capacity greater than 5 tons/hour), installation of baghouse (fabric) filters will be required. These measures should result in significant decrease of PM_{10} emissions from all uncontrolled coal, wood and agricultural waste fired boilers. (Refer to Annex D for further details).

This measure can be implemented in the study area by 2011.

5.1 NET-COSTS

(i) Investment required for equipment:

a. Cyclones: 117 nos, at an average cost of Rs. 1.25 lakhs each: Rs. 14,625,000
b. Baghouses: 4 nos, at an average cost of Rs.12.00 lakhs each: Rs. 4,800,000

Total investment required (a + b): Rs.19,425,000

(ii) Operational and Maintenance Cost[29]

a. Cyclones: Rs. 731,250

b. Baghouses: Rs. 288,000

Total Operational and Maintenance Cost (a + b): Rs. 1,019,250

TOTAL COSTS: (i) + (ii): (Rs. 20,444,250) = **Rs. 20.44 million or US $ 0.43 million**

5.2 BENEFITS

A. Health Benefits (Corresponding to a reduction of 605.3 tons PM_{10} by CY 2011 and 1,128.2 tons PM_{10} by CY 2020 for the entire study area.)

I. Mid-value of the benefits for C4 Scenario, considering Short-term exposure mortality (millions of US$ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.18	0.18
High	1.58	48.39

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	1.83	1.83
High	17.04	526.29

[17] Annual Operating & Maintenance costs at 5% of installed cost for cyclones and 6% of installed cost for baghouses. Source: US Occupational Safety & Health Administration. Control equipment costs obtained from Thermax Limited (India).

II. Mid-value of the benefits for C4 Scenario, considering long-term exposure mortality
(millions of US $ per year)

Year 2011

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	0.43	0.43
High	4.09	126.63

Year 2021

Estimate	*PCI and 1.0 Eta*	*PPP and 0.4 Eta*
Low	4.98	4.98
High	48.71	1,512.5

B. GHG Reductions

There are no GHG reductions from this scenario because the addition of control equipment reduces only particulate emissions and has no effect on GHGs. There may, in fact, be a slight, but very negligible, increase in GHGs due to the power required to run the control equipment. Since increase in GHGs is negligible, it has not been considered.

Total Benefits

2011

Lower Bound: A (I) Lowest = **US $ 0.18 million** = **Rs. 8.48 million**

Upper Bound: A (II) Highest = **US $ 126.63 million** = **Rs. 5,964.27 million**

2021

Lower Bound: A (I) Lowest = **US $ 1.83 million** =**Rs. 86.19 million**

Upper Bound: A (II) Highest = **US $ 1,512.50 million** = **Rs. 71,238.75 million**

Cost Benefit Analysis results are shown in Table 1 and 2 below.

Note:

1. All figures, both costs and benefits, are at 2001 prices.
2. Benefits are calculated for the said years alone, i.e 2011 and 2021 only, and are not cumulative values till 2011/2021.
3. Calculating the Net Present Values of the Benefits and Costs has not been attempted.

Table 1: Year-wise Estimates (in million Rupees)

Scenarios	2011						
	Net Costs	GHG Reductions Value		Health Benefits Values			
				Short-term Exposure		Long-term Exposure	
				PCI and Eta=1.0	PPP and Eta=0.4	PCI and Eta=1.0	PPP and Eta=0.4
C1	698.00	101.74	Low	446.51	446.51	1,098.84	1,098.84
			High	4,328.02	134,258.55	10,870.21	337,974.06
C2	28.16	30.62	Low	12.25	12.25	28.26	28.26
			High	102.68	3,128.38	265.17	8,182.21
C3	-43.40	4.24	Low	7.07	7.07	16.01	16.01
			High	56.99	1,722.92	146.48	4,515.48
C4	20.44	--	Low	8.48	8.48	20.25	20.25
			High	74.42	2,279.17	192.64	5,964.27

Scenarios	2021						
	Net Costs	GHG Reductions Value		Health Benefits Values			
				Short-term Exposure		Long-term Exposure	
				PCI and Eta=1.0	PPP and Eta=0.4	PCI and Eta=1.0	PPP and Eta=0.4
C1	698.00	510.56	Low	2,336.63	2,336.63	6,435.27	6,435.27
			High	22,266.53	689,449.80	63,373.05	1,969,439.40
C2	- 33.84	87.14	Low	92.32	92.32	257.17	257.17
			High	843.09	25,977.53	2,495.83	77,441.82
C3	-81.55	8.01	Low	99.38	99.38	254.81	254.81
			High	929.28	28,717.81	2,487.35	77,220.45
C4	20.44	--	Low	86.19	86.19	234.56	234.56
			High	802.58	24,788.26	2,294.24	71,238.75

