Pune Municipal Corporation

Evaluation of Development Plan towards Sustainability for Pune Metropolitan Area

FINAL REPORT

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January 2011

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Pune Municipal Corporation (PMC) has embarked on the preparation of a new Development Plan (DP) for the period 2007 – 2027 by revising the existing DP for 1987 – 2007. This is an ongoing project conducted by the Corporation. PMC would also like to take up the development of a sustainable transport strategy for Pune, based on land use plans for the future and projections of population and economic development as proposed and envisaged in the development plan.

Several studies, relating to traffic and transportation aspects in Pune Metropolitan Area, have been carried out in the recent past by various organisations. These studies covered transport systems like metro, bus rapid transit, tram, non-motorised transport and aspects like mobility, traffic management and road improvement schemes. A comprehensive mobility plan (CMP) was also got prepared by PMC. The CMP suggested several transportation infrastructure and system improvements necessary for the future. Around the same time, IIT Bombay has developed a transportation planning model for the study area covering Pune and Pimpri – Chinhwad Areas for the purpose of forecasting passenger demand on the proposed metro rail lines. This exercise was part of the Detailed Project Plan on metro rail corridors in Pune taken up by Delhi Metro Rail Corporation (DMRC, the consultant) for PMC (the client).

By the DP-revision new land use plans are outlined for the future. It is crucial that all sector plans (relating to transport) studied in connection to the DP-revision are based on the same basic assessments of population and economic growth and on the same land use scenarios. For example, one possible main change of the future land use pattern in the current DP is connected to the recently proposed increase of the Floor Space Index (FSI) along Metro and BRT lines.

The present consultancy work, with a view to evaluate the development scenarios towards sustainable transport strategy for Pune city, has upgraded the transport planning model developed for the metro study based on the enormous data available from previous transport plans and it is fully integrated with the revised development plan. Hence this work includes evaluating the impacts of various development scenarios proposed in the development plan on the Transportation infrastructure. The evaluation is carried out considering the concepts of sustainability. The boundary of a larger area which includes Pune Municipal Corporation Area and Pimpri Chinchwad Municipal Corporation Area, Pune and Khadki Cantonments and other areas within the outer cordon as worked out based on the requirements has been considered as the study area for the development of the transportation planning model.

1.2 PAST TRAFFIC AND TRANSPORTATION STUDIES IN PUNE CITY

To improve the traffic & transportation situation in Pune Metropolitan Region, the planning authorities in PMC and PCMC have carried out several studies from time to time and implemented the recommended measures to a great extent. The major transportation studies carried out for Pune region include:

- Cycle Network Project for Pune, Town Planning Dept., Pune, 1981
- Traffic and Transportation Plan for Pune Metropolitan Area-2001 by Dept. of Town Planning, Maharashtra, 1984
- Traffic and Transportation Flows for Selected Cities in India by CRRI, 1986
- Transport in Pune Metropolitan Region by CIRT, Pune, 1987
- High Capacity Mass Transit System for Pune: Feasibility Study by MTP (Railways), 1988
- Report of the Pune Action Plan, 1991
- Deshmukh Committee Report for Long Term Measures for Pune Agglomeration, 1994
- Report of the Committee appointed by Divisional Commissioner, Pune Division, Pune to recommend "Short Term Measures for Improvement of Traffic in Pune City", 1994
- Pune Traffic 2000 'Parking', 1996
- Project Report: Mega City of Pune, 1997
- Feasibility Report on Construction of Flyovers, Traffic Planning Cell, Pune, 1998
- Mass Rapid Transit System for Pune Metropolitan Area by RITES, 1998
- Sharing of Inter-City Services Operated by PMT & PCMT, CIRT, 2000
- Final Report on "Study on the Working of Pune Municipal Transport", CIRT, 2000
- A Study on Traffic and Economic Analysis of Road Improvement Project in Pune by CIRT, 2001
- Traffic Study for Pune City by AAKAR Enterprises, 2003
- Comprehensive Traffic & Transportation Study for Pune City, Span Travers Morgan, 2003
- Integrated Traffic Dispersal System for PMC & PCMC, CES, 2004
- Pune Sustainable Urban transport Study; CIRT June 2005
- Comprehensive Mobility Plan for Pune, CMP; IL&FS and Wilbur Smith, December 2008

- Forecasting passenger demand on the proposed metro rail lines, IIT Bombay (submitted to DMRC), 2008

The transportation planning model developed for forecasting passenger demand on the proposed metro rail lines by IIT Bombay contains a four stage travel demand model implemented in CUBE software platform. In this study, this transportation planning model has been upgraded and updated utilizing the data available from a few of the abovementioned recent studies like, Comprehensive Mobility Plan by Wilbur Smith Associates and from Pune Metro Study. This updated model will be used for evaluating various transport land use and economic development strategies worked out from CMP plan and revised Development plan. The study by CIRT on sustainable urban transportation in the year 2005 for Pune has thrown some light on the concepts of sustainability.

1.3 OBJECTIVE AND SCOPE

The evaluation of alternative transportation schemes with respect to their impacts for each of the land use and economic development scenarios as envisaged in the development plan will become possible only when there is a sound transportation planning model is available with the planners. Therefore, updating of the transportation planning model and using it for evaluating the alternative transportation scenarios for the envisaged land use development scenarios towards evolving sustainable strategies is the main objective of this study.

Thus, this study deals with the following aspects:

- A comprehensive compilation of relevant transport and traffic data necessary for the development/upgradation of the transportation planning model
- Development of transportation planning model using CUBE transportation planning software package in GIS platform for plan periods same as that for DP with training to concerned PMC officials.
- Setting realistic, accepted and measurable goals and indices for the evaluation of impacts
- Generation of alternative transport scenarios based on existing traffic situations, CMP & envisaged land use scenarios
- Forecasting traffic for the future horizon years.
- Evaluation of functional, social, economic and environmental impact of different scenarios
- Quantification of impacts and comparison and evaluation of alternatives
- Ranking of the measures for prioritizing into an action plan leading towards a sustainable transport system in Pune.

- Compilation of a summary report “Evaluating development scenarios towards sustainability for Pune city”.

The study is being carried out with proper consultation with PMC and all the stakeholders in Pune as identified by PMC.

1.4 ORGANIZATION OF REPORT

This report is an interim report mainly dwelling on the development of travel demand model and its application for evaluating development scenarios. The whole of this report is organised as follows:

- Chapter 1 deals with the general introduction, previous traffic studies and objectives of the study.
- Chapter 2 defines about the traffic data and methodology adopted for the present study.
- Chapter 3 describes the concept of sustainability and associated indices from literature.
- Chapter 4 provides details of study area, plan period and transport network development.
- Chapter 5 describes the data set required for the study.
- Chapter 6 discusses in detail about the planning variables.
- Chapter 7 presents the development of the travel demand model.
- Chapter 8 deals with the application of the model wherein demand of different transportation infrastructure facilities for a specified development scenario has been worked out using the developed model.

CHAPTER 2

METHODOLOGY

2.1 GENERAL

The modelling structure will resemble the traditional four stage transportation planning model with appropriate modifications to suit to the requirements of the study area and sustainability concepts. To address equity issues, population in the study area has been divided into three groups. This is done on the basis of vehicle ownership as Car Owning Group, Two Wheeler owning group and no vehicle group. Separate models were developed for external (trips crossing the cordon) and internal travel. The model is developed using CUBE5 transportation planning software package in GIS platform. The same will be implemented at the client's office on a CUBE software licence purchased by the client.

The methodology involves development of the model and its application for evaluating appropriate land use and transport scenarios suing sustainability concepts. This is explained in the following steps.

1. Generation and Validation of base year OD Matrices
2. Development of Travel Demand Model
3. Model application
4. Sustainability Indices and evaluation of alternatives

2.2 GENERATION OF BASE YEAR OD MATRICES AND TRAVEL PATTERN

This process starts with the Home Interview Survey data as input. The data collected from HIS is checked for bias and the necessary bias correction is applied and expansion factors are computed. Thus the expanded partial OD matrices for all the three groups are obtained. OD surveys conducted at outer cordon are pooled in to get the OD matrices with all trips. The matrices are loaded on to the network and the assigned values are compared with the ground counts to validate the Matrices.

2.3 DEVELOPMENT OF TRAVEL DEMAND MODEL

Planning variables based on old zonal system as per Metro study (91 internal zones) are available. Equivalencies between old and new zonal systems (267 internal zones) are established. Based on old zonal system, increments of population in each zone are found and the aggregated population is apportioned based on the proportions obtained. Employment is distributed by obtaining the equivalencies between old and new zonal systems based on area and density.

Using the planning variables and validated total O-D matrix for base year (2008), trip end models and Gravity model for all 3 groups are calibrated for total internal passenger travel. The revised skims obtained after successive modal split and traffic assignments will be used to calibrate the gravity model.

A Multi-Nomial logit modal split model is devised, to determine the modal share. The model is mainly based on the transport system attributes. The cost skims obtained from the assignment are used to calibrate the mode choice model. The *Public transport matrix* includes the person trips performed by Public Transport (Bus, IPT and Train), while the *Private vehicle matrix* includes person trips by car and two-wheeler.

The peak hour public transport passenger matrix is assigned to the public transport network, which includes a) Bus b) Intermediate Public Transport (IPT) routes on the road network and c) Rail network with all the existing links. The public transport assignment is based on generalized time, which is a combination of In-Vehicle Travel Time (IVTT), Waiting Time (WT), No of Transfers (TR), Fare and Discomfort in time units. The parameters of this generalized time are obtained from Stated Preference Survey. The public transport assignment is done by assigning no vehicle group first on to the network, and then the 2Wheeler owning group on to the network which is preloaded with no vehicle group and finally the Car owning group is assigned. Hence a multi-class user assignment is attempted.

The public transport assignment is also required to assign the trips as per the observed modal shares. In order to achieve this, the parameters of the generalized time were fixed based on the values obtained from the analysis of stated preference surveys. After performing the public transport assignment, the assigned flows across the screen lines are compared with the observed flows.

Highway assignment is carried out for peak hour, preloading the highway network with peak hour public transport and commercial vehicle flows. The daily public transport loadings are factored by the peak hour flow to daily flow ratios to obtain the peak hour public transport flows. These are converted to PCU's by using appropriate passenger-to-PCU conversion factors. These peak-hour public transport (bus and IPT) and commercial vehicle flows in terms of PCU's are preloaded on to the highway network before loading the private vehicle passenger OD matrices.

The private vehicle passenger matrices are converted into peak hour PCU units, by using appropriate regional peak hour ratios and passenger-PCU conversion factors, based on observed occupancies at screen lines. A user equilibrium procedure based on generalized cost (sum of vehicle operating cost and time cost) is used in loading private vehicle matrices.

The public transport network is revised with the speeds obtained after assigning the private trips. The assignment of public transport trips is performed on the revised network, and the next

iteration of private traffic assignment is carried out by taking the bus, taxi, auto and truck flows as preloads. This iterative process between PT and private vehicle traffic assignment is repeated until there is no appreciable change in the link loadings and link costs.

Three skims namely the highway time, highway travel cost and highway distance are obtained from the loaded network. The skims obtained are used for calibrating the gravity model and the modal split-model. The process of distribution, modal split and assignment is repeated till the OD matrices become stable and it is illustrated through the flow diagram in Figure 2.1.

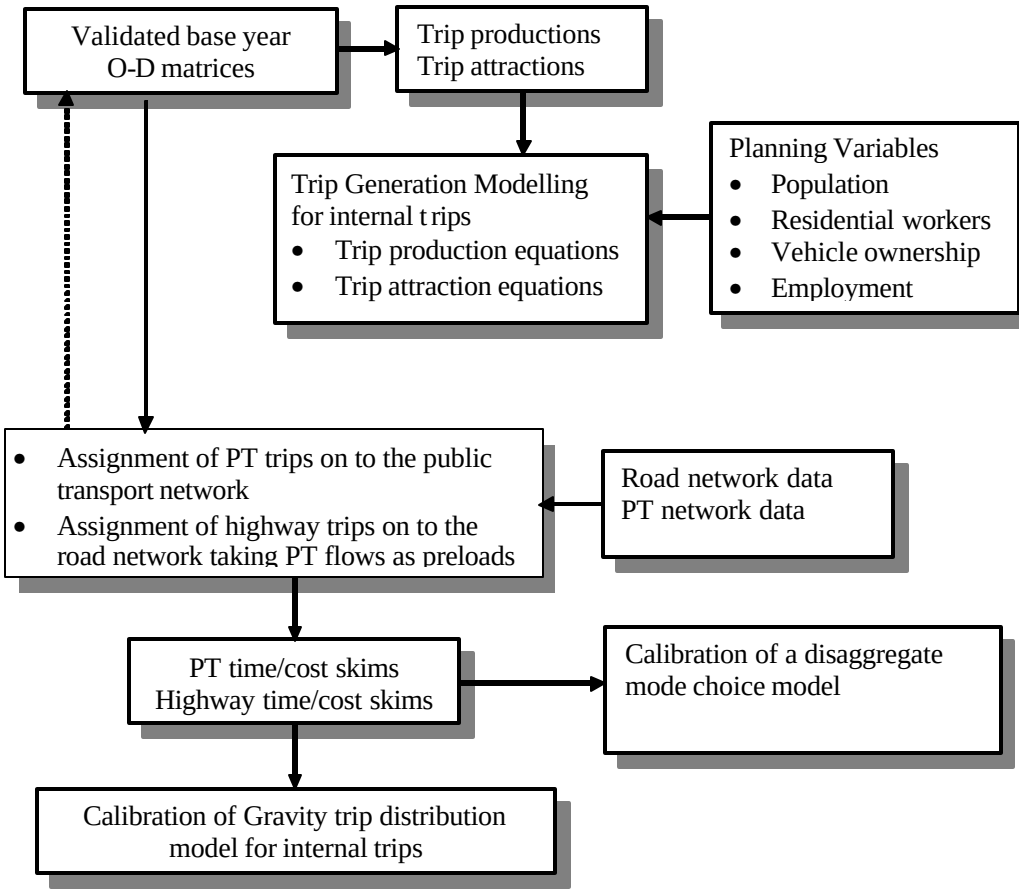

Figure 2.1 Travel Demand Model Development Process

2.4 MODEL APPLICATION

The developed Travel Demand Model is used to forecast the Horizon Year loadings for each mode on all the links. Future forecasts are done for the Horizon years 2011, 2021 and 2031. Planning variables are forecasted for Horizon years based on demographics. The planning variables of horizon year form the input to the Travel demand model along with the future highway and proposed metro corridors. Trip ends are estimated and are fed into the calibrated gravity model along with base year highway skims. The distributed PA matrix so obtained is fed into the Mode split model and mode wise PA matrices are estimated. This forms the internal portion of the PA

matrix. The external passenger PA portion as well as Commercial vehicle trips are estimated by Furness method (by taking 3% and 2% growth rate respectively) and added to the horizon year internal matrices. The combined PA matrix is converted into OD matrix and is loaded on to the PT and highway networks.

Skims obtained from this assignment process are updated in the gravity model and redistribution of trips is done. Mode wise OD matrices are estimated by the updated skims. The final matrices thus produced are loaded on to the network and the cycle is continued till the skims are stable.

2.5 SUSTAINABILITY INDICES AND EVALUATION OF ALTERNATIVES

A sustainable transport system should provide *access* to people, places, goods, and services in an environmentally responsible, socially acceptable, and economically viable manner. A sustainable urban transport strategy should satisfy the objectives relating to economic efficiency, liveable streets, environmental protection, equity, social inclusion and accessibility, safety and security, economic growth, financial viability, practicability and intergenerational equity. Towards achieving these, strategies with combination of policy instruments like, non-motorised promotional schemes, pedestrian streets, BRT lanes, Metro Rail Systems, general public transport improvement measures, congestion pricing, etc., are to be worked out. The different land use and transport scenarios and sustainability indices are to be generated for Pune city, so that the transportation planning model will be able to estimate the impacts of these strategies in terms of congestion levels, travel times, costs, etc. Environmental, social and economic impacts can also be derived from the outputs of the model. Therefore, it is possible to evaluate the alternatives with respect to sustainability indicators. Figure 2.2 shows the methodology of model application.

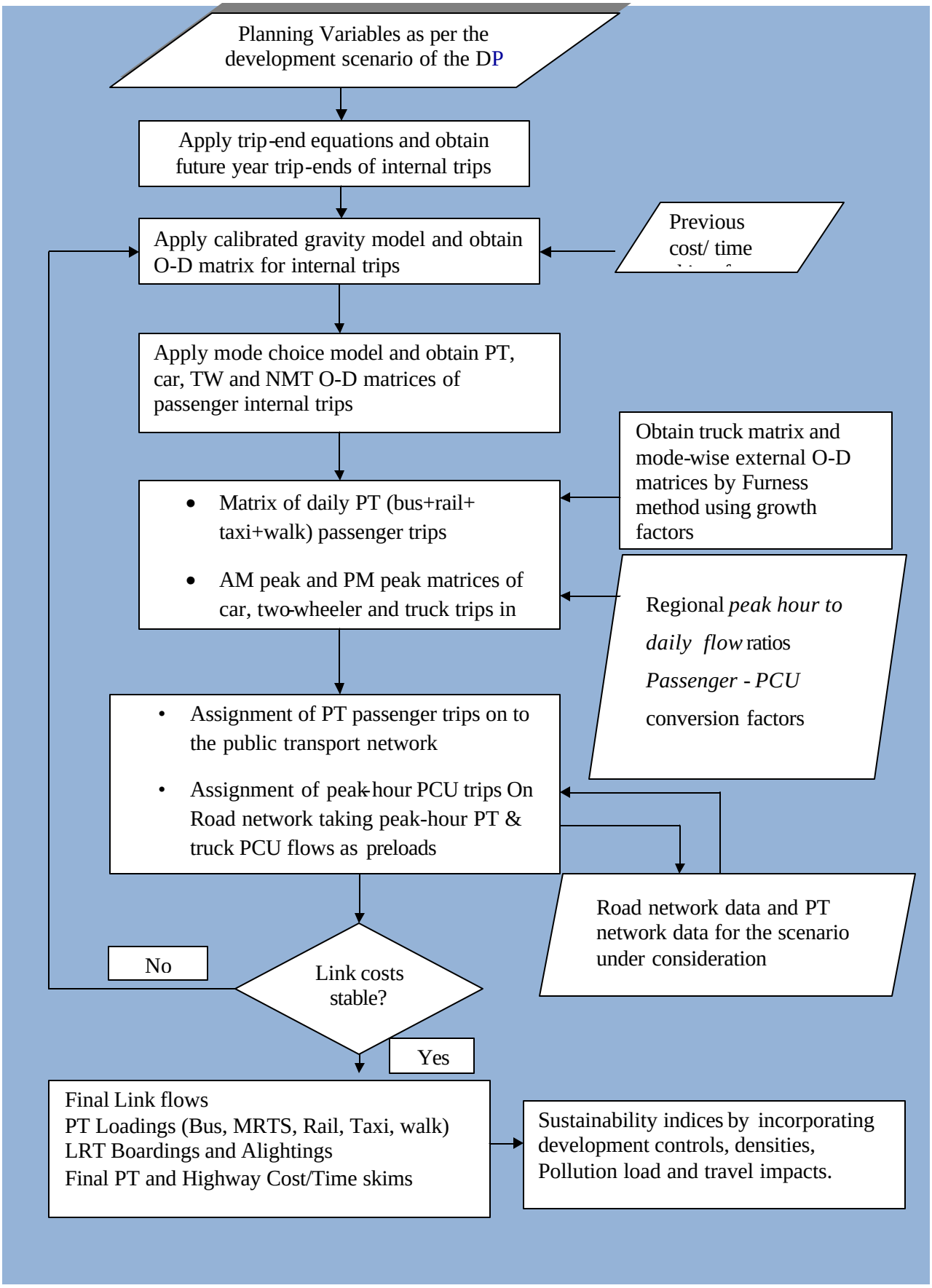

Figure 2.2 Model Application

CHAPTER 3

DEVELOPING SUSTAINABILITY INDICES

3.1 INTRODUCTION

There is growing interest in the concepts of sustainability, sustainable development and sustainable transport. They refer to development that enhances the human and natural environments now and over the long term. Sustainability balances economic, social and environmental goals and objectives. This chapter explores concepts related to the definition of sustainable and livable transportation and the selection of indicators suitable for policy analysis and planning.

3.2 SUSTAINABLE TRANSPORTATION GOALS

Sustainability reflects the fundamental human desire to protect and improve our earth. It emphasizes the integrated nature of human activities and therefore the need for coordinated decisions among different sectors, groups and jurisdictions. Sustainability generally refers to a balance of economic, social and environmental goals, including those that involve long-term, indirect and non-market impacts. They are shown in Figure 3.1. Sustainability planning (also called *comprehensive planning*) expands the objectives, impacts and options considered in a planning process, which helps insure that individual, short-term decisions are consistent with strategic, long-term goals.

Figure 3.1: Sustainable Transportation Goals

Table 3.1 Summary of Sustainable Transportation Goals, Objectives and Performance Indicators

(Source : Todd Litman,2010)

Sustainability Goals	Objectives	Performance Indicators
Economical		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	Per capita GDP Portion of budgets devoted to transport. Per capita congestion delay. Efficient pricing (road, parking, insurance, fuel, etc). Efficient prioritization of facilities
Economic development	Economic and business development	Access to education and employment opportunities. Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	Per capita transport energy consumption Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	Performance audit results. Service delivery unit costs compared with peers. Service quality.
Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	Transport system diversity. Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	Per capita traffic casualty (injury and death) rates. Traveler assault (crime) rates. Human exposure to harmful pollutants. Portion of travel by walking and cycling.
Community development	Help create inclusive and attractive communities. Support community cohesion.	Land use mix. Walkability and bikability Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	Preservation of cultural resources and traditions. Responsiveness to traditional communities.

Table 3.1 Contd.

Environmental		
Climate stability	Reduce global warming emissions Mitigate climate change impacts	Per capita emissions of global air pollutants (CO2, CFCs, CH4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	Per capita emissions of local air pollutants (PM, VOCs, NOx, CO, etc.). Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	Traffic noise levels
Protect water quality and minimize hydrological damages.	Minimize water pollution. Minimize impervious surface area.	Per capita fuel consumption. Management of used oil, leaks and stormwater. Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage more compact development. Preserve high quality habitat.	Per capita land devoted to transport facilities. Support for smart growth development. Policies to prot ect high value farmlands and habitat.

3.3 DEFINING SUSTAINABILITY AND SUSTAINABLE TRANSPORTATION

There are many definitions available for sustainability and sustainable transportation, in which some of them are defined here below,

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

ii. *A sustainable transport system is one that is accessible, safe, environmentally-friendly, and affordable.* (ECMT 2004)

iii. Environmentally Sustainable Transportation (EST) is: *Transportation that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes.* (OECD 1998)

iv. A sustainable transportation system is one that (CST 2005):

a) Allows the basic access needs of individuals and societies to be met safely and in a manner consistent

b) with human and ecosystem health, and with equity within and between generations.

c) Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.

d) Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of nonrenewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

The principles (general guidelines for decision making) and *goals* (what people ultimately want) help define *objectives* (specific ways to achieve goals) and *targets* (specific, realistic, measurable objectives to be achieved). Common sustainable transport objectives include: (Source: Todd Litman,2010)

i. *Improved transport system diversity:* This generally means improving walking, cycling, ridesharing, public transit, car sharing, and creating more walkable and transit-oriented communities.
ii. *Smart growth land use development:*. This includes land use policies that create more compact, mixed, connected, multi-modal development, and provide more affordable housing in accessible, multi-modal locations.
iii. *Energy conservation and emission reductions:* This may include more fuel efficient vehicles, shifts to alternative fuels, and reductions in total motor vehicle travel. This includes improving the quality of energy efficient modes including walking, cycling, ridesharing, public transit and increase land use accessibility.
iv. *Efficient transport pricing:* This includes more cost-based pricing of roads, parking, insurance, fuel and vehicles.

Conventional planning often evaluates transport system performance based primarily on mobility (using indicators such as traffic speed and vehicle operating costs), ignoring other accessibility factors and improvement options. For example, with mobility-based planning, the only practical solution to traffic congestion is to expand roadway capacity. Accessibility-based planning allows other solutions to be considered, including improvements to alternative modes, more accessible land use patterns, and improvement to mobility substitutes. Accessibility-based transport planning tends to support sustainability by expanding the scope of analysis and supporting more resource-efficient solutions. As a result, as much as possible, sustainable transportation indicators should reflect accessibility-based planning.

The sustainable transportation planning usually fallows the steps as described as below.

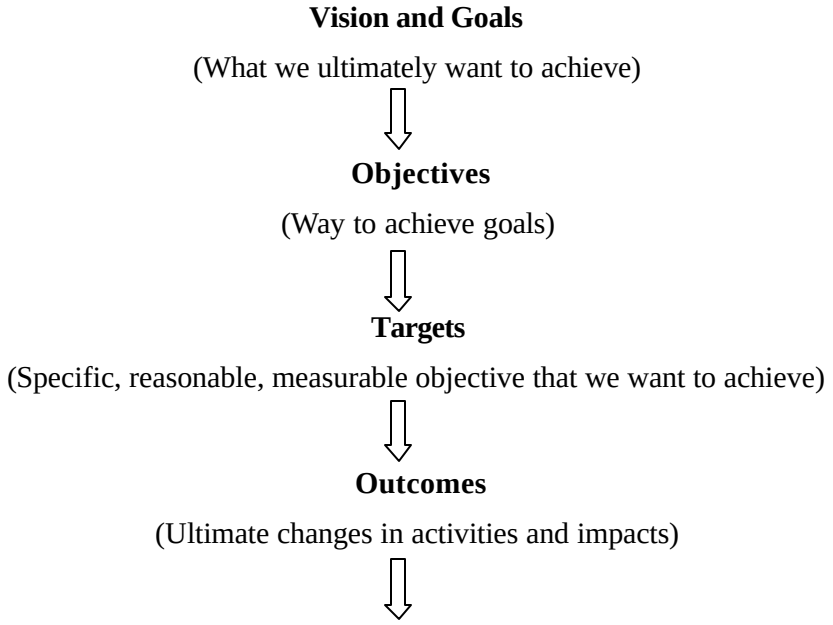

Figure 3.2: Steps for the sustainable transportation planning

3.4 PRINCIPLES FOR SELECTING THE INDICATORS OF SUSTAINABILITY TRANSPORTATION

i. The indicators should reflect in various levels of analysis such as planning, design, decision making, travel pattern and physical & economic impacts.

ii. In order to avoid the double counting of impacts (i.e. the selection of indicators which leads to the same impact) we should take the relationship between the various indicators.

iii. For comprehensive and balanced analysis, the chosen indicator set should consist of indicators which lead to all broad categories of sustainable transportation goals. But it is not compulsory to consider the indicators from every category, because some indicators may indicate more than one goals of sustainable transportation.

iv. The following are various impacts which are reflected usually in an indicator set.

v. We should select the indicator set so that the necessary data can be collected possibly.

vi. The selected indicators should be in an understandable way to the public and decision and makers.

vii. Indicator should reflect ultimate impacts rather than the intermediary effects.

Table 3.2 Probable set of indicators for sustainable transportation

(Source : Todd Litman,2010)

Economic	Social	Environmental
A. Accessibility, B. Traffic Congestion, C. Infrastructure costs, D. User Costs, E. Accidents, F. Reduction of non renewable and renewable resources	A. Equity B. Human health C. Aesthetics D. Affordability	A. Air Pollution B. Noise Pollution C. Effect on natural resources

3.5 CONCLUSIONS

By following above principles and depending on the data availability the most suitable indicators for sustainable transportation are selected and they will be used to evaluate various development plans including different land use and transportation scenarios given by the Pune Municipal Planning commission. Then the conclusions will be drawn from those results.

3.6 REFERENCES

1. Todd Litman(2010),"*Developing Indicators for Sustainable and Livable Transport Planning*" Victoria transport Policy Institute, US.
2. ECMT (2004), *"Assessment and Decision Making for Sustainable Transport"*, European Conference of Ministers of Transportation and the OECD.
3. CST (2005), *"Defining Sustainable Transportation"*, Centre for Sustainable Transportation (http://cst.uwinnipeg.ca); at http://cst.uwinnipeg.ca/documents/Defining_Sustainable_2005.pdf.

CHAPTER 4

STUDY AREA, DELINEATION, PLANING PERIOD & TRANSPORT NETWORKS

4.1 STUDY AREA

The study area will be taken as the area comprising the present Pune Municipal Corporation area, Pimpri Chinchwad Municipal Corporation area and both the cantonment areas namely Pune and Khadki (with major concentration on PMC area). The study area that will be adopted in this study will be similar to the one adopted during the Pune metro study by IIT Bombay but with appropriate modifications as stated above and as per the area decided by the development plan. The map in Figure 4.1 shows the Pune Metropolitan Region showing the areas mentioned above forming the study area.

Figure 4.1 Study Area

4.2 DELINEATION

Traffic Analysis Zones

The zoning system considered for the Pune metro study by IIT Bombay comprises of only 91 internal zones and 13 external zones. In the present study, it is proposed to redefine these traffic

analysis zones (TAZ) to the extent possible as per the administrative units like wards utilizing the available GIS maps with PMC and PCMC. Accordingly, the zoning system of the present study has been adopted based on the City Development Plan (2007-2027) comprising 144 zones in the PMC area, 105 zones in PCMC area and 16 zones in hinjewadi. Pune and Khadki cantonments have been considered as two zones. In addition to these 267 internal zones, 13 external zones are considered. These 13 external zones represent the catchments of the 13 entry points at the outer cordon. This delineation of the study area as adopted in this study is shown in Figure 4.2 and 4.3.

Figure 4.2 Zonal Map of PMC region

Figure 4.3 Zonal Map of PCMC region

Screen-lines and Cordon-Lines

Screen lines will be established along the natural barriers viz., railway lines and rivers in PMA. Screen line count stations will be formed at the intersection of the transport links and the screen lines. The volume counts at screen line stations will be utilised for validating the O-D matrix as well as the models. All the past studies more or less adopted two screen lines, one along the existing railway line and other along Mula – Mutha River. In this study also the same two standard screen lines will be adopted. The boundary of the study area will be the outer cordon line. Figure 4.4 shows the location of these screen lines and screen line stations at which traffic counts were taken in Metro study. Figure 4.5 shows the external cordon line and the cordon stations where in addition to traffic counts, origin – destination surveys were done.

Figure 4.4 Locations of Screen Lines in Study Area

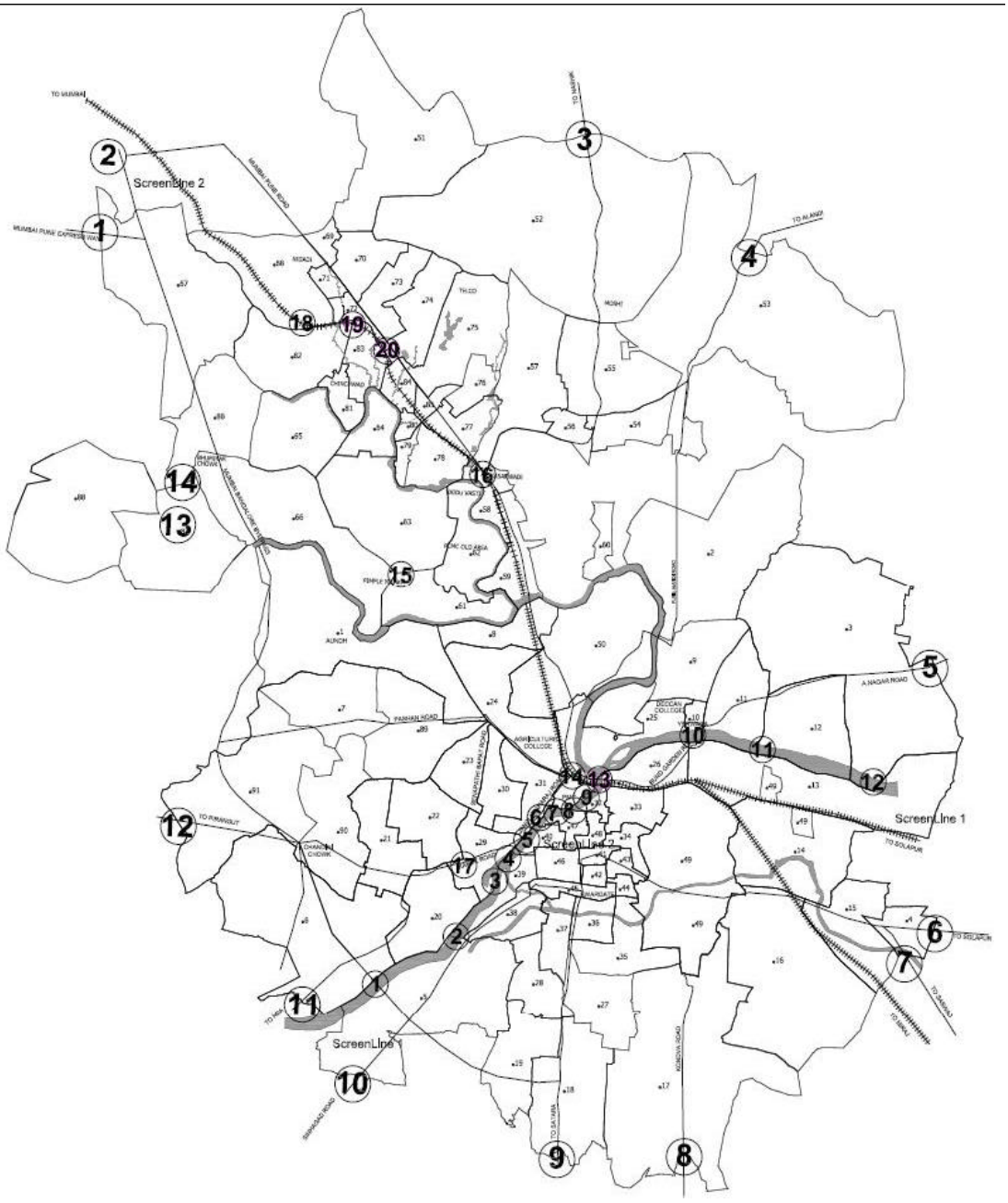

Figure 4.5 Locations of Screen Lines and the External Cordon

4.3 PLANNING PERIOD

The plan period for the Transportation planning model will be kept same as that for the DP. As majority of the traffic and transportation data that was collected is for the year 2008, the same will be considered as base year. The model will be utilized to forecast traffic for various scenarios for the future years 2011, 2021 and 2031. Forecasts for intermediate years, if required, will be made through interpolation.

4.4 NETWORK DEVELOPMENT

Transport network developed for the model comprises of two components,

• Highway Network for vehicles

• Transit Network for public transport system i.e. buses, rail and any new public transportation system.

Highway Network

13 different types of road links have been adopted for the study. All these links types are appropriately recorded while coding the road network and preparing the link list for basic network for study area. Table 4.1 shows the different types of road links with their link characteristics and parameters of the speed flow functions. The network considered for the Private Vehicle assignment is as per the new network developed in Development Plan of PMC with extension of width. The length of road network coded is 1270 km which do not include Rail, Metro, BRTS and Monorail and the same is shown in Figure 4.6. The strategic network is considered for public transport assignment. The length of strategic road network coded is 922 km. Coded highway network with existing Sub Urban Railway and proposed BRT, Metro and monorail alignments is shown in Figure 4.7.

Table 4.1 Different types of links in network and their characteristics

Link Type	No. of lanes	Divided/ Undivided	Type of flow	Capacity Per Dirn. (PCU/hr)	Free Flow speed (km/h)	Speed at Cap. (km/h)
1	One Lane	Undivided	One-way	1650	30	15
2	Two Lane	Undivided	One-way	3200	40	15
3	Three Lane	Undivided	One-way	4350	40	15
4	Four Lane	Undivided	One-way	5300	50	18
5	Five Lane	Undivided	One-way	6200	50	18
10	One Lane	Undivided	Two-way	600	25	12
11	Two Lane	Undivided	Two-way	1100	35	15
12	Three Lane	Undivided	Two-way	1500	35	15
13	Four Lane	Undivided	Two-way	2150	40	18
17	Four Lane	Divided	Two-way	2600	50	18
18	Six Lane	Divided	Two-way	3800	50	18
19	Eight Lane	Divided	Two-way	6200	55	20
31	Four Lane	Divided	Two-way	2600	80	25

Figure 46 The Road Network for the PMR region

Public Transport Network

The network developed for public transport consists of all road links, suburban rail links, BRT links and future metro links along with the routes coded on them. The fare tables currently in force are appropriately coded in routes file. Total of 288 bus routes are coded. The types of transit links coded on the network are shown in Table 4.2.

Table 4.2 Description of Other Links Used in the Network

Link Type	Description
21	Highway Node to Transit Stop
22	Road Node to Zone Centroid Connection
25	Suburban Rail Links
26	BRT Links
27	Metro Links
28	Monorail Links

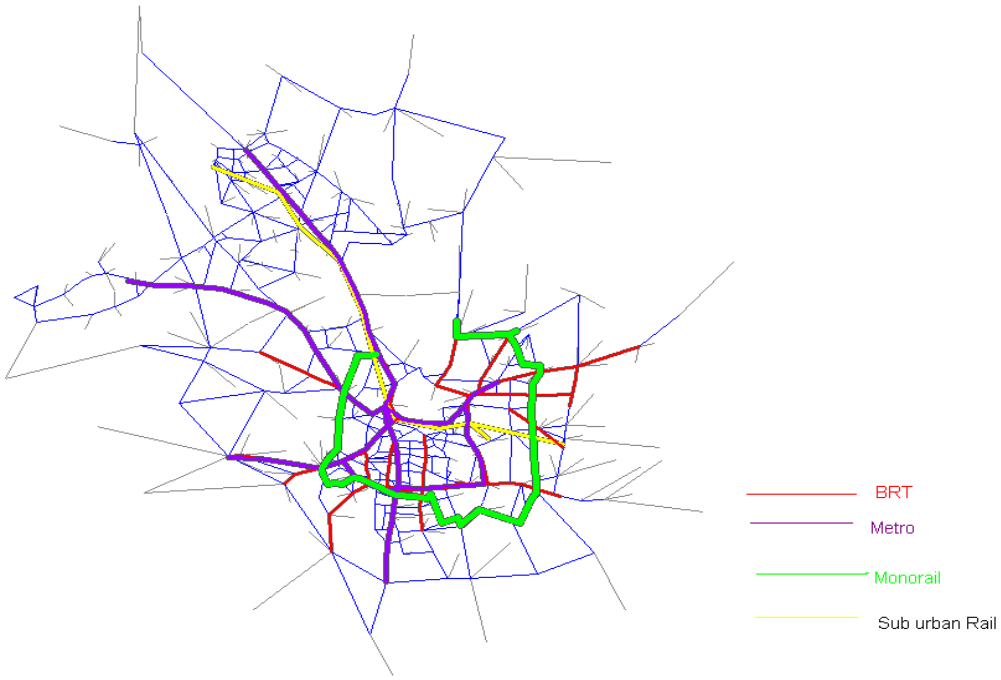

Figure 4.7 Highway Network with existing Sub Urban Railway and proposed BRT, Metro and Monorail alignments

CHAPTER 5

TRAFFIC DATA

The data on planning variables and the transportation system as listed below, which were collected during previous studies, were made available for the present study.

- Planning Variables
- Population
- Employment
- Transport System data
- Highway network and link attributes
- Public transport network and link attributes
- Public transport routes and system data

The data compiled from the metro rail study, the CMP study and the DP revision studies which are essential for the development, calibration and validation of the transportation planning model has been described in the following sections.

5.1 TRAFFIC VOLUME COUNTS

In order to establish the base year travel pattern in the study area, traffic volume counts and occupancy counts were taken at all the cordon and screen line stations during the metro study. As explained in Chapter 4, the outer cordon line and the 2 screen lines were considered in this study for arriving at the travel pattern and validating the base year travel pattern. Screen line count stations were established at all those points where the road links cross the screen line. Cordon stations were established at all those points where the external road links cross the cordon line entering the study area. The locations of all these screen line and cordon count stations were shown in Figure 4.4 and 4.5 of chapter 4. The details of the location of cordon stations are provided in Table 5.1 and those of screen line stations are provided in Table 5.2.

The traffic volume surveys were undertaken for 24 hours in case of important screen line stations and for other screen line count stations traffic surveys were undertaken for 16 hours i.e. from 7.00 Hrs to 23.00 Hrs. The traffic volume counts were undertaken during 15th December 2007 to 20th January 2008. Only normal week days were considered for carrying out the traffic volume surveys. Holidays, days of the weekend and Mondays and Fridays were avoided as far as possible. In all, the traffic volume surveys were undertaken at 20 locations across the 2 screen lines and at 14 locations on the cordon line.

Summaries of traffic volume counts in terms of Average Daily Traffic (ADT) and Directional Design Hour Volume (DDHV) were produced by converting all classes of vehicle into passenger car units (PCU). The PCU values adopted for this purpose are shown in Table 5.3. Directional design hour volume is the peak hour volume in peak direction in PCU per hour. In addition, K-factor (the proportion of daily volume occurring during peak hour) and D-factor (proportion of total peak hour volume occurring in peak direction) were also worked out. Table 5.4 gives the daily traffic volumes at all the screen line stations. The observed DDHV, K-factor and D-factor for all the screen line count stations are shown in Table 5.5. The daily traffic volumes at all the cordon stations are provided in Table 5.6. Table 5.7 gives the observed DDHV, K-factor and D-factor for all Outer Cordon Stations.

The observed modal shares of the traffic at outer cordon are shown in Figure 5.1. The proportion of total external traffic entering and leaving the study area through each of the cordon stations is displayed in Figure 5.2.

Table 5.1 Location Details of Cordon Stations

Station No	Name of the Station	Landmark	Duration	Remark
1	Talegaon	Toll Plaza, MSRDC	24 Hrs	OD and Volume Count
2	Somatane	Toll Plaza, MSRDC	24 Hrs	OD and Volume Count
3	Nasik Road	Toll Plaza, PWD	24 Hrs	OD and Volume Count
4	Alandi Road	Merging Road near NH50	16 Hrs	OD and Volume Count
5	Ahmednagar Road	Merging Road near Wagoli Road	24 Hrs	OD and Volume Count
6	Sholapur Road	Toll Plaza, NHAI	24 Hrs	OD and Volume Count
7	Saswad Road	Toll Plaza, MSRDC	16 Hrs	OD and Volume Count
8	Saswad Kondwa Road	Kondwa junction	16 Hrs	Volume Count
9	Satara Road	Toll Plaza, NHAI	24 Hrs	OD and Volume Count
10	Sinhagad Road	After bridge	16 Hrs	OD and Volume Count
11	Warje Road	After bus terminal	16 Hrs	OD and Volume Count
12	Perangut Road	Near Junction	16 Hrs	OD and Volume Count
13	Hinjewadi Road	Bhumkar chowk – Hinjewadi Chowk	16 Hrs	OD and Volume Count
14	Hinjewadi Chowk	Hinjewadi Chowk	24 Hrs	OD and Volume Count

Table 5.2 Location Details of Screen Line Stations

Station No	Name of the Station	Landmark	Duration	Occupancy Survey
1	Westerly Bye Pass	Mutha river crossing	24	Y
2	Rajaram Bridge	Sinhagad Road	16	-
3	Mathre Bridge	Anant Kan Kahare Path - Eradhawane Road	24	Y
4	SM Joshi Marg	LBS Road -Karve Road	16	-
5	Sambhaji Bridge	Connecting Laxmi Road and Prabhat Road	24	Y
6	Shinde Bridge	JM Road - Laxmi Road	16	-
7	Shivaji Bridge	Veer Santaji Ghorpade Road (Parallel to Dhagdi Pool)	24	Y
8	Causeway	Parallel to Shinde Bridge	16	-
9	Dhagdi Pool	Veer Santaji Ghorpade Road	16	-
10	Bund Garden Road	Bund Garden Road – Deccan College Road	24	Y
11	Wellesley Road – Nagar Road	Mula-Mutha river crossing (Yerwada IT Park)	24	-
12	Ghorpadi Mundwa Road- A Nagar Road	Mula-Mutha river crossing	16	-
13	Sangam Bridge	Mumbai Pune Road – R.B Mothilal Road	24	Y
14	Shivaji Nagar Bridge	JM Road Sangam Bridge	16	Y
15	Pimple Nilakh	Pimple Nilakh Junction	24	Y
16	Pune Mumbai Road	Between Dapodi and Kasarwadi	24	Y
17	Karve Road	Near Law College Road Junction	16	-
18	Nigdi Crossing	Chinchwad - Nigdi Road	16	Y
19	Akurdi Crossing	Chinchwad - Akurdi Road/Nigdi Road	16	-
20	Chinchwad Crossing	Chinchwad - Akurdi Road (MIDC ROAD)	24	Y

Table 5.3 PCU Values adopted for the Study

S. No	Vehicle Type	Adopted PCU Values

1	Car / Jeep	1.0
2	Bus	3.0
3	Autorickshaw	0.8
4	Two-wheeler	0.5
5	LCV/ Mini-bus	2.5
6	Truck	3.0
7	Truck Trailer	3.5

Table 5.4 Daily Traffic in PCU at Screen Line Stations

Station	Daily Traffic in PCU's		
	South Bound	North Bound	Total
Akurdi Crossing	11176	10243	21419
Causeway	14185	12751	26936
Dhagdi pool	28942	24257	53199
Ghorpadi Mundwa	20990	15250	36240
Karve road	60763	52562	113325
Nigdi Road	15790	14063	29853
Rajaram bridge	26855	19430	46285
SM Joshi bridge	10240	14103	24343
Shinde bridge	10818	15675	26492
Sancheti Bridge	18134	43497	61631
Bund garden	22752	43873	66625
Chinchwad crossing	16281	17310	33591
Mathre Bridge	22142	22635	44777
Pimple Nilakh	22628	25239	47867
Pune Mumbai	34184	47477	81662
Satara to Mumbai	28488	33476	61964
Sambhaji Bridge	26821	20956	47777
Sangam Bridge	35151	41321	76472
Shivaji bridge	12481	13752	26233
Wellesley Road	22493	19329	41822

Table 5.5 DDHV at Screen Lines Stations

Station	K-FACTOR	D-FACTOR	DDHV
Akurdi Crossing	0.08	0.68	1223
Causeway Dangre	0.09	0.56	1416
Dhagdi pool	0.08	0.68	2965

Ghorpadi Mundwa	0.08	0.62	1777
Karve road	0.07	0.55	4367
Nigdi Road	0.13	0.67	2578
Rajaram bridge	0.08	0.56	2087
SM Joshi bridge	0.08	0.7	1386
Shinde bridge	0.07	0.53	1027
Sancheti Bridge	0.07	0.68	2933
Bund garden	0.07	0.75	3748
Chinchwad crossing	0.07	0.54	1233
Mathre Bridge	0.09	0.52	2087
Pimple Nilakh	0.07	0.58	1983
Pune Mumbai	0.08	0.67	4232
Satara to Mumbai	0.08	0.6	3065
Sambhaji Bridge	0.09	0.87	3615
Wellesley Road	0.08	0.52	1674