Table 2: Cost Benefits Summary

Scenarios	2011			2021		
	Net Costs (Rs. million)	**Benefits (Rs. million)**		**Net Costs (Rs. million)**	**Benefits (Rs. million)**	
		Lower Bound	**Upper Bound**		**Lower Bound**	**Upper Bound**
C1	698.00	548.24	338,075.79	698.00	2,847.20	1,969,949.96
C2	28.16	42.86	8,212.83	-33.82	179.45	77,528.96
C3	-43.40	11.30	4,519.72	-81.55	107.39	77,228.46
C4	20.44	8.48	5,964.27	20.44	86.19	71,238.75

6.0 SUMMARY AND RECOMMENDATIONS

Among the four alternative scenarios considered, the C1- Alternative Bus Transit system shows the greatest potential for social benefits, in terms of both health benefits and GHG reductions. While the expected cost of implementation would be around Rs. 698 million (US $ 15 million) in 2001 prices, the extent of potential benefits is indicated by the calculated benefit figures (in 2001 prices) for CY 2011 and CY 2021. C1-Alternative Bus Transit System is expected to reduce GHGs worth approximately Rs. 101.74 million (US $ 2.16 million) and Rs. 510.56 million (US $ 10.84 million) in 2011 and 2021 respectively.

Health benefits due to PM_{10} reductions vary depending upon the parameters considered (whether PCI or PPP, whether mortality due to short-term exposure or long-term exposure, whether Eta=1.0 or Eta=0.4, etc), and the calculated values show a range from Rs. 446.51 million (US $ 9.48 million) to Rs. 337,974.06 million (US $ 7,175.67 million) in 2011, and from Rs. 2,336.63 million (US $ 49.61 million) to Rs. 1,969,439.40 million (US $ 41,814 million) in 2021.

Total benefits have been calculated by adding health benefits to the value of GHG reductions. Thus, the total expected benefits from C1 alternative bus transit scenario ranges from a minimum of Rs. 548.24 million (US $ 11.64 million) to a maximum of Rs. 338,075.79 million (US $ 7,177.83 million in 2011, and from Rs. 2,847.20 million (US $ 60.45 million) to Rs. 1,969,949.96 million (US $ 41,824.84 million) in 2021.

C2- Alternative Combined Industrial Mitigation Scenario using Natural Gas and Biogas is expected to result in net negative costs in 2021, implying private economic returns which are higher than the cost of implementation. Negative net-costs implies that it makes economic sense for businesses to invest in these scenarios even if they ignore the social benefits emerging from pollution reduction. Both the natural gas scenario and the biogas scenario show positive net-costs in 2011. But in 2021, both scenarios show negative net-costs. The combined scenario is expected to result in Rs. 33.82 million (US $ 0.72 million) of economic gain to the investors over and above their investment in 2021. This does not include health and GHG benefits. As the above table indicates, expected social benefits, combining health benefits and GHG reductions, from C2 scenario ranges from Rs. 42.86 million (US $ 0.91 million) to Rs. 8,212.83 million (US $ 174.37 million) in 2011 and from Rs. 179.45 million (US $ 3.81 million) to Rs. 77,528.96 million (US $ 1,646.05 million) in 2021.

C3-Alternative Fuel Additive Scenario is expected to have negative net-costs in both 2011 and 2021. The expected total economic gains for businesses, over and above the investment required for the scenario, is Rs. 43.40 million (US $ 0.92 million) and Rs. 81.55 million (US $ 1.73 million) in 2011 and 2021 respectively. Expected social benefits, combining health benefits and GHG reductions from C3 scenario, ranges from Rs. 11.30 million (US $ 0.24 million) to Rs. 4,519.72 million (US $ 95.96 million) in 2011, and from Rs. 107.39 million (US $ 2.28 million) to Rs. 77,228.46 million (US $ 1,639.67 million) in 2021.

C4-Alternative Industrial Control Scenario is expected to cost Rs. 20.44 million (US $ 0.43 million) in 2011. Since no GHG reductions are expected from the scenario, expected social benefits considered are only the health benefits. These range from Rs. 8.48 million (US $ 0.18 million) to Rs. 5,964.27 million (US $ 126.63 million) in 2011, and from Rs. 86.19 million (US $ 1.83 million) to Rs. 71,238.75 million (US $ 1,512.5 million) in 2021.

Therefore, it can be seen from the above analysis, that while all four scenarios show positive health benefits in terms of short term and long term mortality, health benefits are greatest for the bus transit scenario. GHG reduction benefits are also greatest for the bus transit scenario, followed by the combined natural gas and biogas (NG & BG) scenario. The NG & BG scenario (in the long term) and the Fuel Additive scenario show net benefit to industry, even before considering health benefits.

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