Table 5.6 Daily Traffic in PCU at Outer Cordon Stations

Station	Daily Traffic in PCU's		
	IN	OUT	Total ADT
Hinjewadi Road	13561	11885	25446
Perangut Rd.	9377	11382	20759
Saswad Kondwa rd.	10715	9538	20253
Saswad Rd.	12743	9939	22682
Sinhagad Rd.	13566	6363	19930
Warje Rd.	9994	7939	17933
Alandi	13657	11778	25434
Ahmednagar Rd	12580	12655	25234
Hinjewadi(Shivaji chowk)	19158	16829	35987
Nasik Rd.	22959	23253	46212
Satara Rd. Shindewadi	16129	19110	35239
Sholapur Rd.	19560	20633	40193
Somatane Phata	22419	21778	44197
Talegaon express highway	25070	25469	50539

Table 5.7 DDHV in PCU at Outer Cordon Stations

Station	K- Factor	D-Factor	DDHV
Hinjewadi Road	0.08	0.62	1236
Perangut Rd.	0.07	0.63	923
Saswad Kondwa rd.	0.07	0.53	710

Saswad Rd.	0.06	0.54	757
Sinhagad Rd.	0.07	0.63	897
Warje Rd.	0.06	0.6	680
Alandi	0.1	0.6	1547
Ahmednagar Rd	0.07	0.61	1142
Hinjewadi(Shivaji chowk)	0.08	0.68	2048
Nasik Rd.	0.07	0.53	1634
Satara Rd. Shindewadi	0.06	0.7	1481
Talegaon express highway	0.05	0.51	1246

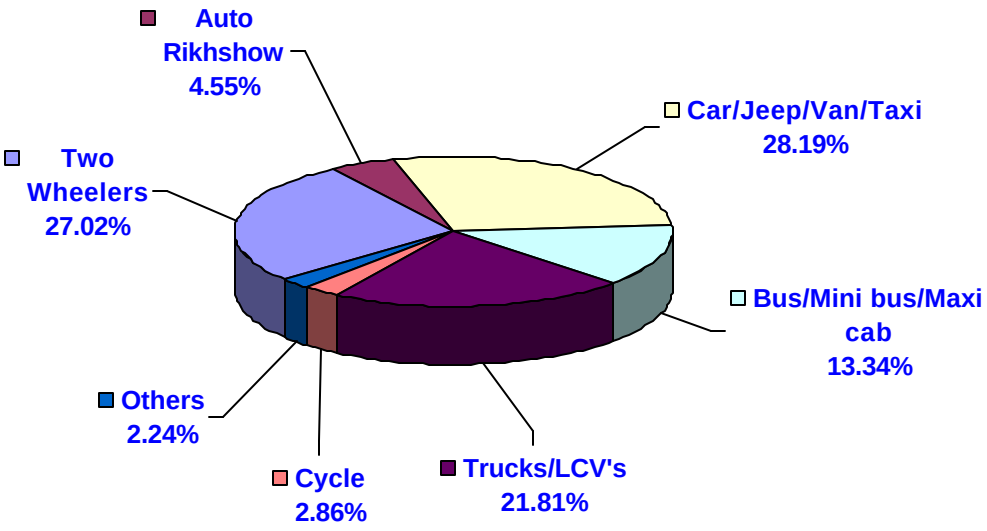

Figure 5.1 Modal Share at Outer Cordon Stations

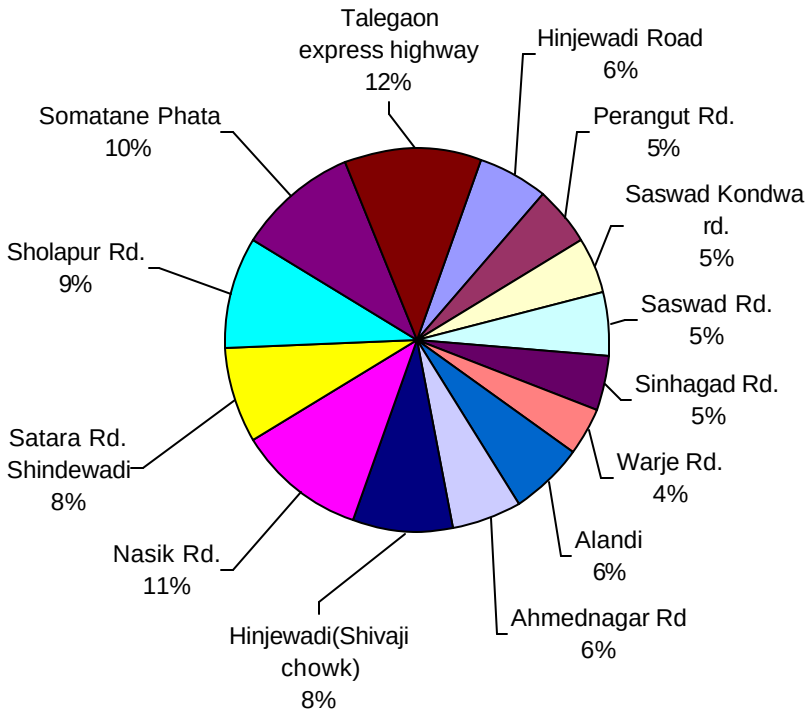

Figure 5.2 Proportion of traffic at each Outer Cordon Station

5.2 OCCUPANCY COUNTS

Occupancy counts were taken at selected screen line stations. These occupancy counts were made during morning and evening peak hours and as well as during the lean hours of the day. The average occupancy of various vehicle types for the whole day are given in Table 5.8. These values were obtained at all the 20 screen lines. These occupancy values corresponding to appropriate time of the day were used to convert vehicles to passengers and vice-versa.

Table 5.8 Average Occupancy of Vehicles

Vehicle type	Average occupancy
Two Wheeler	1.56
Autorickshaw	2.32
Maxi Cab	4.02
Taxi	3.24
Car/Jeep/Van	2.91
Mini-Bus	16.71
PMC/PCMC Bus	35.19
ST Bus	34.37
Other Buses	25.23

5.3 O-D SURVEYS

In order to establish the external trips entering and leaving the study area, Origin and Destination (O-D) surveys were carried out at the outer cordon stations. The O-D surveys were carried out by using the standard Road Side Interview method on a sample basis at the outer cordon stations. The O-D survey carried out at the outer cordon was utilised in deriving the external travel pattern for the study area. Mode wise origin-destination matrices were obtained from outer cordon data and home interview survey data. The overall magnitude of travel in the study area as obtained from these surveys is provided at the end of section 5.4 of this chapter.

5.4 HOME INTERVIEW SURVEY

Home interview survey data is essential for arriving at the origin-destination trip matrices purpose wise, mode wise and socioeconomic segment wise. Home interview survey was done during the Pune metro project and the same survey data has been used for the present study. This home interview survey was carried out in the year 2008. Home Interview Survey was conducted on a sample basis in 3000 households to establish the base year travel pattern. The survey included collection of information regarding the Household, Persons and Trips.

From the HIS data it was observed that the share of Public Transit was as low as 13%. Figure 5.3 shows the obtained Modal Split form HIS data.

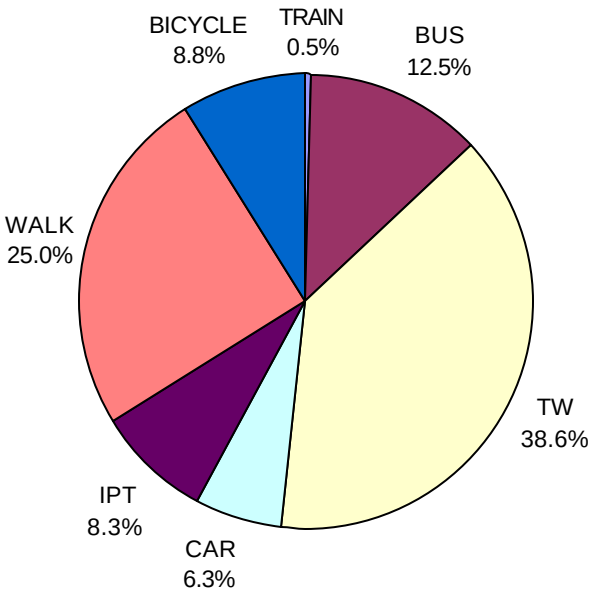

Figure 5.3 Modal Split from HIS

From HIS data, trips made by the residents of the study area were obtained. The mode wise daily

trips made by the residents of the study area are depicted in Figure 5.4

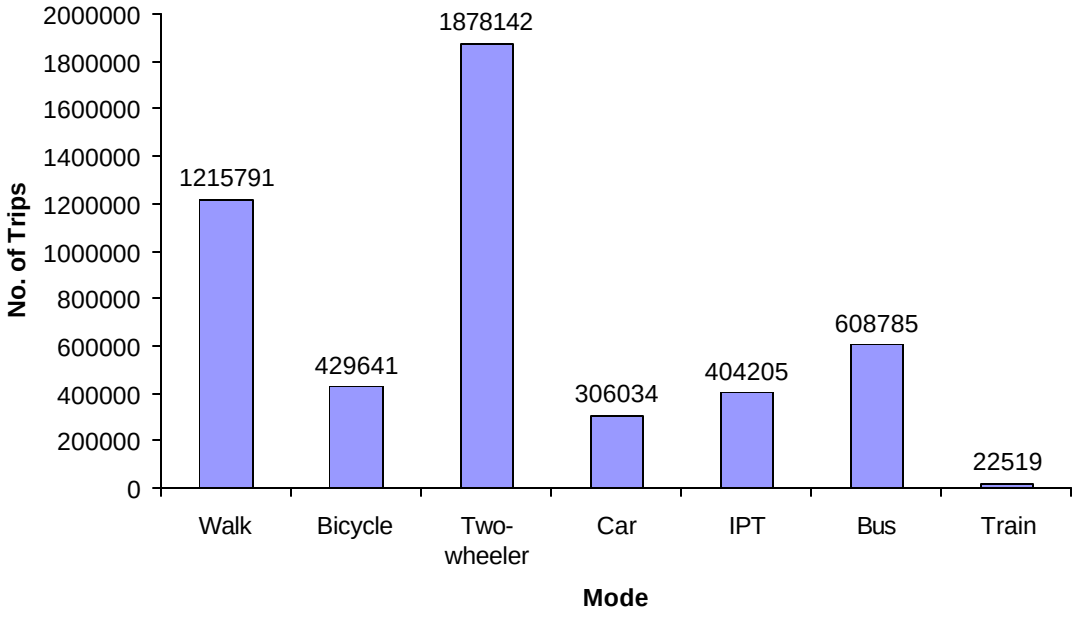

Fig 5.4 No of Trips Mode wise from HIS

From OD survey and Traffic volume count at outer cordon the magnitude of external travel made by the residents as well as the non residents is obtained. The travel pattern thus obtained from both HIS and outer cordon OD surveys was collated to get the overall travel pattern of the study area. The same is reported in Table 5.9.

Table 5.9 Overall Travel pattern obtained for the Study Area(2008)

Mode	No. of Daily Passenger Trips			
	Internal to Internal	Internal to External	External to Internal	External to External
Two Wheeler	1837861	44468	49269	11538
Car	296343	129000	125893	54851
IPT	389537	23099	20159	8379
PT	928734	278538	314849	180567

5.5 SPEED & DELAY SURVEY

Speed and delay survey has been carried out along the potential corridors of mass transit. The main

purpose of this survey is to get the present journey times and delays along these corridors. This information has been used to adjust the parameters of the speed-flow relationships of various road links. This information has also been used to validate the public transport and highway assignment models. These journey times also gave the extent of travel time saving that one could expect on Metro.

In order to get accurate data on travel times, delays and their locations, a handheld GPS (Global Positioning System) palmtop has been used in a probe vehicle moving with the traffic. GPS receiver logs data continuously at time interval of one second.

Four Major Corridors were selected for doing this survey. Each of these corridors was further subdivided in to segments in order to capture the exact peak-hour traffic conditions in the corridor. The description of these corridors and the prominent roads on the corridors is given in Table 5.10.

Table 5.10 Description of the Corridors chosen for Speed and Delay Study

Sl. No.	Corridors	Roads	Direction
1	Shivajinagar- Swargate	JM road, Tilak Road	Sancheti to Swargate
			Swargate to Sancheti
2	Shivajinagar- Nigdi	Mumbai-Pune Road	Sancheti to Nigdi Circle
			Nigdi circle to Sancheti
3	Shivajinagar- Yerwada	Bund Garden road, Nagar road	Sancheti to Wagoli
			Wagoli to Sancheti
4	Shivajinagar- Warje	JM road, Karve road	Sancheti to Karve Circle
			Karve Circle to Sancheti

The data that was collected using the GPS palmtop during the speed and delay survey was analysed to find variation of speed along the stretches of the four corridors in northbound as well as southbound directions. The summary of journey speeds for each of the four corridors is presented in Table 5.11.

From the analysis of speed and delay data it can be observed that the journey speeds are falling below 16 km/hr over certain corridors during peak hours. From Table 5.11 It can be inferred that the journey speeds during peak hour vary between a low of 16 km/hr to a high of 26 km/hr on these four corridors. All these corridors are the main arterials of the city feeding traffic to the CBD. Considering this nature of these urban arterials and based on the present journey speeds it can be

concluded that the level of service on most of the stretches along these arterials is D. This indicates that the traffic flows on these streets may have to experience severe congestion with stop and go movements.

Table 5.11 Summary of Average Speeds in kmph along the Corridors

Corridors	Morning Peak		Evening Peak	
	Onward	Return	Onward	Return
Shivajinagar - Swargate	24.06	16.19	14.62	14.50
Shivajinagar - Nigdi	29.82	29.46	20.02	27.57
Shivajinagar - Yerwada	20.05	18.91	13.85	17.42
Shivajinagar - Warje	18.84	15.01	14.47	18.72

5.6 ROAD INVENTORY SURVEY

The road network information will be updated from the maps of the study area available with PMC and PCMC, past studies, Google earth imagery and ground verification and collection using GPS palmtops.

5.7 PUBLIC TRANSPORT AND IPT SURVEY

The information on the routes of public transport buses operated by PMPL and the 5-seater auto rickshaws was collected and coded on the transport network during the metro traffic study. The required additional information on the bus routes due to the enlarged study area will be collected and coded.

5.8 LAND USE AND PLANNING VARIABLES

Land use data, location of work places, educational institutions, shopping areas, recreational areas, etc., data on planning variables like population and employment will be collected and apportioned as per the adopted zoning system from the recent census, electoral lists and the development plans.

CHAPTER 6

PLANNING VARIABLES

6.1 GENERAL

The travel demand in an area depends on land use distribution and its intensity. The variables that describe the travel demand traditionally have been the population, employment and vehicle ownership. The growth of population, employment and vehicles in study area and their projection into the future is described in the following sections.

6.2 POPULATION

The total population of study area in 2001 was 35.6 lakh (more than thrice the 1971 population of 10.7 lakh). The 2001 Census data estimated the populations of PMC and PCMC are 2538473 and 1012472 respectively.

Table 6.1 Population Growth in Study Area

(Source: Census of India)

	PMC	PCMC	Pune Cantonment	Khadki Cantonment
1961	595762	46031	65838	58496
1971	856105	83542	69451	65497
1981	1203351	220966	85986	80835
1991	1566651	517083	82139	78323
2001	2328349	1083967	80191	77473

The decadal growth in PCMC area is almost 100% in the past three decades. PMC area has registered an average decadal growth of around 35% and a decline in population has been observed in both the cantonments

The base estimates of population for the horizon years are based on RITES (1998) study. A lot of modifications have been applied to the RITES estimates to incorporate the dynamics of the development. It has been noticed that the population of PMC has been underestimated by RITES and the population of PCMC has been overestimated. This finding was the result of validation of RITES forecasts using 2001 population. Appropriate diminishing compound annual growth rates have been applied to counter these findings. The population of the cantonments was considered to remain constant, keeping in view the steady decline in the past decades. The forecasts were made in terms of gross population of PMC, PCMC and Cantonments separately. The proposed residential development in Hinjewadi area in PCMC has been appropriately considered in estimating the

population of the zones containing the area. The estimated population figures of study area for the base year 2008, and the horizon years are given in Table 6.2. The zone wise population data is given in Annexure I.

Table 6.2 Projected Population of Pune

Region	2008	2011	2021	2031
PMC	3394948	3784015	5239886	6197016
PCMC	1473210	1642042	2273805	2689144
Pune Cantonment	82988	92498	128086	151483
Khadki Cantonment	80296	89498	123931	146569
Hinjewadi	42810	47716	66075	78144
Total	**5074254**	**5655770**	**7831785**	**9232356**

*Projected

6.3 EMPLOYMENT

The aggregate employment data of study area was obtained by assuming worker participation rates of 32%. Modifications have been done in view of the recent IT developments as the RITES study did not witness the IT boom in Pune. A proxy index for employment has been developed from the HIS data and has been used to moderate the Zone wise Employment values. A lot of change has been observed in the recently developed zones like Hinjewadi, Talwade, Hadapsar and Yerwada and the changes have been incorporated in the respective zones. The changes incorporated in view of the IT boom are displayed in Table 6.3. The aggregate forecasts of employment are given in Table 6.4. Table 6.5 shows the workers participation ratio obtained for PMR. Zone wise employment data is given in Annexure I.

Table 6.3 Additional Employment due to new developments

(Source: Pune Metro Study)

Area	2008	2011	2021	2031
Rajiv Gandhi InfoTech Park Hinjewadi Phase I	21750	21750	21750	21750
Rajiv Gandhi InfoTech Park Hinjewadi Phase II	19075	27250	54500	54500
Rajiv Gandhi InfoTech Park Hinjewadi Phase III SEZ	7000	17500	56000	70000
Rajiv Gandhi InfoTech Park Hinjewadi Phase IV	0	10000	70000	100000
Kharadi Knowledge Park	6750	6750	6750	6750
Talawade InfoTech Park	6563	9375	18750	18750

Table 6.4 Projected Employments in Pune

Region	Employment (Million)			
	2007*	2011*	2021*	2031*
Pune Municipal Corporation	1.11	1.35	1.78	2.36
Pune Cantonment	0.04	0.04	0.05	0.05
Khadki Cantonment	0.04	0.04	0.05	0.05
Pimpri-Chinchwad Municipal Corporation	0.54	0.72	1.26	1.89
Rest of the PMR	0.25	0.29	0.39	0.5
Total Pune Metropolitan Region (PMR)	**1.98**	**2.44**	**3.52**	**4.85**

Table 6.5 Workers Participation Ratio

YEAR	WORKER PARTICIPATION RATIO
2008	0.38
2011	0.41
2021	0.43
2031	0.46

6.4 STUDENT ENROLMENT

The student enrolment in 1996 is observed from census data as 6.62 lakhs. The base year aggregate student enrolment is obtained from HIS and it is forecasted to the future and the same has been divided into all the zones depending on the zonal proportions. Zone wise student enrolment data is given in Annexure I.

CHAPTER 7

TRAVEL DEMAND MODEL DEVELOPMENT

7.1 ESTABLISHING BASE YEAR TRAVEL PATTERN

As explained in section 2.2 of chapter 2 the travel pattern in the form of mode wise OD matrices were obtained following the process described in the flowchart shown in Figure 2.1. The sources used for arriving at the base year OD pattern are the home interview survey, outer cordon OD survey, screen line traffic volume counts and occupancies. The mode wise OD matrices obtained form these primary sources were then validated by assigning them on to the respective networks and comparing the assigned and observed flows from ground counts. As the outer cordon surveys give only the external commercial vehicle trips, the internal commercial vehicle trips have been estimated from link counts using standard matrix estimation procedure.

Highway and public transport networks as detailed in chapter 4 were coded in CUBE, a transportation planning software package. The characteristics of these networks were also explained in chapter 4.

7.2 TRAFFIC ASSIGNMENT

Public Transport Assignment

Peak hour public transport passenger matrix, which includes trips made by bus, Intermediate Public Transport (IPT) and train, was assigned on to the public transport network. Public transport network is prepared by coding all the bus and IPT routes on the road network. In addition, the public transport network consists of all the existing rail links with the suburban train route coded on the rail links. All the zone centroids were connected to the nearest road nodes by walk links. Road to rail node walk connections were also given appropriately.

The public transport assignment is done based on generalized time. The components of generalized time are in-vehicle travel time (IVTT), waiting time (WT), transfer penalty, fare and discomfort in time units. Accordingly, the generalized time, GT, is worked out as

GT = IVTT + WTFAC*WT +TRFAC*NTR + FARE / VOT + DF

Where,

GT	=	Generalized time in minutes
WTFAC	=	Wait time factor worked out as a ratio between value of WT and value of
IVTT	=	In vehicle travel time
TRFAC	=	Transfer penalty in minutes per transfer between modes

VOT = Value of travel time, in Rs per minute

FARE = Fare paid for journey between origin and destination in Rs.

DF = Discomfort Factor (worked out from SP Survey)

The values of the above parameters used in public transport assignment are worked out from the choice models developed using the Stated Preference and Revealed Preference (Home Interview Survey) data obtained fro primary surveys.

There are two important steps in public transport assignment, viz., path building and loading trips on to these paths. The purpose of path building is to identify all reasonable paths between zones and provide associated travel information in generalised time so that the proportion of trips using each path may be calculated at the loading stage. Between any pair of zones maximum number of trips are loaded on to the best path and other paths with longer generalized times will be loaded with fewer trips. The proportion of trips to be loaded is calculated on the basis of a logistic choice function based on generalized time.

The public transport (PT) assignment is also required to assign the trips as per the observed modal shares. In order to achieve this, the parameters of the generalised time were fixed based on the values obtained from the analysis of stated preference and revealed preference surveys. However, these values were slightly modified to get the assigned flows close to the observed ones. Several skim matrices for PT were obtained at the end of assignment which can be used for calibration of other demand models. The calibrated parameters of PT assignment Model are shown in Table 7.1

Table 7.1 Calibrated parameters of PT assignment

Parameter	Value
WTFAC	1.2
TRFAC	3
VOT	Rs 0.53/ min
DF	As per Table 6.2

Table 7.2 Crowding Table for PT Modes

Percent Standees	DF(Min)
0	3
50	5
75	20
95	45
100	300

Highway Assignment

Highway assignment has been carried out for peak hour, preloading the highway network with peak hour public transport flows. The peak hour public transport passenger trips were converted into PCUs by using appropriate PCU-passenger ratios. These peak-hour public transport (bus and IPT) flows in terms of PCUs were preloaded on to the highway network before loading the two-wheeler and car O-D matrices. The passenger matrices of car and two-wheeler were converted into peak hour PCU units by using appropriate K factors (proportion of daily flow occurring during peak hour) and passenger-PCU conversion factors based on observed occupancies. An equilibrium procedure based on generalized cost was used in loading these car and two-wheeler matrices. The Commercial Vehicle (CV) trips were taken as preloads on highway network. The generalized cost, GC, used in highway assignment has the following form

GC = VOT * TT + TC

where,

VOT = Value of travel time

TT = Travel time

TC = Travel cost

Travel cost for car/two-wheeler is the perceived operating cost which was taken as the cost of fuel and oil. Two skims namely the highway time and highway travel cost were obtained from the loaded network for use with other demand models. The parameters of Generalised cost used in Highway assignment are given in Table 7.3.

Table 7.3 Parameters of Generalised cost used in Highway Assignment

MODE	VOT (Rs/Hr)	TC (Rs/ Km)
Two Wheeler	34	1
Car	107	5

The assignment of PT and private vehicle trips were done iteratively till an overall equilibrium was reached between PT and highway networks. After every step of this equilibrium assignment, the observed and assigned flows were compared and the matrices were adjusted if required using O-D Matrix estimation procedure.

7.3 VALIDATION OF BASE YEAR TRAVEL PATTERN

The assigned total road-based flows during peak hour (in PCU) and public transport passengers in peak hour in peak direction are compared with the flows observed across the screen lines. The assigned traffic flow in terms of passenger car equivalencies across all screen lines was found to match very closely with the observed flows. In fact, the percent error between observed and assigned flows across the screen line was found to be with in 0.5%. The percent error at individual screen line points, however, was found to be within 20 % at most of the screen line points. As many of the adjacent links across the screen line provide alternate crossing paths, the above error at individual links is acceptable. The public transport passenger flows assigned by the model and those observed across screen lines also match within 1% indicating that the model is capable of capturing the observed distribution of public transport trips between bus and IPT modes. The comparison between observed and estimated trips across screen lines is shown Table 7.4. Therefore, the estimated travel pattern of the base year (2008) was found to be fairly accurate and the model performance was acceptable as established through these observations.

Table 7.4 Observed and Estimated Trips across Screen Line

	Observed	Estimated	% Error
All vehicles (PCU)	72963	72784	-0.25
PT Trips (passengers)	124855	123818	-0.83

7.4 TRIP GENERATION MODELS

The Productions (P) and Attractions (A) of internal passenger trips by all modes for the base year (2008) are calculated from the validated P to A matrices. Trip generation models are developed using stepwise multiple linear regression technique. The calibrated trip end equations for different

income groups are presented below.

Table 7.5 Trip Production Models for various categories

Category	Model	R^2	$(t_{stat})_{POP}$
Car Owning Group	0.58 x POP_hig	0.957	2.51
Two Wheeler Owning Group	0.58 x POP_mig	0.88	6.18
No Vehicle Group	0.58 x POP_lig	0.949	9.85

Where,

POP_hig: population of high income group (car owning group)

POP_mig: population of medium income group (two wheeler owning group)

POP_lig: population of low income group (no vehicle group)

Table 7.6 Trip Attraction Models for various categories

Category	Model	R^2	$(t_{stat})_{EMP}$	$(t_{stat})_{STEN}$
Car Owning Group	1.45 x EMP+0.12 x STEN	0.695	19.28	2.72
Two Wheeler Owning Group	1.28 x EMP+0.1 x STEN	0.80	18.69	1.87
No Vehicle Group	1.18 x EMP	0.639	8.58	

Where,

EMP: Employment

STEN: student enrollment

7.5 TRIP DISTRIBUTION MODEL

A Gravity Trip Distribution model of the following form is calibrated for distributing the total internal passenger trips.

$$T_{ij} = A_i O_i B_j D_j F_{ij}$$

Where,

$$A_i = \frac{1}{\sum_j B_j D_j F_{ij}}$$

$$B_j = \frac{1}{\sum_i A_i O_i F_{ij}}$$

F_{ij} = the deterrence function

$= (C_{ij})^a \exp(bC_{ij})$

C_{ij} = Highway travel time from i to j

T_{ij} = Number of trips between zones i and j.

a = Calibration parameter – power function

ß = Calibration parameter – exponential function

Following Gravity Model parameters for trip distribution were obtained.

S.No	Class	a	ß
1	Car owning Group	-2.09557	-0.0001819
2	Two Wheeler Group	-1.07986	-0.0236587
3	No vehicle Group	-0.897392	-0.0255572

The observed and Modeled Trip length Frequency Distributions are displayed in Figure 7.1. It can be seen that the Gravity model is very closely representing the observed trip length frequency.

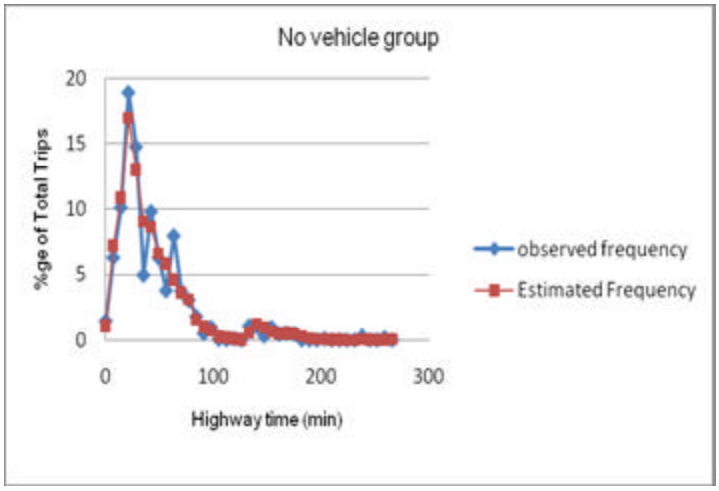

Figure 7.1 (a) Trip Length Frequency Distributions corresponding to no vehicle group

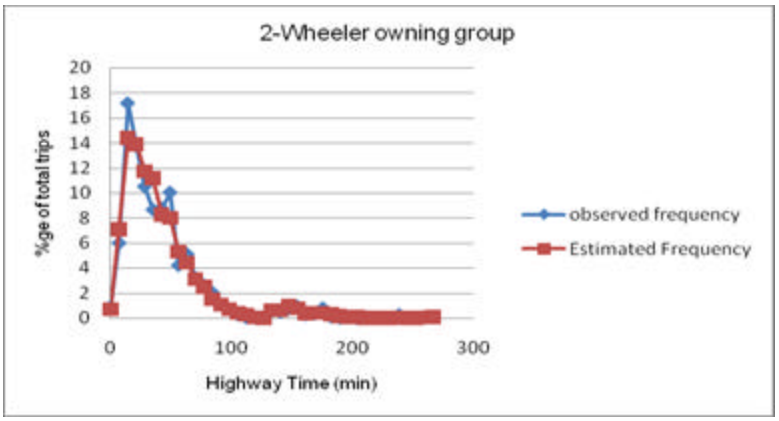

Figure 7.1 (b) Trip Length Frequency Distributions corresponding to 2-wheeler owning group

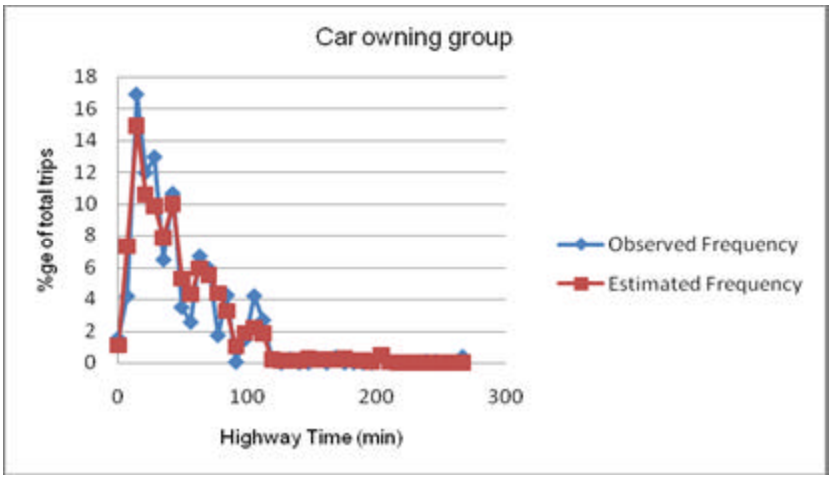

Figure 7.1 (c) Trip Length Freque ncy Distributions corresponding to car owning group

7.6 Modal Split Model

A multi-nomial logit model of mode choice for different income groups is developed which is shown below for all group category. The following multinomial mode choice model was calibrated for this purpose.

Figure 7.2 Multi-nomial logit model for different group category

$$P_j = \frac{e^{V_j}}{\sum_l e^{V_l}}$$

Where,

Pj = probability of choosing mode j, (Car, Two wheeler, PT)

Vj = deterministic component of utility for mode j and

j and l are indices for modes

The utility functions of the following specifications are calibrated.

Vcar = α TTcar + β TCcar + Constcar

V2w = α TT2w + β TC2w + Const2w

Vpt = α TTpt + β TCpt + γ WTPt

The modal split parameters for PT and private vehicle split are estimated using the skims obtained from PT and Highway assignments.

Sr No	Category	ρ square	Equation
01	Car Owning Group	0.1664	a) U_{car} =0.5425-0.0004147*TT-0.001059*TC b) U_{2W} = 0.3125-0.0004147*TT-0.001059*TC c) U_{PT} =-0.0004147*TT-0.001059*TC-0.03141*WT
02	Two Wheeler Owning group	0.1732	a) U_{2w} =1.312-0.003475*TT-0.07817*TC b) U_{PT} =-0.003475*TT-0.07817*TC-0.00687*WT

The results of the mode choice are given in Table 7.7 wherein the percentage share of the motorised passenger trip made in the internal to internal zones of PMR is shown for different horizon year.

Table 7.7 Mode choice results for different horizon years (Internal Daily Passenger Trips)

	Private Vehicle (PV)	**Public Transport (PT)**	**%share of PV**	**%share of PT**
2008	1866952	1076130	64	36
2011	2026408	1253934	61	39
2021	2750124	1792310	60	40
2031	3163262	2208904	59	41

7.7 FORECASTING OF EXTERNAL TRIPS AND COMMERCIAL VEHICLE TRIPS

All the external passenger trips are forecasted using growth factor method. These growth factors are arrived at based on the growth of external traffic observed at the cordon. The commercial vehicle matrix is forecast using growth factor method. The growth factors are obtained by observing the growth rates of employment.

CHAPTER 8

EVALUATION OF DEVELOPMENT SCENERIOS

8.1 GENERAL

There are various development scenarios that can be evaluated taking into consideration the sustainability concept. The various sustainability indices were explained in Chapter 3. Since for any evaluation of development plans it is necessary to have a four stage travel demand model the same was developed as explained in chapter 7. Using this developed travel demand model, various transportation system improvements have been evaluated and the ridership for different transit options for Pune city have been estimated for the horizon years 2011, 2021 and 2031. Comparison of pollution load due to personalized vehicles with and without metro is also done in this study. Further different land use scenarios are taken into consideration for evaluation of development plans.

The scenarios that are been developed for the PMR are as follow:

1) **Usual Land Use Scenario (Scenario 1)**: With the prevailing land use pattern (base year is taken as 2008), forecasting the traffic for future with different transportation network for the horizon year 2011, 2021 and 2031. Figure 8.1 shows the graphical representation of the scenario.

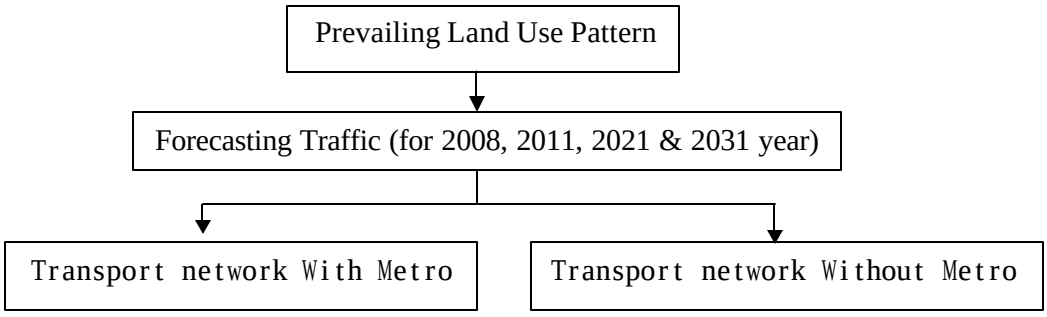

Figure 8.1 Scenario 1 - Usual Land Use Scenario

2) **Increasing Floor Space Index (FSI) along Metro corridor (Scenario 2)**: Increasing the FSI of 4, along the Metro corridor for the year 2021, and forecasting the traffic for the transportation network consisting of metro and comparing it with the 2021 usual land use scenario with transport network consisting of metro. Figure 8.2 shows the graphical presentation of the land use scenario.

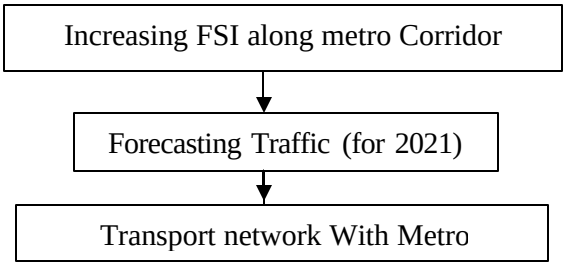

Figure 8.2 Scenario 2 - Increasing FSI along Metro corridor (year 2021)

3) **Considering Public transport share as 80% (Scenario 3)**: A hypothetical scenario has been developed wherein the share of Public Transport is considered as 80%. Due to large Public Transport share its effect on the Public transport is been analysed. Figure 8.3 shows the graphical presentation of the scenario.

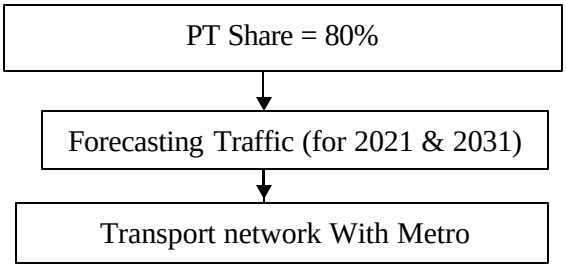

Figure 8.3 Scenario 3 – Public Transport Share as 80%

4) **Considering Work Participation Ratio of 0.6 (Scenario 4)::** A hypothetical scenario has been developed wherein the work participation ratio considered is 0.6. Due to increase in work participation ratio results to increase in employment which results in increase in trips. Traffic is been forecasted for future year 2021 and 2031 wherein the transportation network consist of Metro. Figure 8.4 shows the graphical presentation of the scenario.

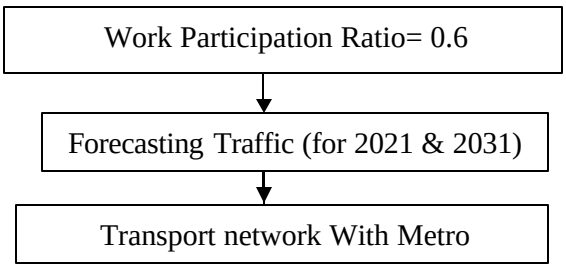

Figure 8.4 Scenario 4 – Work Participation Ratio as 0.6

8.2 DETAILS OF PUBLIC TRANSPORT NETWORK FOR DIFFERENT SCENARIOS

The Transport network scenarios which is been evaluated for different horizon years is given in Table 8.1. Basically the With Metro and Without Metro are the two basic scenarios that have been considered and the difference in the transport network is given in Table 8.1.

Table 8.1 Transport Network for different Scenario for future years

	Public Transport	
	Transport Network Scenario	
	With Metro	**Without Metro**
2008 (Base Year)	Not Applicable	• Bus Routes • Suburban rail Routes • BRT Network (Prevailing BRTS Routes Coded)
2011	• Bus Routes • Suburban rail Route • Metro Route (Only two lines) • BRT Route (All routes) • Monorail Route	• Bus Routes • Suburban rail Routes • BRT Route (All routes) • Monorail Route
2021 & 2031	• Bus Routes • Suburban rail Routes • Metro Routes (All lines) • BRT Routes (All routes) • Monorail Route	• Bus Routes • Suburban rail Route • BRT Routes (All routes) • Monorail Route

8.3 EVALUATING SCENARIO 1 (USUAL LAND USE SCENARIO)

With the prevailing land use pattern, the traffic has been forecasted for base year 2008, and horizon year 2011, 2021 and 2031 and the same is compared with and without metro. Comparison is done based on different parameters which are described in the following sections.

8.3.1 Details of Forecast

The calibrated travel demand models have been incorporated in CUBE software. For each forecasting year the model is run in an iterative manner with complete feedback structure amongst the sub models. The overall travel estimated by the model in the above manner for the forecast years 2011, 2021, 2031 is given in Table 8. 2. The model also gives the demand by individual modes for various network scenarios.

Table 8.2 Estimated Travel for Base year and Forecast Years (Daily Passenger Trips)

Mode	**2008**	**2011**	**2021**	**2031**
PT	1939173	2190583	3050631	3900096
PV	2277615	2481573	3361606	3985096
CV (PCU)	13425	13725	15338	16005

*This are the passenger trips which include all the trips from internal to internal, internal to external and external to external also.

8.3.2 If PT is improved, how much percentage of people are shifting from PV to PT

The percentage share by PT and PV for the future year is given in the Table 8. 3. From this table the percentage shift can be obtained by comparing with and without metro scenario which is given in Table 8.4.

Table 8.3 Proportion of passenger trips with and without metro

	2011		**2021**		**2031**	
	Without Metro	**With Metro**	**Without Metro**	**With Metro**	**Without Metro**	**With Metro**
% PT Share	45%	47%	46%	48.5%	47%	49.5
% PV Share	55%	53%	54%	51.5%	53%	50.5

Table 8.4 Proportion of shift from PV to PT for Future years

Year	**2011**	**2021**	**2031**
Proportio n of shift	4.4%	5.4%	5.4%

8.3.3 LOADINGS CORRESPONDING TO PROPOSED TRANSIT MODES

The existing and proposed public transport systems were considered in the model and the ridership for all these modes was worked out for the future years 2011, 2021 and 2031 considering a standard

land use scenario. Table 8.5 provides the summary of loadings on all these transit systems. The details of ridership estimation mode wise are discussed in the following sections.

Table 8.5 Peak Hour Passenger Boardings and Passenger Distance for all modes

	2008		2011		2021		2031	
Mode	**Passenger Boardings**	**Passenger Distance (km)**	**Passenger Boardings**	**Passenger Distance (km)**	**Passenger Boardings**	**Passenger Distance (km)**	**Passenger Boardings**	**Passenger Distance (km)**
BUS	163071	768007	117223	526334	107899	422375	119804	456826
IPT	42386	132942	31424	103633	30807	100084	36244	114333
TRAIN	3699	53513	915	15845	326	4945	372	5610
BRTS	16995	69806	55276	186577	32234	93222	49098	140537
METRO	-	-	76380	531989	217654	1528152	289960	2135564
MONO RAIL	-	-	28232	149207	35160	157410	47050	214506
TOTAL	226151	1024268	309450	1513585	424080	2306187	542528	3067376

8.3.4 Ridership Estimation

Ridership estimation on Metro Corridors

In order to know the priority of the metro lines, 2 lines are coded in the network for 2011 and the remaining 4 for 2021 and 2031. The forecast of ridership on all these lines for each of the forecast year has been presented below:

Forecast for Year 2011 : The estimated peak hour loading for year 2011 is displayed in Table 8.6. The corresponding flow map is given in Figure 8.5.

Table 8.6 Peak Hour Metro Loading for the Year 2011

LINE NAME	Length	Passenger Boardings	Passenger Distance	Passenger-km/km	Combined max. link load	PHPD
Pimpri Station to Swar Gate	16.58	39196	339805	20495	25772	15525
Chandini Chowk to Ramwadi	17.96	37184	192040	11583	28105	16930

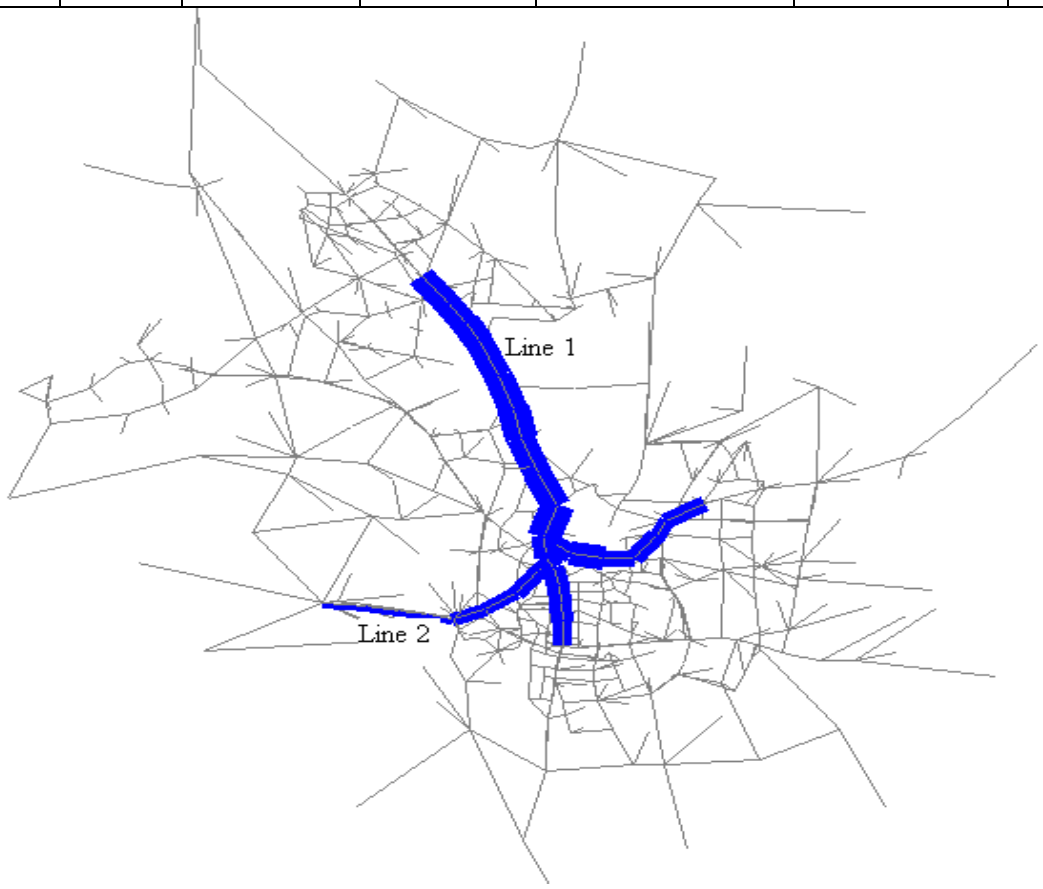

Figure 8.5 Flow Diagram for Metro for Horizon year 2011 (Scenario -1)

The salient features of loading in the year 2011 are as follows:

• In terms of peak hour passenger boarding Line 1 running from Pimpri station to Swar Gate carries the maximum number of passengers i.e. around 39196.

• However, with respect to the index of Passenger kilometers per kilometer, Line 1 gets the first priority followed by Line 2.

• The Peak hour peak direction passenger flow (PHPD) is maximum on Line 2 at 16930.

Forecast for Year 2021: The estimated loading for horizon year 2021 is displayed in Table 8.7. The corresponding flow map is given in Figure 8.6.

Table 8.7 Peak Hour Metro Loading for the Year 2021

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	41133	346723	21861	30575	18418
AC to Hinjewadi	15.65	41711	437427	27950	32405	19521
AC to Katraj	12.01	36449	254099	21157	26548	15992
Chandini Chowk to Ramwadi	17.96	54677	283289	15773	39225	23629
Deccan GymKhana to Yarawada Bridge	13.94	45040	214817	15410	24403	14700

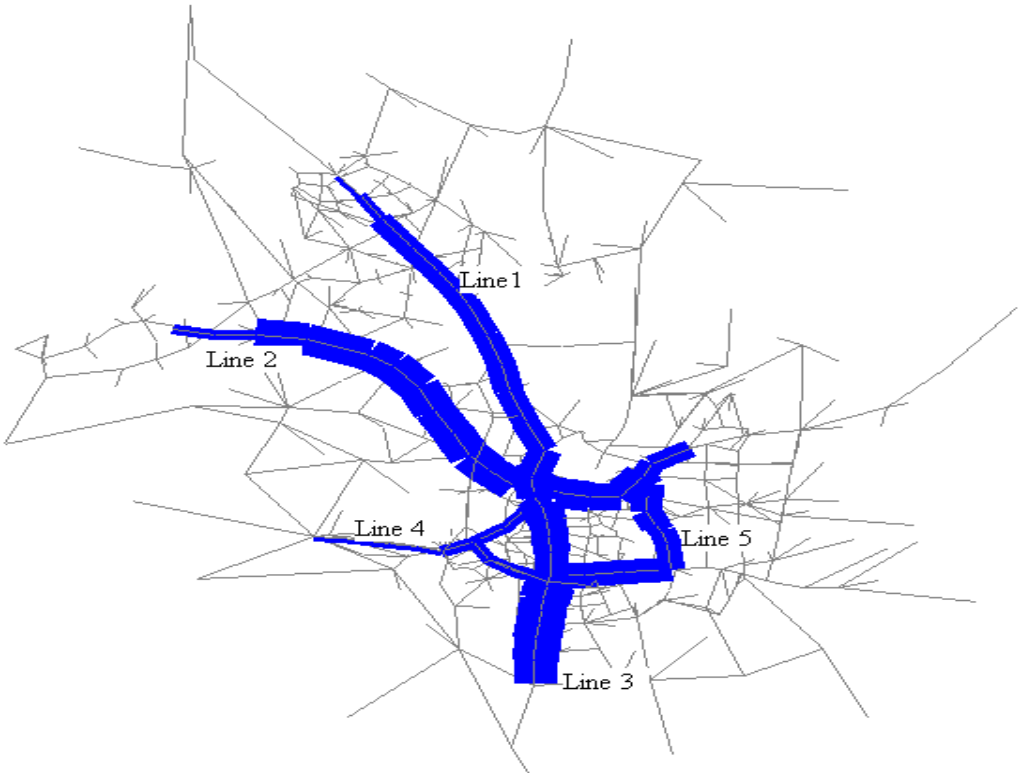

Figure 8.6 Flow Diagram for Metro for Horizon year 2021 (Scenario -1)

The salient features of loading in the year 2021 are as follows:

• In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers.

• The Peak hour peak direction passenger flow (PHP D) is maximum on Line 4 at 23629

• However, with respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority followed by Line 1 and Line 3.

Forecast for Year 2031 : The estimated loadings for horizon year 2031 are shown in Table 8.8. The corresponding flow map is given in Figure 8.7.

Table 8.8 Peak Hour Metro Loading for the Year 2031

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger-km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	55823	472570	29796	40261	24253
AC to Hinjewadi	15.65	58452	632314	40403	46972	28296
AC to Katraj	12.01	49996	396338	33000	36069	21728
Chandini Chowk to Ramwadi	17.96	68876	361098	20105	49680	29927
Deccan GymKhana to Yarawada Bridge	13.94	56812	273724	19635	30789	18547

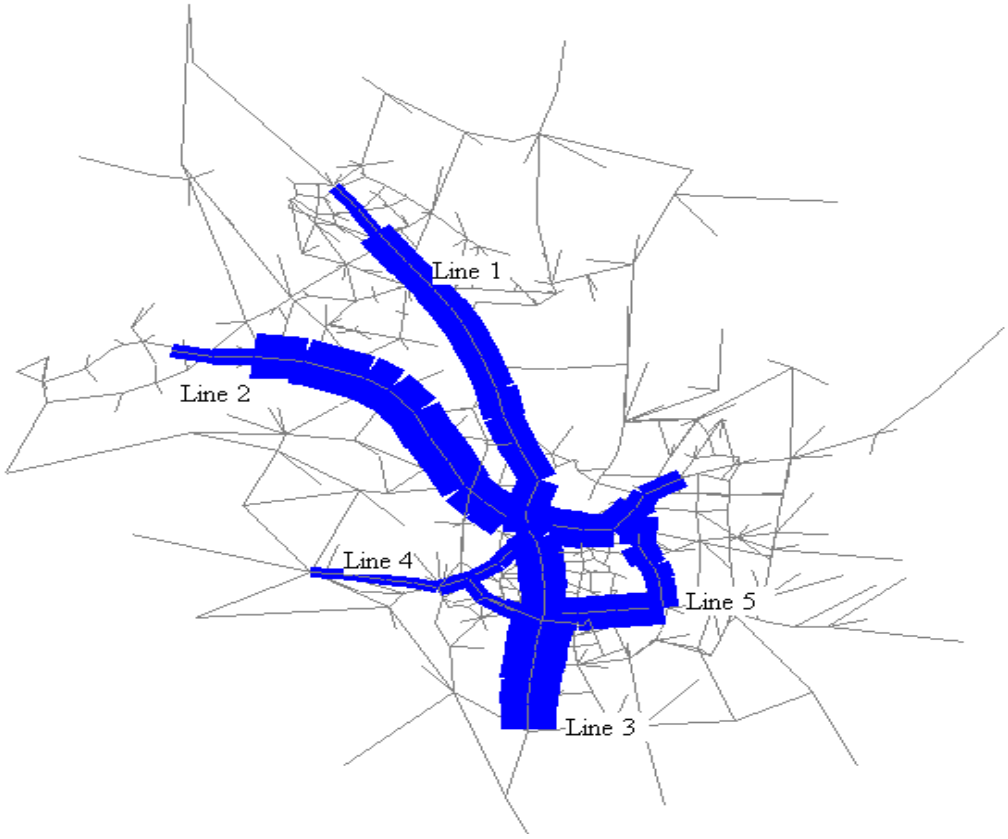

Figure 8.7 Flow Diagram for Metro for Horizon year 2031 (Scenario -1)

The salient features of loading in the year 2031 are as follows:

- In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers of 68876.
- With respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority again as in 2021.
- The Peak hour peak direction passenger flow (PHPD) is maximum on Line 4 at 29927.

Ridership Estimation on Monorail Corridor

A monorail system was considered along the proposed HCMTS corridor. The ridership figures on this corridor are given in Table 8.9. The flow map showing the variation of ridership along the route is shown in Figures 8.8, 8.9 and 8.10 for the forecast years 2011, 2021 and 2031 respectively.

Table 8.9 Peak Hour loading for horizon years

YEAR	Length	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
2011	32	28232	149207	4662	11037	6648
2021	32	35160	157410	4919	15188	9149
2031	32	47050	214507	6703	18669	11246

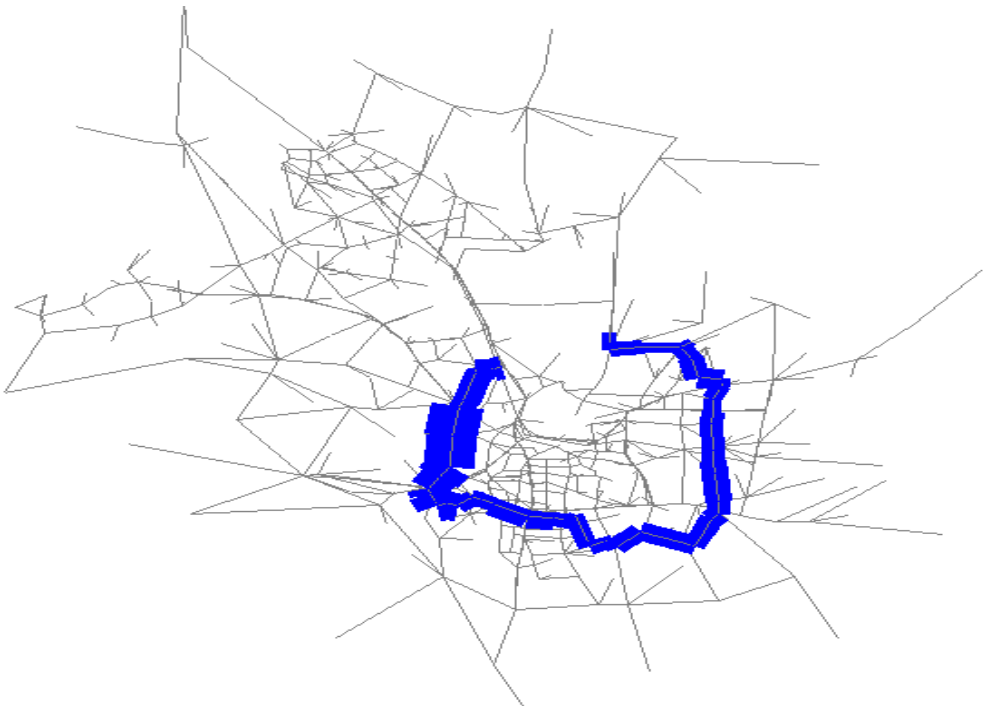

Figure 8.8 Flow Diagram for Monorail for Horizon year 2011 (Scenario-1)

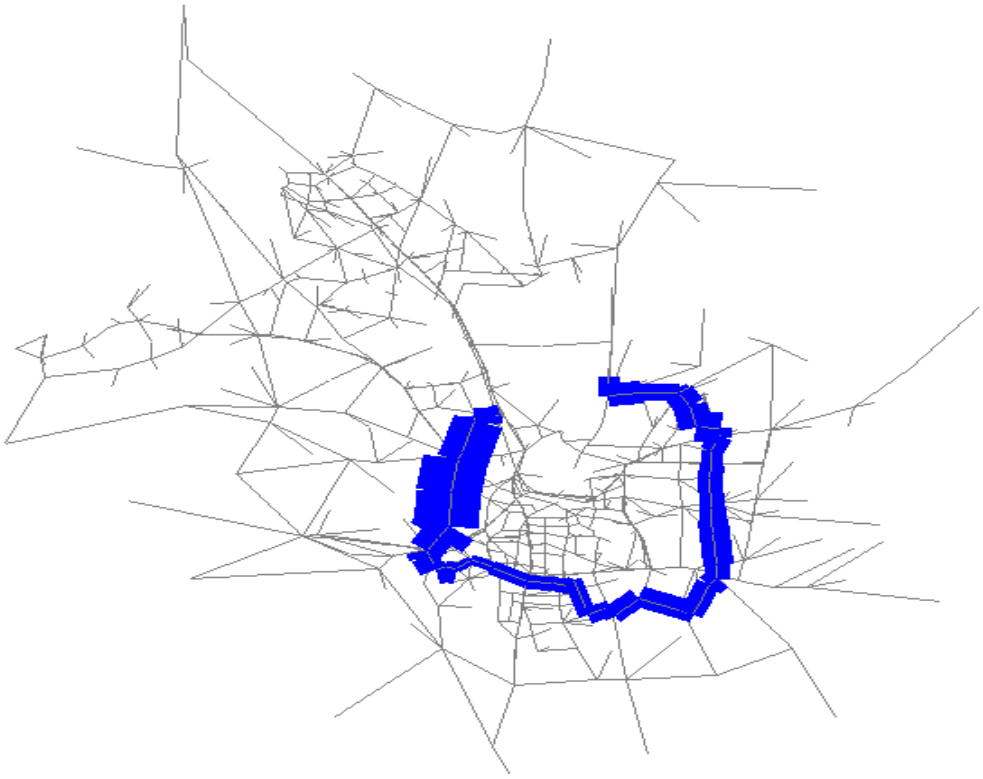

Figure 8.9 Flow Diagram for Monorail for Horizon year 2021 (Scenario-1)

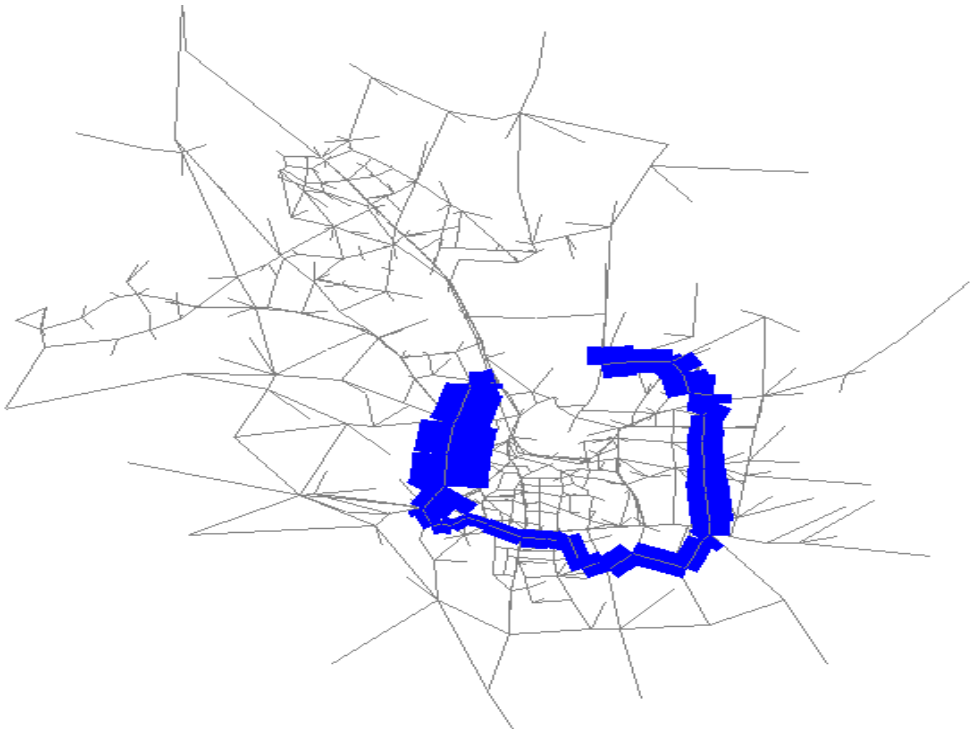

Figure 8.10 Flow Diagram for Monorail for Horizon year 2031 (Scenario 1)

Loadings on BRT Corridor

The BRT routes as finalized during the comprehensive mobility plan were considered and coded. Table 8.10 which describes about the passenger boardings and passenger distance of BRTS for future years, it can be observed that the passenger boardings are more in the year 2011 while in 2021 it reduces because the all the metro lines are expected to be implemented in the year 2021. The flow map showing the variation of ridership on BRT corridors is shown in Figures 8.11, 8.12 and 8.13 for the forecast years 2011, 2021 and 2031 respectively.

Table 8.10 Peak Hour Passenger Boardings and Passenger Distance for BRTS

	2011		2021		2031	
Mode	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)
BRTS	55276	186577	32234	93222	49098	140537

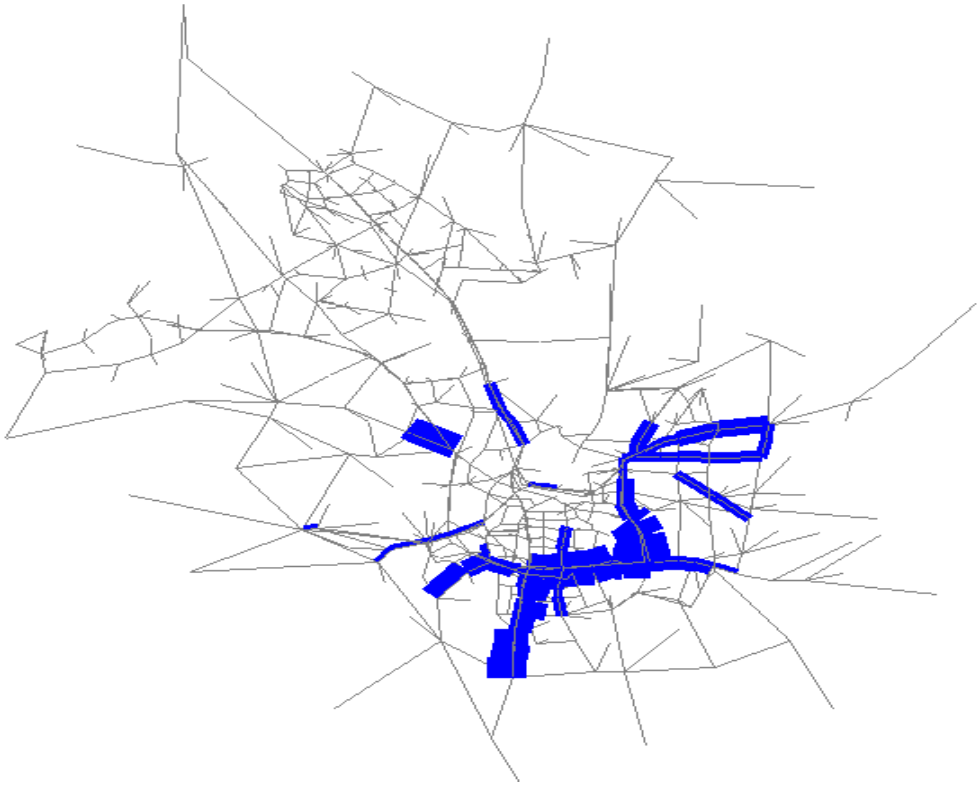

Figure 8.11 Flow Diagram for BRTS for Horizon year 2011 (Scenario -1)

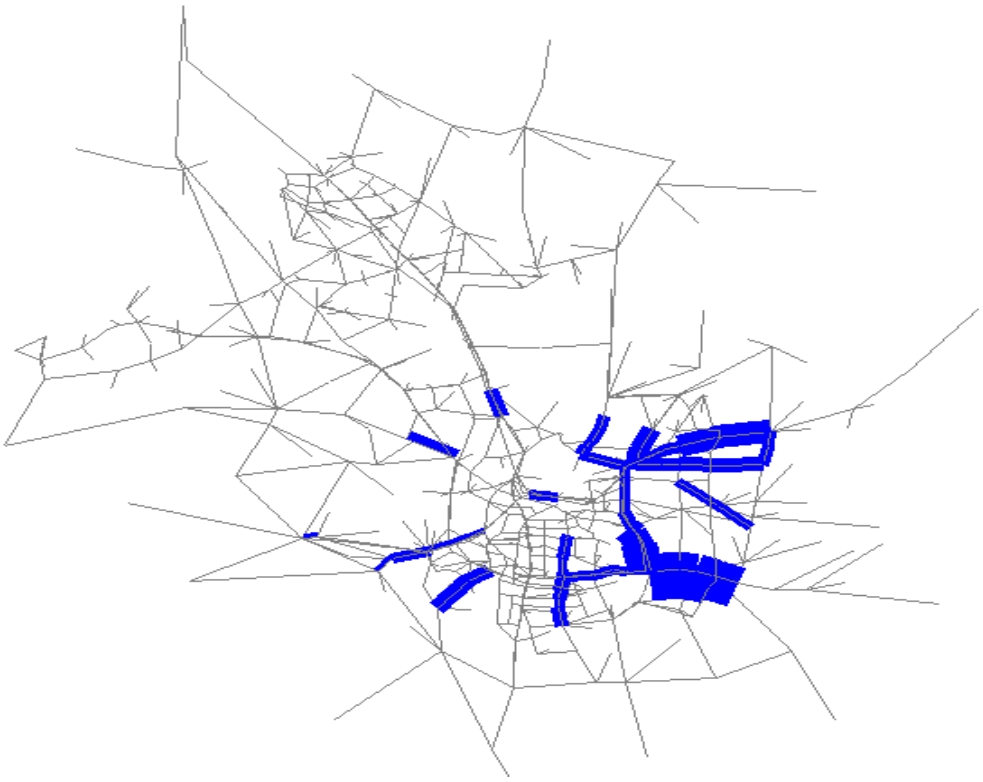

Figure 8.12 Flow Diagram for BRTS for Horizon year 2021 (Scenario-1)

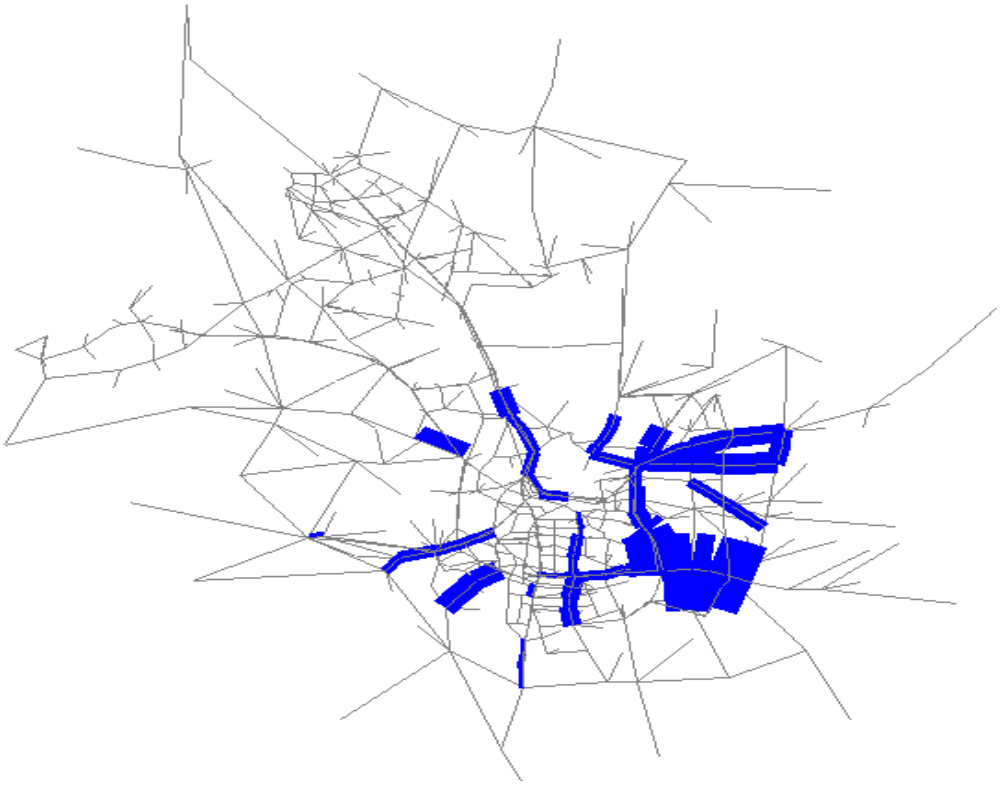

Figure 8.13 Flow Diagram for BRTS for Horizon year 2031 (Scenario-1)

8.4 EVALUATING SCENARIO 2 (INCREASING FSI ALONG THE METRO CORRIDOR)

In this scenario horizon years are considered as 2021 and 2031, wherein the transport network consists of metro. FSI of 4 is considered, 500 m along both the side of the metro corridor. The basic variables used in the four stage planning model are the population and the employment. Population and employment has been forecasted for years 2021 and 2031 and the distribution is done as per the land use scenario considered. Employment can be worked out with the type of commercial and industrial activity to be increased along the metro corridor.

8.4.1 Details of Forecast

The calibrated travel demand models have been incorporated in CUBE software. For each forecasting year the model is run in an iterative manner with complete feedback structure amongst the sub models. The overall travel estimated by the model in the above manner for the forecast years 2021, 2031 is given in Table 8.11(a).

Table 8.11(a) Estimated Travel for Base year and Forecast Years (Daily Passenger Trips) for Scenario 2

Mode	2021	2031
PT	3307700	3741537
PV	3104541	3500441
CV (PCU)	15395	15548
Total	6427636	7257526

*These are the passenger trips which include all the trips from internal to internal, internal to external and external to external also.

8.4.2 Calculating Area under influence of Metro

The zonal map is superimposed on the road network of the PMC region and the area along the metro corridor taking 500 m on both the side is been calculated for the zones through which the metro line is passing using the ArcGIS software. Figure 8.14 shows the area under the influence of metro. Also the zonal map of PMC (144 zones) is superimposed on Google Earth to study the land use pattern zonal wise as shown in Figure 8.15. The total area under the influence of metro for PMC area is given in Table 8.11(b).

Table 8.11(b) Area under influence of Metro

Total area of PMC Km^2	Area under influence of metro corridor Km^2
243.94	32.95

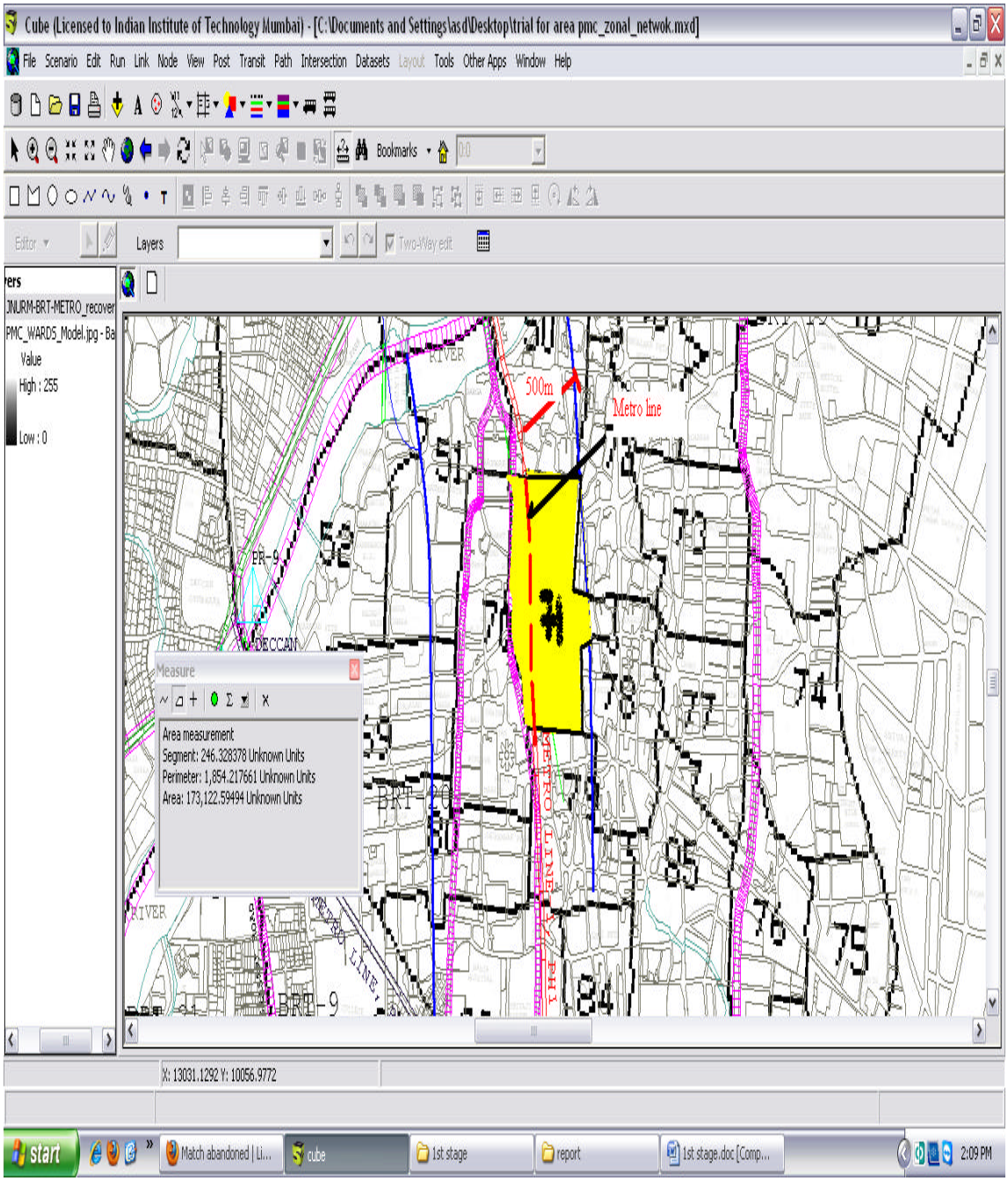

Figure 8.14 Area under influence of Metro line

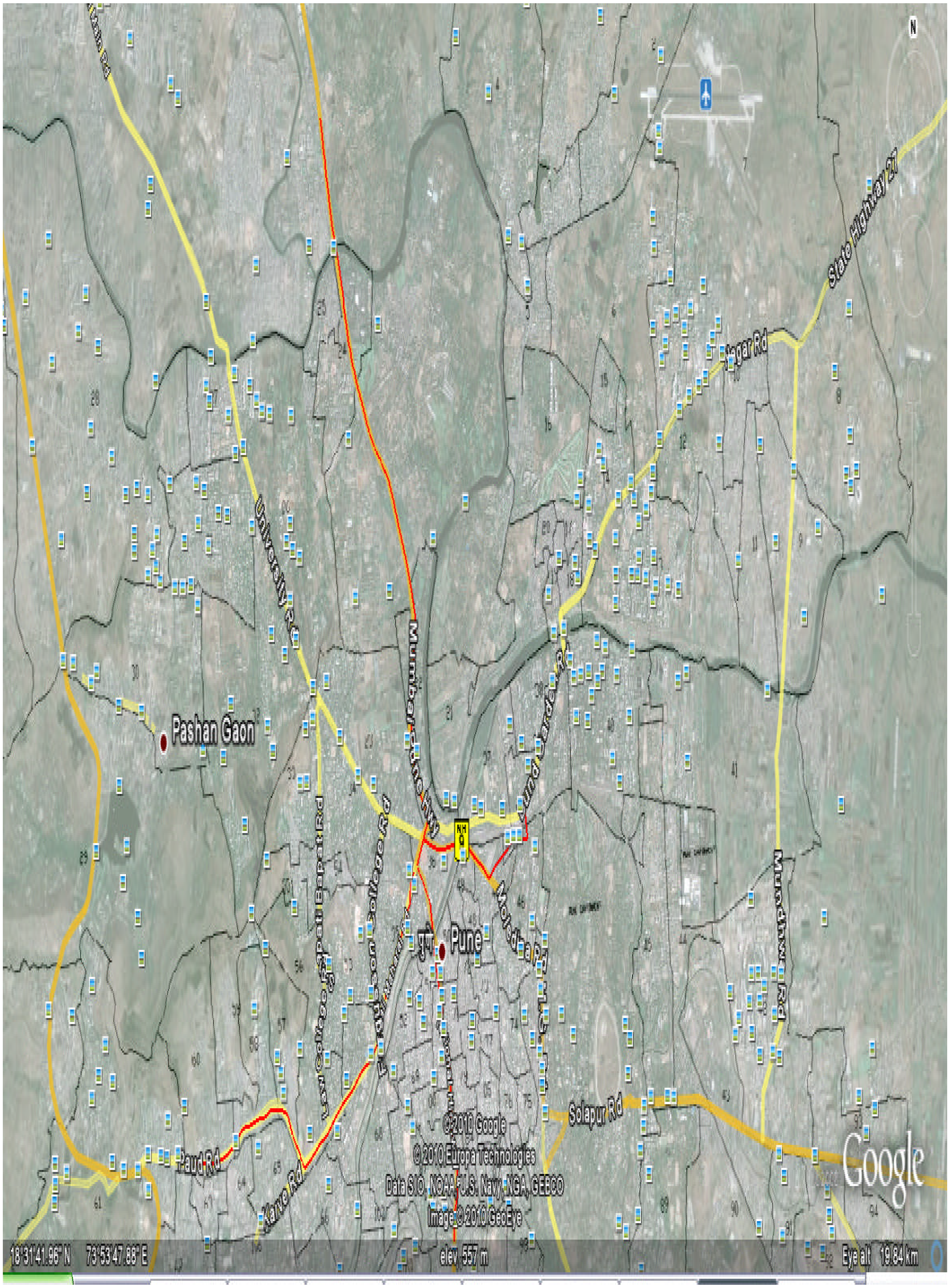

Figure 8.15 Superimpose of Zonal layer on Google Earth

8.4.3 Calculating Population and employment under influence of Metro

The population is estimated for the area under the influence of metro by taking the FSI of 4. This scenario is developed for horizon years 2021 and 2031 since 75% of the land has been used as a part of construction as per the DP plan implemented by the Pune Municipal Corporation.

The basic assumption made to calculate the population along metro corridor is as follow.

1) The size of each dwelling house is considered as 80 sq m.
2) Household size is taken as 4.
3) Also among FSI of 4, FSI 2 is provided for commercial activity and FSI 2 is provided for residential.

The population under influence of metro corridor for each zone is found out as follow:

Population= (Area under influence of metro) *FSI * 4 / size of each dwelling house

= (Area under influence of metro) * 2 * 4/ 80

Since the total population of the PMC in the horizon years will remain same, the population for all other zones has been calculated as per the prevailing condition of land use pattern of individual zones.

The basic assumption made to calculate the employment along metro corridor is as follow.

1) Employment is considered as 12 people per 1000 sq. m area.
2) Also among FSI of 4, FSI 2 is provided for commercial activity and FSI 2 is provided for residential.

The employment under influence of metro corridor for each zone is found out as follow:

Employment= (Area under influence of metro) *FSI * (employment/area)

= (Area under influence of metro) * 2*12 /1000

Since the total employment of the PMR in the horizon years will remain, the employment for all other zones is been calculated as per the prevailing condition of land use pattern of individual zones. The zone wise population and employment data is given in Annexure I.

8.4.4 Comparing the Trip length distribution

The Trip length Frequency Distributions for all different category has been compared between the Scenario 1 (Increasing the FSI along Metro Corridor) and the Usual Land use scenario as displayed in Figure 8.16(a), 8.16(b) & 8.16(c). The average trip length for different category of groups is given in Table 8.12.

Table 8.12 Comparison table forAverage Trip length for two different land use scenario

Scenario	Group Category	Average Trip length in terms of Highway Time (Mins)	
		2021	2031
Land Use Scenario 1- Usual land use scenario	No vehicle owning group	33.8	34.6
	TW owning group	35.7	36.5
	Car owning gr oup	34.4	35.2
Land Use Scenario 2- Increasing FSI along metro corridor	No vehicle owning group	25.7	26.6
	TW owning group	26.5	27.3
	Car owning group	25.5	25.7

From the above Table 8.12, it can be observed that for a horizon year 2021, the average reduction in the trip length in Scenario 2 when compared with Scenario 1 is approx 9 mins. So overall 25% reduction is observed in average trip length in Scenario 2 when compared with Scenario 1.

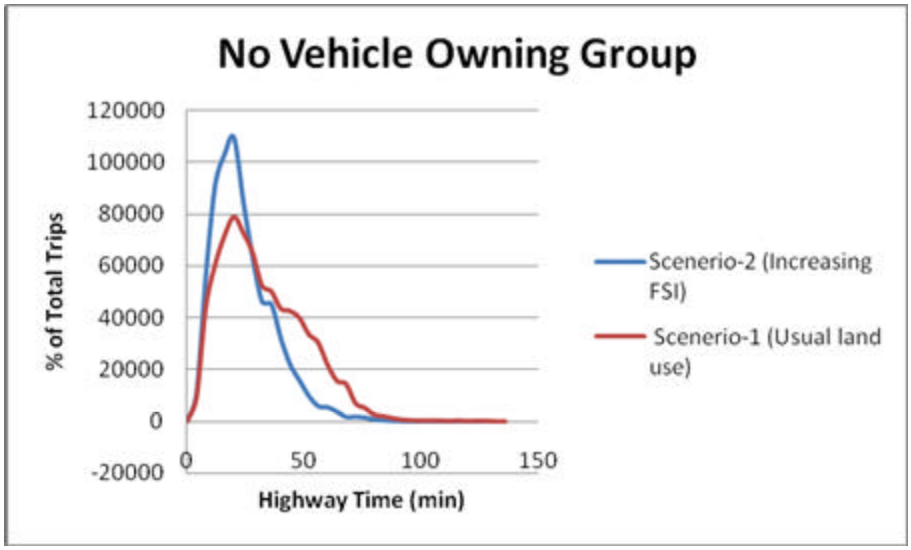

Figure 8.16 (a) Trip Length Frequency Distributions corresponding to no vehicle group (2021)

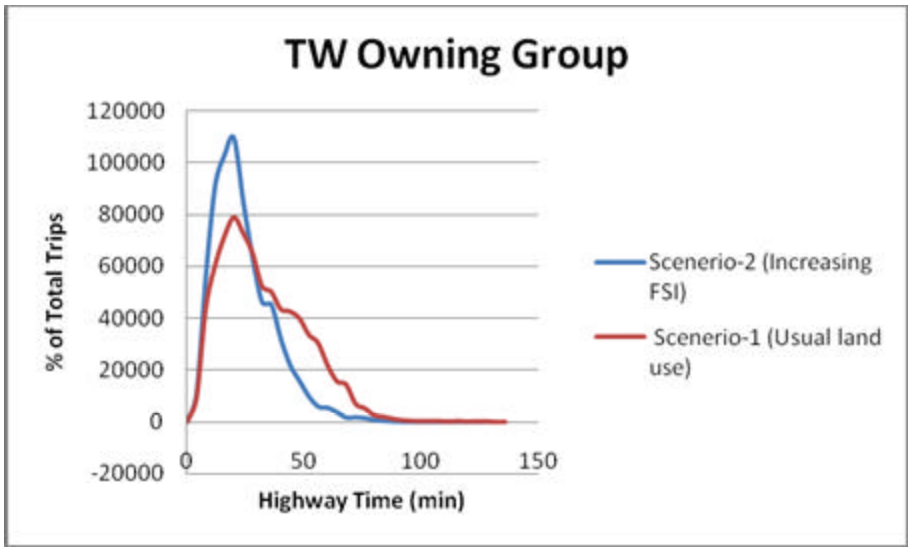

Figure 8.16 (b) Trip Length Frequency Distributions corresponding to 2-wheeler owning group (2021)

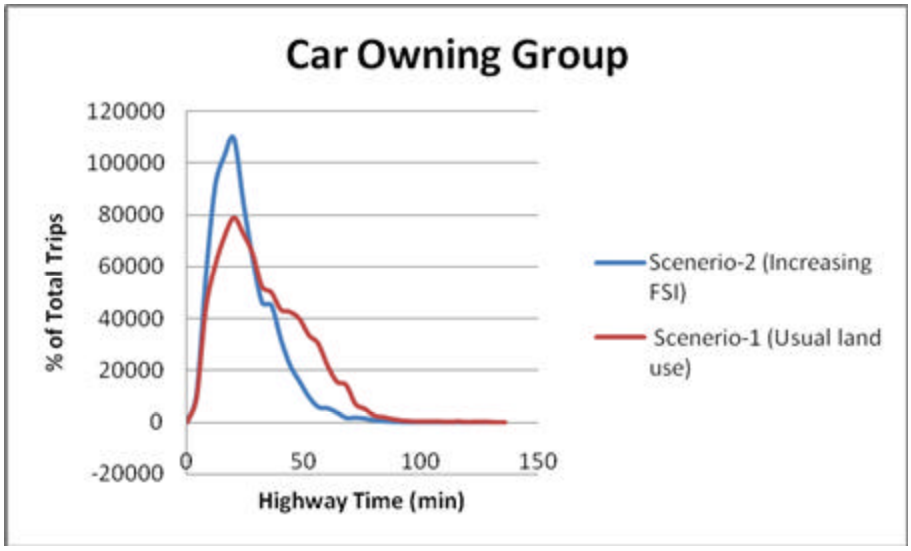

Figure 8.16 (c) Trip Length Frequency Distributions corresponding to car owning group (2021)

8.4.5 Comparing the distribution of passenger trips on different modes between scenario 1 and scenario 2

Tables 8.13(a) and 8.13(b) shows comparison of the Passenger boardings and passenger distance for different P.T modes for horizon years 2021 and 2031 between Scenario 1 and Scenario 2 wherein the transport network consist of metro in both the scenario.

Table 8.13(a) Peak Hour Passenger boardings and passenger distance for different P.T modes for horizon year 2021

	Scenario 1 (Usual scenario)		Scenario 2 (Increasing FSI along metro corridor)	
Mode	**Passenger Boarding**	**Passenger Distance (km)**	**Passenger Boarding**	**Passenger Distance (km)**
BUS	107899	422375	104818	374739
IPT	30807	100084	19713	55340
TRAIN	326	4945	8.8	125
BRTS	32234	93222	24465	62388
METRO	217654	1528152	222356	1370980
MONO RAIL	35160	157410	32759	119726

Table 8.13(b) Peak Hour Passenger boardings and passenger distance for different P.T modes for horizon year 2031

	Scenario 1 (Usual scenario)		Scenario 2 (Increasing FSI along metro corridor)	
Mode	**Passenger Boarding**	**Passenger Distance (km)**	**Passenger Boarding**	**Passenger Distance (km)**
BUS	119804	456826	112311	394997
IPT	36244	114333	24437	69465
TRAIN	372	5610	9	135
BRTS	49098	140537	27090	68528
METRO	289960	2135564	245623	1533537
MONO RAIL	47050	214506	36635	137043

8.4.6 Ridership estimation for Metro

The estimated loading for horizon years 2021 and 2031 is displayed in Tables 8.14(a) and 8.14(b). The corresponding flow map is given in Figures 8.17(a) and 8.17(b).

Table 8.14(a) Peak Hour Metro Loading for the Year 2021

		Scenario 1 - Usual Land Use				
LINE NAME	**Length (km)**	**Passenger Boardings**	**Passenger Distance**	**Passenger - km/km**	**Combined max link load**	**PPHPD**
AC to Nigdi	15.86	41133	346723	21861	30575	18418
AC to Hinjewadi	15.65	41711	437427	27950	32405	19521
AC to Katraj	12.01	36449	254099	21157	26548	15992
Chandini Chowk to Ramwadi	17.96	54677	283289	15773	39225	23629
Deccan GymKhana to Yarawada Bridge	13.94	45040	214817	15410	24403	14700
		Scenario 2 - Increasing FSI				
LINE NAME	**Length (km)**	**Passenger Boardings**	**Passenger Distance**	**Passenger - km/km**	**Combined max link load**	**PPHPD**
AC to Nigdi	15.86	37255	250765	16811	26826	16160
AC to Hinjewadi	15.65	40813	354212	22633	26927	16221
AC to Katraj	12.01	40558	278654	23201	27988	16860
Chandini Chowk to Ramwadi	17.96	54057	256293	14291	32347	19485
Deccan GymKhana to Yarawada Bridge	13.94	49672	231057	16575	25023	15073

The salient features of loading in the year 2021 are as follows:

• From the Table 8.13(a), it can be observed there is a 14% reduction in the passenger distance (km) for Scenario-2 when compared with Scenario-1. This is due to mix land use plan i.e. increasing FSI for both residential and employment.

• Also from the ridership estimation Table 8.14(a), it is observed that most of the metro lines are getting more or less same PPHPD. The maximum PPHPD is for line 4.

• However, with respect to the index of Passenger kilometers per kilometer, Line 3 gets the first priority followed by Line 2 and Line 1.

Table 8.14(b) Peak Hour Metro Loading for the Year 2031

		Scenario 1- Usual Land Use				
LINE NAME	**Length (km)**	**Passenger Boardings**	**Passenger Distance**	**Passenger-km/km**	**Combined max link load**	**PPHPD**
AC to Nigdi	15.86	55823	472570	29796	40261	24253
AC to Hinjewadi	15.65	58452	632314	40403	46972	28296
AC to Katraj	12.01	49996	396338	33000	36069	21728
Chandini Chowk to Ramwadi	17.96	68876	361098	20105	49680	29927
Deccan GymKhana to Yarawada Bridge	13.94	56812	273724	19635	30789	18547
		Scenario 2- Increasing FSI				
LINE NAME	**Length (km)**	**Passenger Boardings**	**Passenger Distance**	**Passenger-km/km**	**Combined max link load**	**PPHPD**
AC to Nigdi	15.86	42394	280532	17688	28902	17410
AC to Hinjewadi	15.65	50819	453573	28982	36092	21742
AC to Katraj	12.01	42061	283870	23636	28793	17345
Chandini Chowk to Ramwadi	17.96	57333	271666	15126	34105	20545
Deccan GymKhana to Yarawada Bridge	13.94	53014	243893	17496	26379	15890

The salient features of loading in the year 2031 are as follows:

• From the Table 8.13(b) , it can be observed there is a 28% reduction in the passenger distance (km) for Scenario-2 when compared with Scenario-1. This is due to mix land use plan i.e. increasing FSI for both residential and employment.

• Also from the ridership estimation Table 8.14(b), it is observed that PPHPD of the metro lines are varying. The maximum PPHPD is for line 4.

• However, with respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority followed by Line 3 and Line 1.

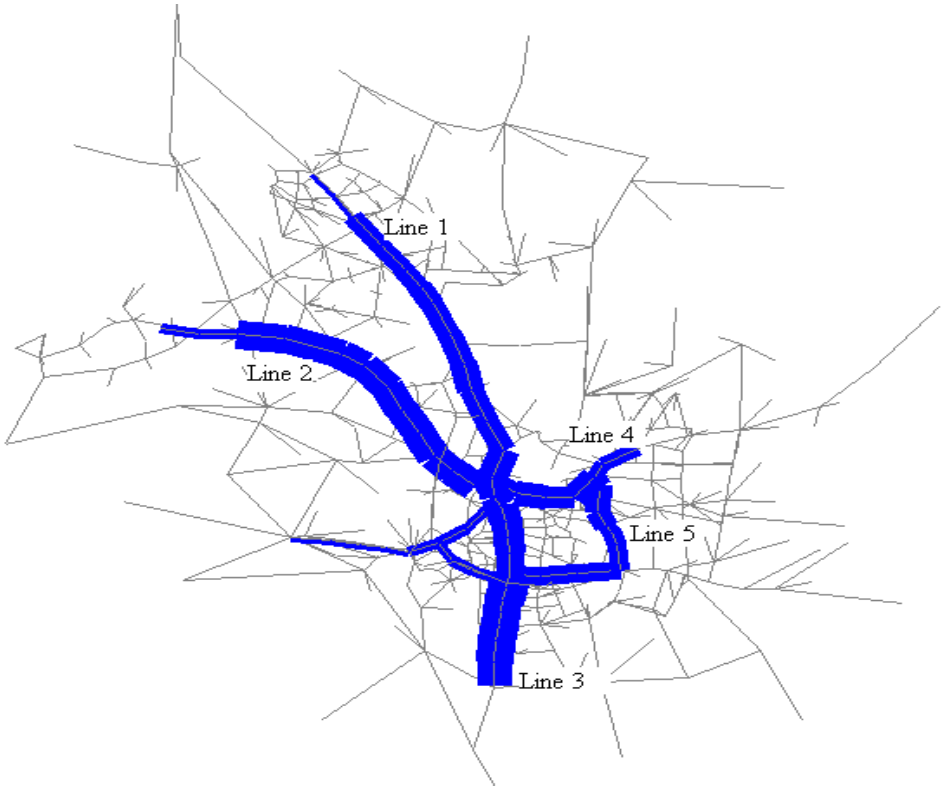

Figure 8.17 (a) Flow Diagram for Metro for Horizon year 2021 (Scenario- 2)

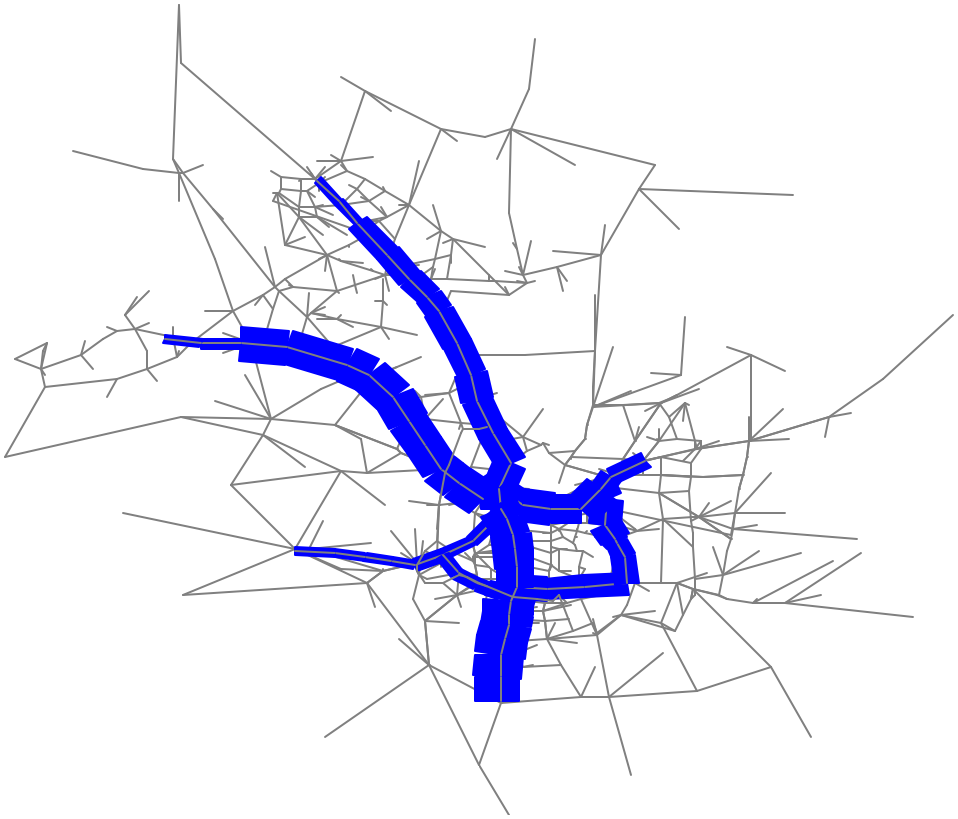

Figure 8.17 (b) Flow Diagram for Metro for Horizon year 2031 (Scenario- 2)

8.4.7 If PT is improved, how much percentage of people are shifting from PV to PT

The percentage share by PT and PV for the years 2021 and 2031 is given in the Tables 8.15 (a) and 8.15(b). From these tables the percentage shift can be obtained by comparing land use scenario-1 with scenario-2. Hence 5% shift is been observed from PV to PT in Scenario 2 when compared with Scenario 1.

Table 8.15(a) Proportion of passenger trips for scenario 1 and scenario 2

	2021	
	Scenario 1	**Scenario 2**
% PT Share	48.5%	51%
% PV Share	51.5%	49%

Table 8.15(b) Proportion of passenger trips for scenario 1 and scenario 2

	2031	
	Scenario 1	**Scenario 2**
% PT Share	49.5%	51.7%
% PV Share	50.5%	48.3%

8.5 EVALUATING SCENARIO 3 (Public Transport Share of 80%)

A hypothetical scenario has been developed considering the Public Transport share of 80% for the horizon year 2021 and 2031. The traffic has been forecasted for base year horizon year 2021 and 2031. Comparison is done based on different parameters which are described in the following sections.

8.5.1 Details of Forecast

The calibrated travel demand models have been incorporated in CUBE software. For each forecasting year the model is run in an iterative manner with complete feedback structure amongst the sub models. The overall travel estimated by the model in the above manner for the forecast years 2021, 2031 is given in Table 8.16. The model also gives the demand by individual modes for various network scenarios.

Table 8.16 Estimated Travel for Base year and Forecast Years (Daily Passenger Trips) for Scenario 3

Mode	2021	2031
PT	5045786	6170485
PV	1366444	1714699
CV (PCU)	15395	15548
Total	6427625	7900732

*These are the passenger trips which include all the trips from internal to internal, internal to external and external to external also.

8.5.2 LOADINGS CORRESPONDING TO PROPOSED TRANSIT MODES

The existing and proposed public transport systems were considered in the model and the ridership for all these modes was worked out for the future years 2021 and 2031 considering a standard land use scenario. Table 8.17 provides the summary of loadings on all these transit systems. The details of ridership estimation mode wise are discussed in the following sections.

Table 8.17 Comparison of Peak Hour Passenger Boardings and Passenger Distance for all modes between Scenario 1 and Scenario 3

	Scenario 1				Scenario 3			
	2021		2031		2021		2031	
Mode	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)
BUS	107899	422375	119804	456826	214854	2236964	234821	2291674
IPT	30807	100084	36244	114333	35438	114027	49710	150637
TRAIN	326	4945	372	5610	282	4291	1438	21027
BRTS	32234	93222	49098	140537	67621	184887	97204	252908
METRO	217654	1528152	289960	2135564	336481	2319802	401953	2779827
MONO RAIL	35160	157409	47050	214506	66754	295954	91977	447707
TOTAL	424080	2306187	542528	3067376	721431	5155924	877103	5943781

8.5.3 Ridership Estimation

Ridership estimation on Metro Corridors

The forecast of ridership on all these lines for each of the forecast year has been presented below:

Forecast for Year 2021 : The estimated loading for horizon year 2021 is displayed in Table 8. 18. The corresponding flow map is given in Figure 8.18.

Table 8.18 Peak Hour Metro Loading for the Year 2021 (Scenario-3)

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	63971	515773	32520	46104	27662
AC to Hinjewadi	15.65	67332	693830	44334	50630	30378
AC to Katraj	12.01	49567	307719	25622	34844	20906
Chandini Chowk to Ramwadi	17.96	89603	466904	25997	59578	35747
Deccan GymKhana to Yarawada Bridge	13.94	66007	336318	24126	31777	19066

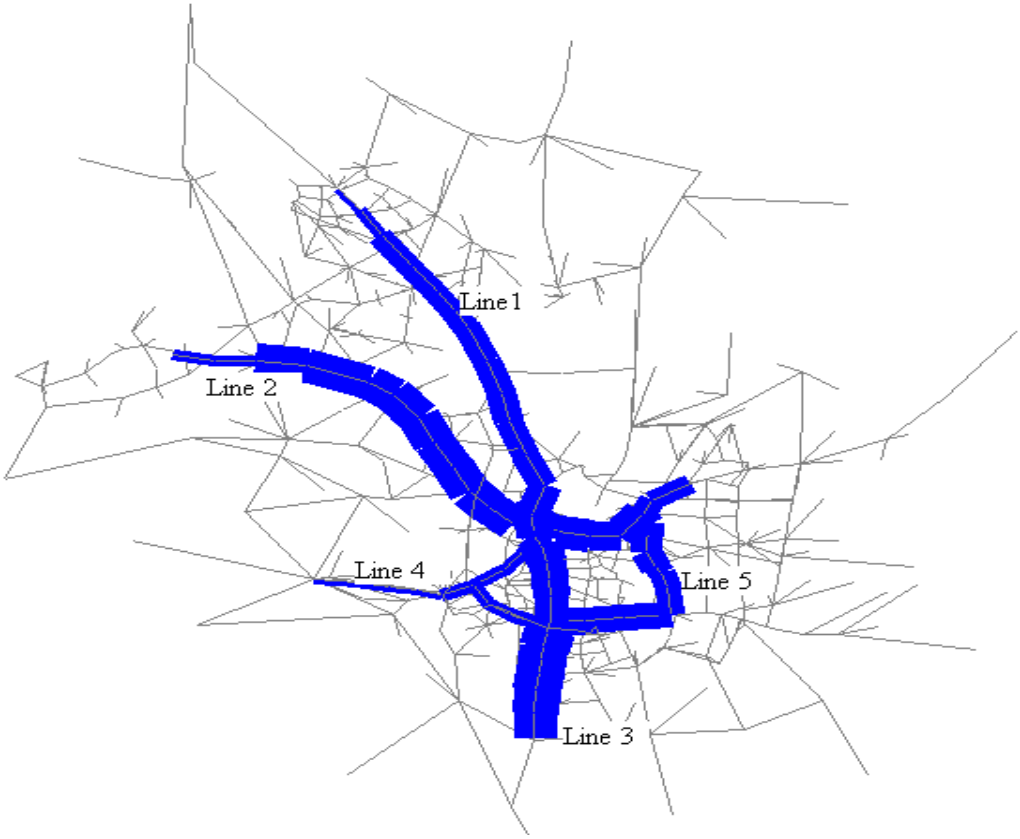

Figure 8.18 Flow Diagram for Metro for Horizon year 2021 (Scenario-3)

The salient features of loading in the year 2021 are as follows:

• In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers.

• The Peak hour peak direction passenger flow (PHP D) is maximum on Line 4 at 35747.

• However, with respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority followed by Line 1 and Line 3.

Forecast for Year 2031 : The estimated loadings for horizon year 2031 are shown in Table 8.19. The corresponding flow map is given in Figure 8.19.

Table 8.19 Peak Hour Metro Loading for the Year 2031

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger-km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	79450	643123	40550	52819	31691
AC to Hinjewadi	15.65	84656	808746	51677	59490	35694
AC to Katraj	12.01	60956	416682	34695	40593	24356
Chandini Chowk to Ramwadi	17.96	99085	497625	27707	62891	37735
Deccan GymKhana to Yarawada Bridge	13.94	77804	414428	29729	36510	21906

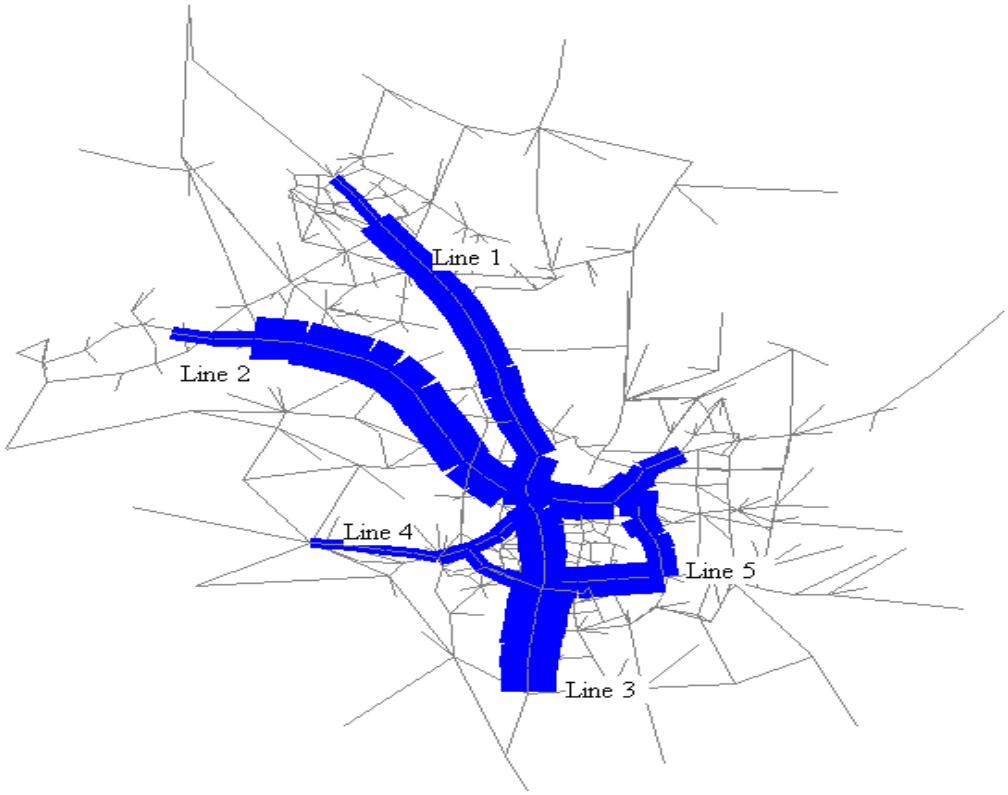

Figure 8.19 Flow Diagram for Metro for Horizon year 2031 (Scenario-3)

The salient features of loading in the year 2031 are as follows:

- In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers.
- With respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority again as in 2021.
- The Peak hour peak direction passenger flow (PHPD) is maximum on Line 4.

Ridership Estimation on Monorail Corridor

A monorail system was considered along the proposed HCMTS corridor. The ridership figures on this corridor are given in Table 8.20. The flow map showing the variation of ridership along the route is shown in Figures 8.20, and 8.21 for the forecast years 2021 and 2031 respectively.

Table 8.20 Peak Hour loading for horizon years

YEAR	Length	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
2021	32	66754	295954	9249	28098	16859
2031	32	91977	447707	13991	35471	21283

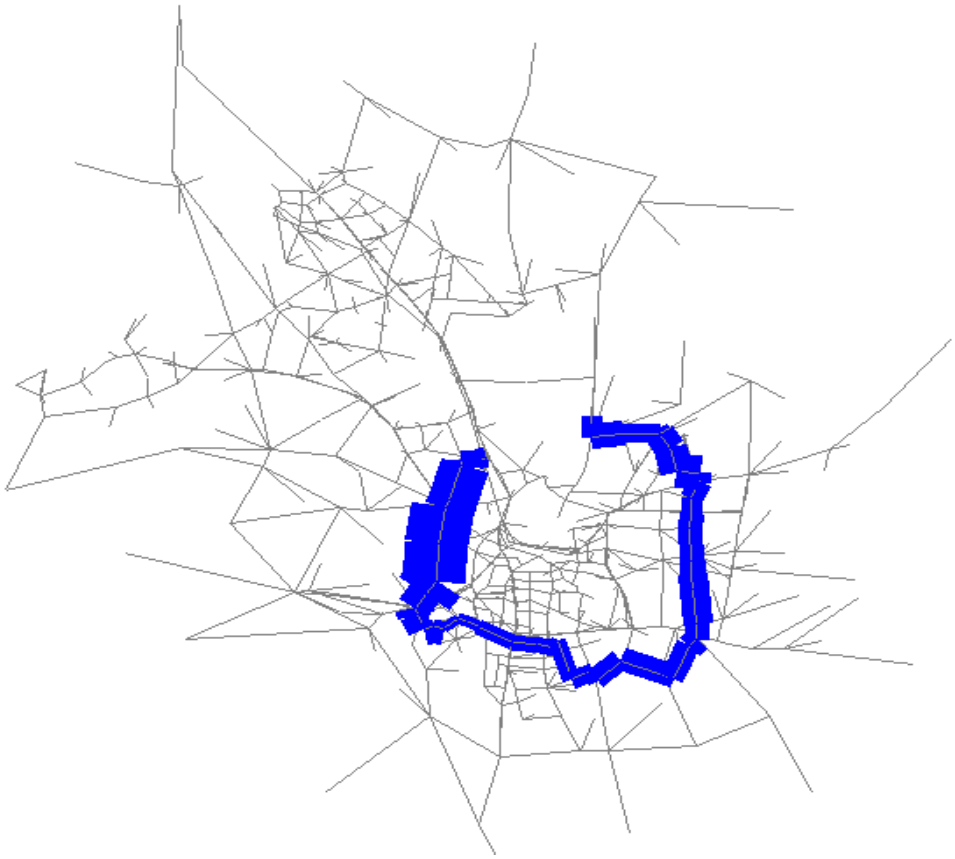

Figure 8.20 Flow Diagram for Monorail for Horizon year 2021 (Scenario -3)

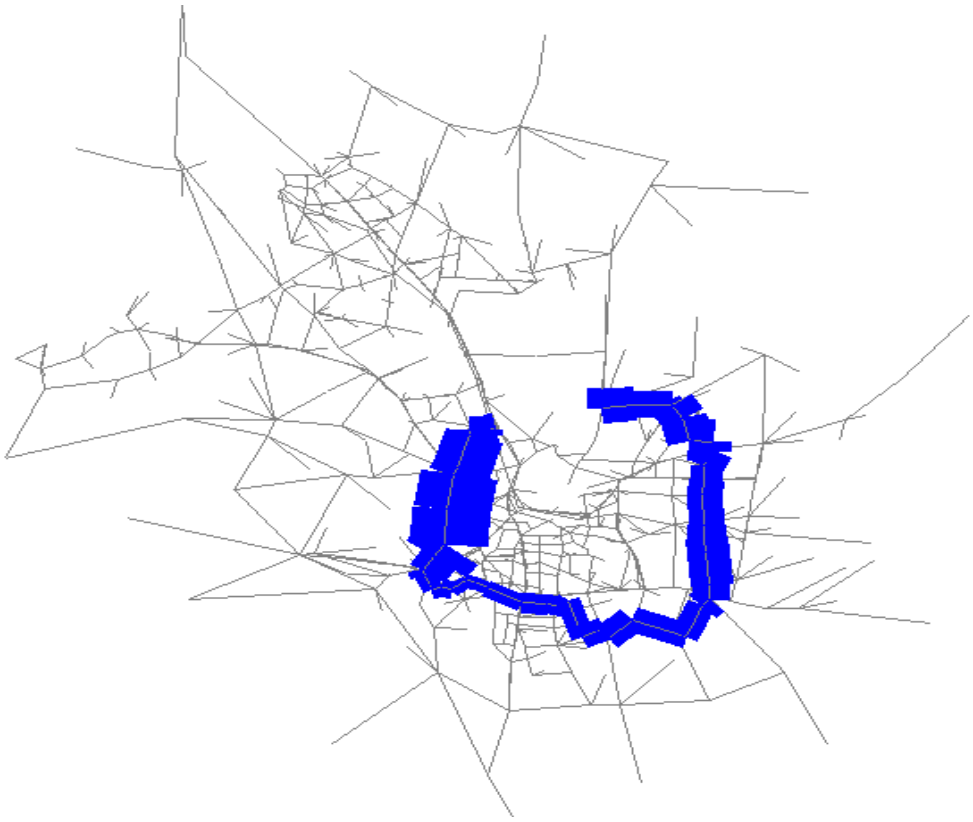

Figure 8.21 Flow Diagram for Monorail Horizon year 2031 (Scenario -3)

Loadings on BRT Corridor

The BRT routes as finalized during the comprehensive mobility plan were considered and coded. Table 8.20 which describes about the passenger boardings and passenger distance of BRTS for future yearsThe flow map showing the variation of ridership on BRT corridors is shown in Figures 8.22, and 8.23 for the forecast years 2021 and 2031 respectively.

Table 8.21 Peak Hour Passenger Boardings and Passenger Distance for BRTS

	2021		2031	
Mode	**Passenger Boardings**	**Passenger Distance (km)**	**Passenger Boardings**	**Passenger Distance (km)**
BRTS	67621	184887	97204	252908

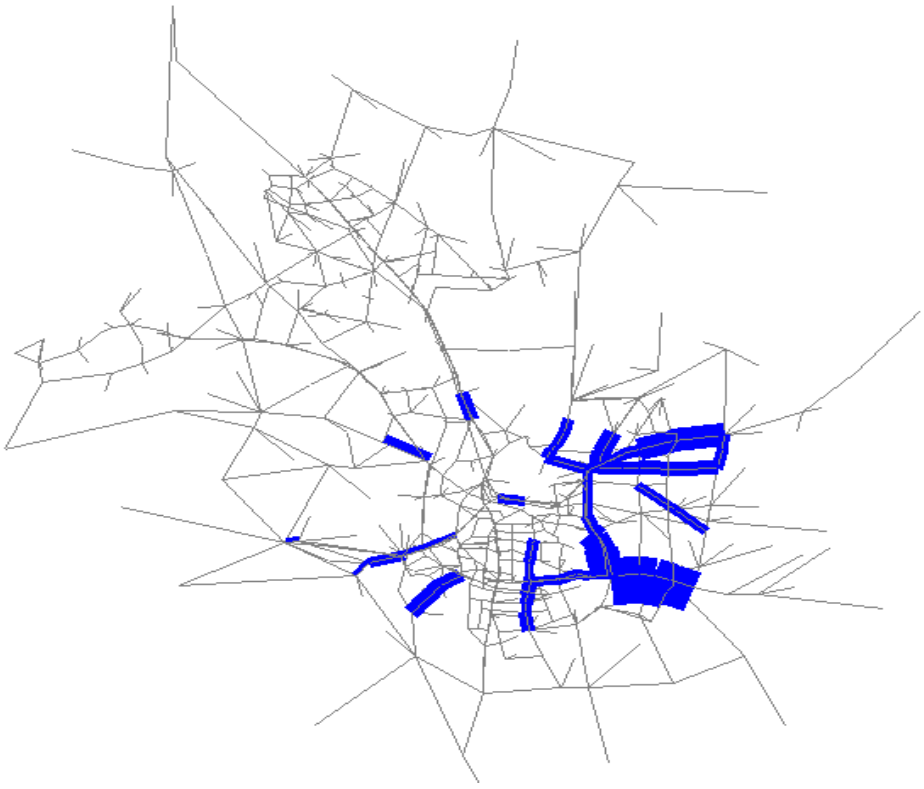

Figure 8.22 Flow Diagram for BRTS for Horizon year 2021 (Scenario-3)

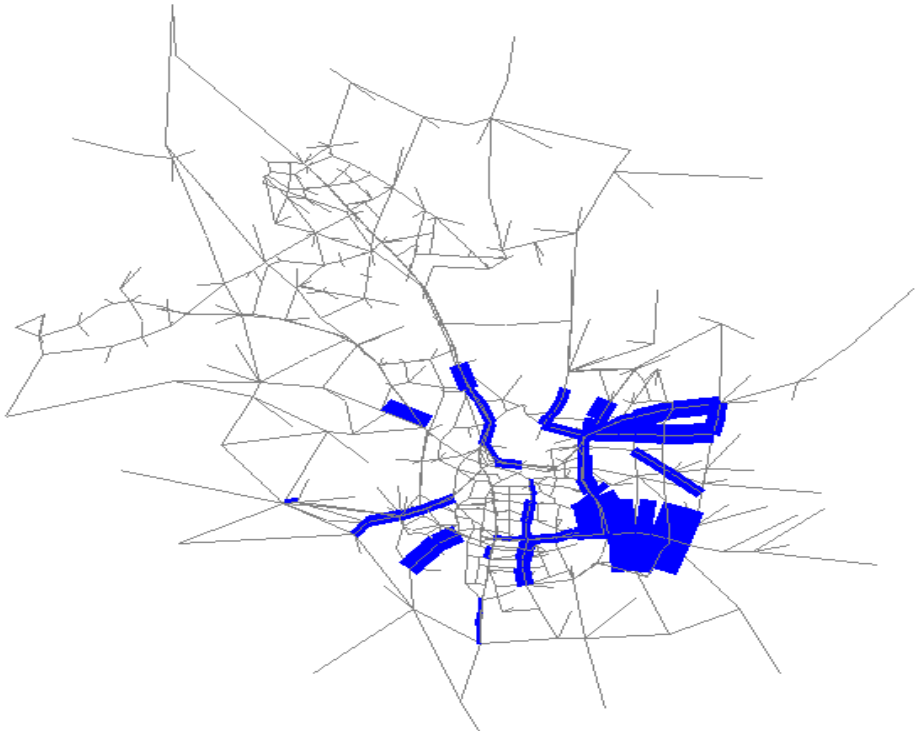

Figure 8.23 Flow Diagram for BRTS for Horizon year 2031 (Scenario-3)

8.6 EVALUATING SCENARIO 4 (Work Participation Ratio as 0.6)

The Pune municipal corporation is planning for achieving work participation ratio of 0.6. So a hypothetical scenario has been developed considering the work participation ratio as 0.6. Employment is been considered as per the usual land use scenario. The traffic has been forecasted for base year horizon year 2021 and 2031. Comparison is done based on different parameters which are described in the following sections.

8.6.1 Details of Forecast

The calibrated travel demand models have been incorporated in CUBE software. For each forecasting year the model is run in an iterative manner with complete feedback structure amongst the sub models. The overall travel estimated by the model in the above manner for the forecast years 2021, 2031 is given in Table 8.22. The model also gives the demand by individual modes for various network scenarios.

Table 8.22 Estimated Travel for Base year and Forecast Years (Daily Passenger Trips)

	Scenario 1		Scenario 4	
Mode	**2021**	**2031**	**2021**	**2031**
PT	3050631	3900096	3639251	4663259
PV	3361606	3985096	4261023	4981778
CV (PCU)	15338	16005	15395	15548
Total	6427575	7901197	7915669	9660585

*These are the passenger trips which include all the trips from internal to internal, internal to external and external to external also.

From the above Table 8.22, it can be inferred that due to increase in work participation ratio, 23% increase in number of passenger trips for horizon year 2011 & 2031 has been observed when compared with Scenario 1.

8.6.2 LOADINGS CORRESPONDING TO PROPOSED TRANSIT MODES

The existing and proposed public transport systems were considered in the model and the ridership for all these modes was worked out for the future years 2021 and 2031 considering a standard land use scenario. Table 8.23 provides the summary of loadings on all these transit systems. The details of ridership estimation mode wise are discussed in the following sections.

Table 8.23 Peak Hour Passenger Boardings and Passenger Distance for all modes

	Scenario 1				Scenario 4			
	2021		2031		2021		2031	
Mode	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)	Passenger Boardings	Passenger Distance (km)
BUS	107899	422375	119804	456826	187520	2144029	200564	2191081
IPT	30807.2	100084	36244	114333	37081	119440	46468	140228
TRAIN	326	4945	372	5610	477	7113	522	7661
BRTS	32234	93222	49098	140537	42663	120255	63928	175685
METRO	217654	1528152	289960	2135564	257602	1816065	335871	2435751
MONO RAIL	35160	157409	47050	214506	43948	196852	62277	290209
TOTAL	424080	2306187	542528	3067376	569290	4403753	709630	5240616

8.6.3 Ridership Estimation

Ridership estimation on Metro Corridors

The forecast of ridership on all these lines for each of the forecast year has been presented below:

Forecast for Year 2021: The estimated loading for horizon year 2021 is displayed in Table 8.24. The corresponding flow map is given in Figure 8.24.

Table 8.24 Peak Hour Metro Loading for the Year 2021

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	50262	418794	26406	36295	21777
AC to Hinjewadi	15.65	52083	549453	35109	40342	24205
AC to Katraj	12.01	39091	261900	21807	28238	16943
Chandini Chowk to Ramwadi	17.96	66101	345344	19229	46170	27702
Deccan GymKhana to Yarawada Bridge	13.94	50065	241064	17293	27024	16214

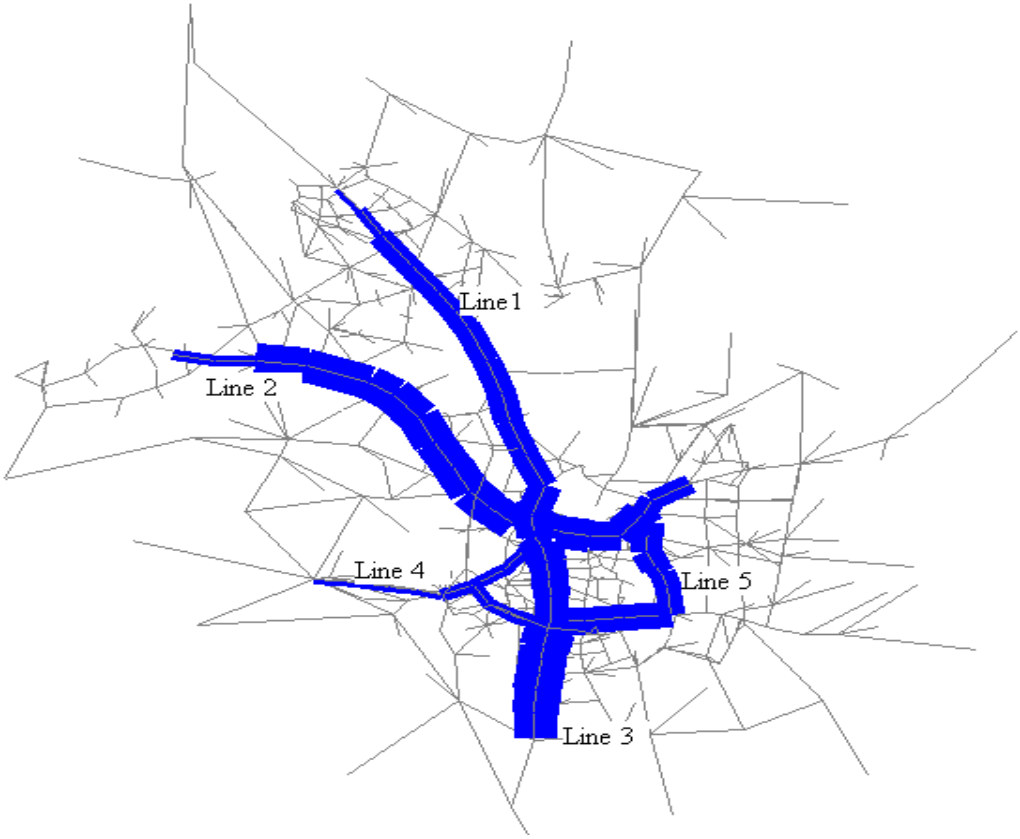

Figure 8.24 Flow Diagram for Metro for Horizon year 2021 (Scenario-4)

The salient features of loading in the year 2021 are as follows:

• In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers.

• The Peak hour peak direction passenger flow (PHP D) is maximum on Line 4 at 27702.

• However, with respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority followed by Line 1 and Line 3.

Forecast for Year 2031 : The estimated loadings for horizon year 2031 are shown in Table 8.25. The corresponding flow map is given in Figure 8.25.

Table 8.25 Peak Hour Metro Loading for the Year 2031

LINE NAME	Length (km)	Passenger Boardings	Passenger Distance	Passenger-km/km	Combined max link load	PPHPD
AC to Nigdi	15.86	67757	563752	35546	47209	28325
AC to Hinjewadi	15.65	71565	732878	46829	53723	32234
AC to Katraj	12.01	53532	401532	33433	37488	22493
Chandini Chowk to Ramwadi	17.96	81158	426558	23750	55715	33429
Deccan GymKhana to Yarawada Bridge	13.94	61858	311641	22356	31585	18951

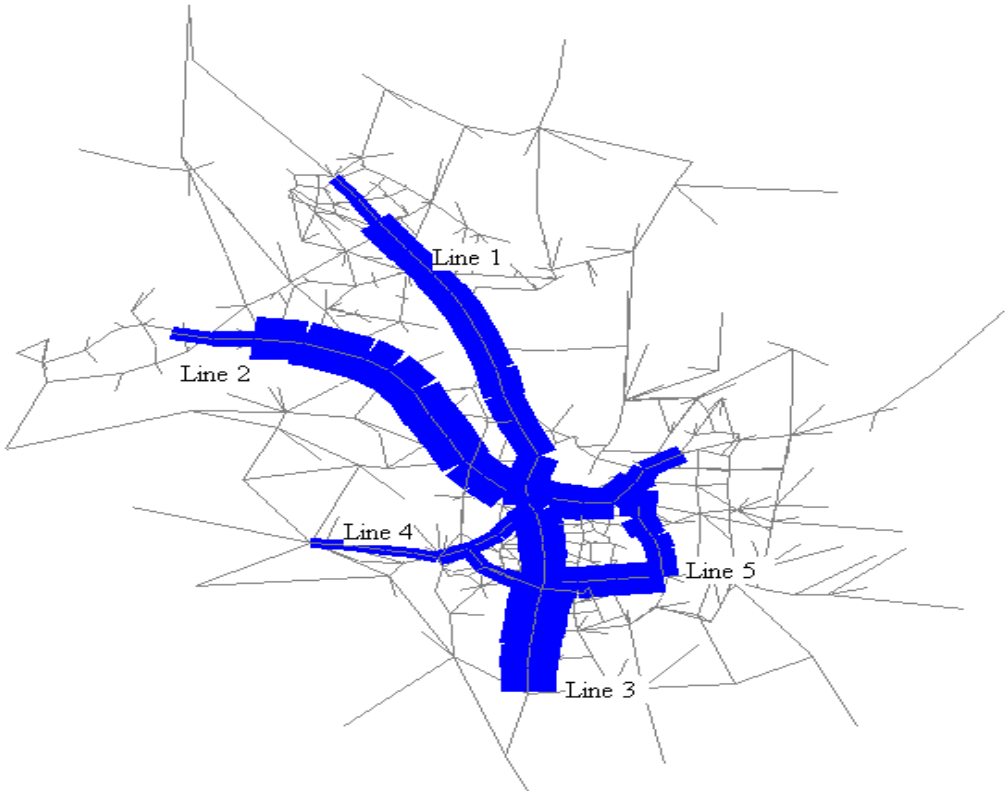

Figure 8.25 Flow Diagram for Metro for Horizon year 2031 (Scenario-4)

The salient features of loading in the year 2031 are as follows:

- In terms of peak hour passenger boarding Line 4 ruining form Chandini Chowk to Ramwadi carries the maximum number of passengers.
- With respect to the index of Passenger kilometers per kilometer, Line 2 gets the first priority again as in 2021.
- The Peak hour peak direction passenger flow (PHPD) is maximum on Line 4.

Ridership Estimation on Monorail Corridor

A monorail system was considered along the proposed HCMTS corridor. The ridership figures on this corridor are given in Table 8.26. The flow map showing the variation of ridership along the route is shown in Figures 8.26, and 8.27 for the forecast years 2021 and 2031 respectively.

Table 8.26 Peak Hour loading for horizon years

YEAR	Length	Passenger Boardings	Passenger Distance	Passenger km/km	Combined max link load	PPHPD
2021	32	43948	196852	6152	18985	11391
2031	32	62277	290209	9069	23336	14002

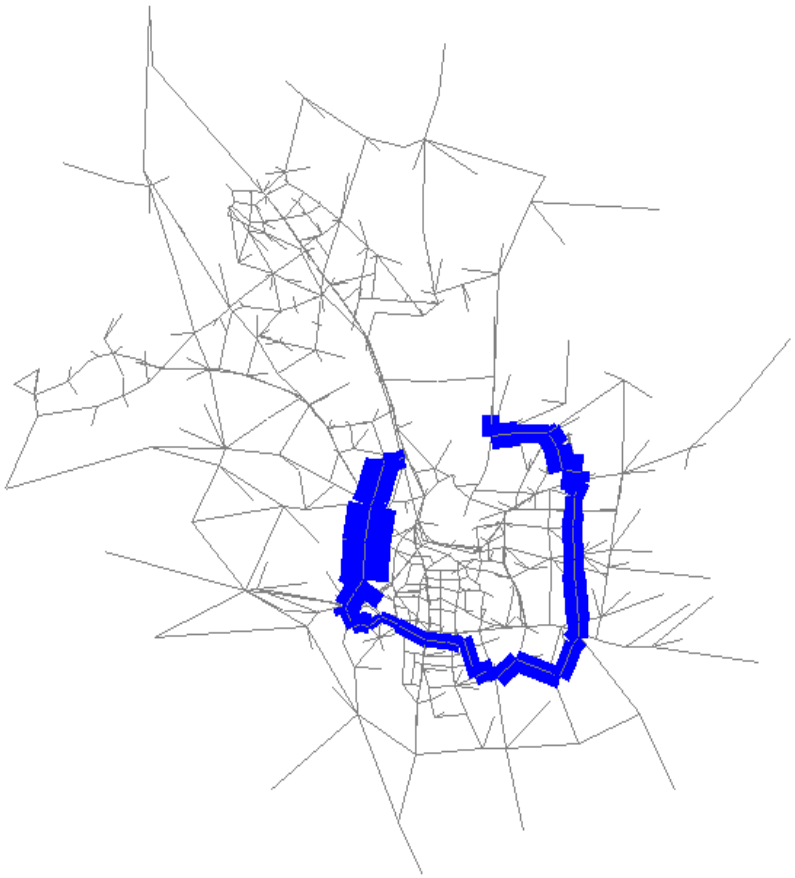

Figure 8.26 Flow Diagram for Monorail for Horizon year 2021 (Scenario -4)

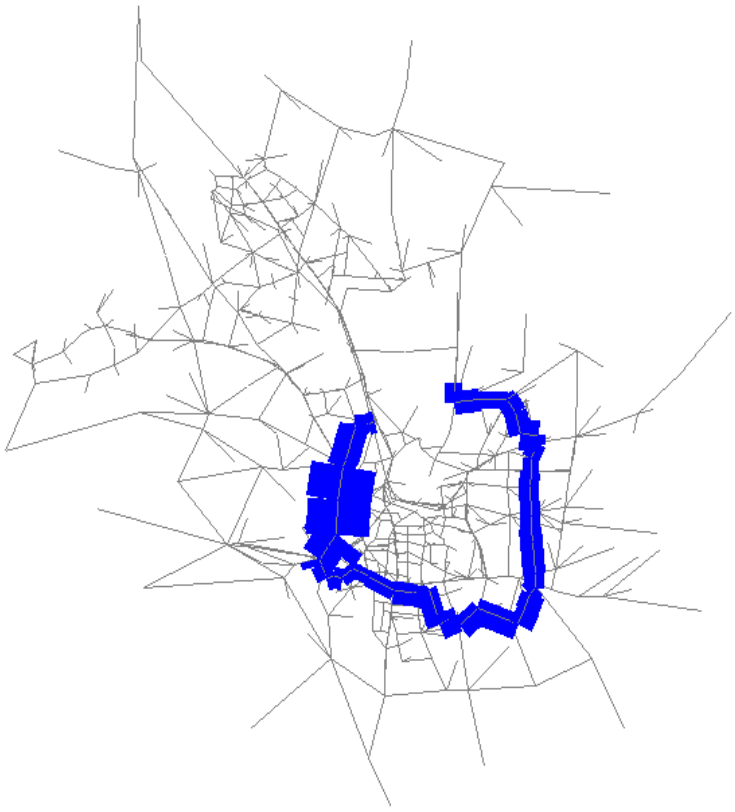

Figure 8.27 Flow Diagram for Monorail for Horizon year 2031 (Scenario -4)

Loadings on BRT Corridor

The BRT routes as finalized during the comprehensive mobility plan were considered and coded. Table 8.27 which describes about the passenger boardings and passenger distance of BRTS for future years. The flow map showing the variation of ridership on BRT corridors is shown in Figures 8.28, and 8.29 for the forecast years 2021 and 2031 respectively.

Table 8.27 Peak Hour Passenger Boardings and Passenger Distance for BRTS

	2021		2031	
Mode	**Passenger Boardings**	**Passenger Distance (km)**	**Passenger Boardings**	**Passenger Distance (km)**
BRTS	42663	120255	63928	175685

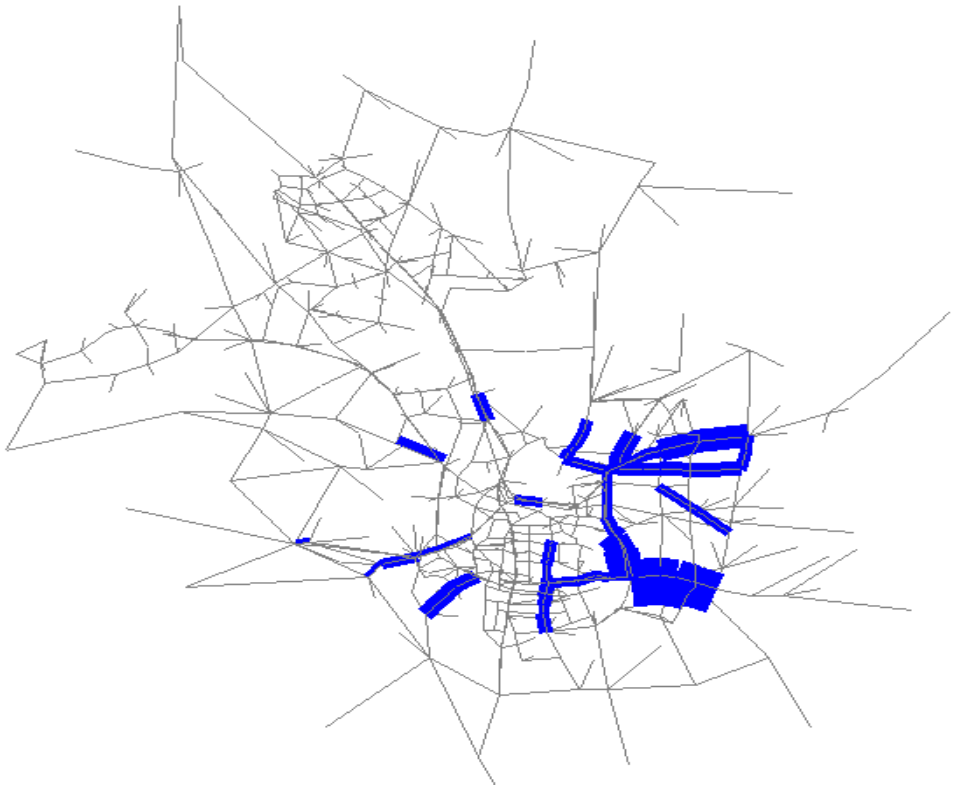

Figure 8.28 Flow Diagram for BRTS for Horizon year 2021 (Scenario-4)

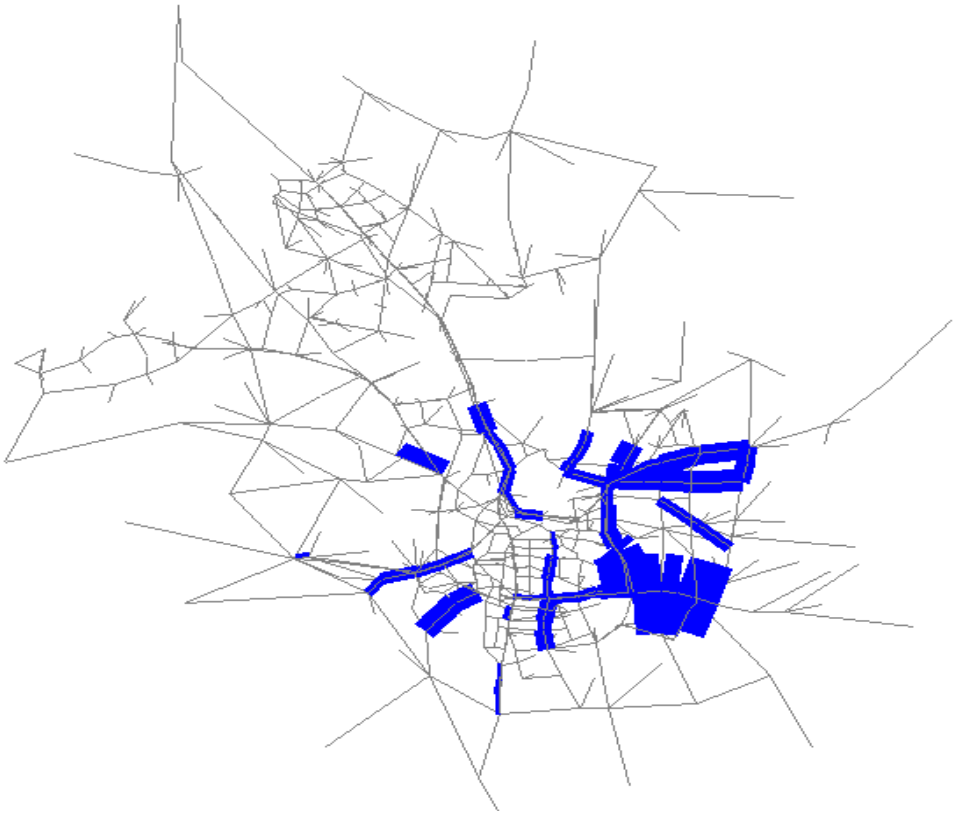

Figure 8.29 Flow Diagram for BRTS for Horizon year 2031 (Scenario-4)

CHAPTER 9
CONCLUSIONS

The observed modal shares in the base year (2008) indicate that the share of trips by public transport is only 13% and whereas the share of private transport and intermediate public transport respectively is 45% and 8.3%. Considering the accelerated growth in population that has been observed in the recent past and the potential of future growth of Pune Metropolitan Region as evident from the population projections, implementation of land use and transport policies for moving towards a more sustainable modal share is of paramount importance. Considering the concept of sustainable urban transportation, implementing high capacity transit systems in a phased manner with appropriate last mile connections (preferably with walk, bicycle, bus and IPT, in that order) and appropriate transit oriented development schemes becomes the need of the hour. The concept of mixed land use minimizing commuter trips should be adopted in the large IT and ITES employment centres and other employment and growth centres that are being currently implemented and the ones planned in the future.

The travel demand model developed for the Pune Region was used to test the land use and transport scenarios arrived at based on the above concepts.

In Scenario 1, the impact of the base land use scenario with the prevailing controls has been evaluated on the proposed transport system improvements with and without metro options (Table 8.1). The shift that has been found from Private Vehicle (PV) to Public Transport (PT) due to the implementation of metro is 5%. This shift is much on the lower side due to the inherent deficiency of the Mode choice modal which was developed only on revealed preference data of the base situation. In reality the shift will be much higher resulting in increased passenger loads on metro rail. The reduction in pollution load due to implementation of metro rail is significant.

The peak hour passengers in peak direction reported for 2301 on metro corridors indicates the necessity of going for high capacity metro rail system as per the master plan finalized. Though a light rail transit system (like monorail) can satisfy the peak loads forecasted for 2031 on HCMTS corridor, considering the sustainability concept of inter generational equity, metro rail system may also be planned on this corridor which can even satisfy the future needs beyond 2031. This will also allow for dense developments along this corridor. This HCMTRS corridor also facilitates interchange between the metro rail corridors. The BRT, BUS and IPT systems also get significant passenger loads indicating their necessity.

In conclusion even as per the usual land use scenario the metro rail, HCMTRS and BRTS are to be implemented as per the master plan and as per the phasing reported in the previous chapter.

In Scenario 2, wherein densification has been done along the metro corridor, it has been observed that there is a reduction of 25% in the average trip length and also the boarding's in the Metro has increased. Also based on other impacts that have been analyzed for this scenario, it is observed that increasing FSI along metro corridor will surely help rather than developing the city outwards. Therefore transit oriented development, i.e., densification along with new public transportation infrastructure like metro can lead to a sustainable development.

In Scenario 3, a hypothetical scenario of 80% public transport share has been analyzed to find its effect on the public transport system planned as per Table 8.1. With 80% share for public transport, the public transport system has reached its saturation level. All the public transport services will get over crowded. Hence to survive this demand increase in the public transport services would be required or new Metro lines have to be developed for the areas not covered earlier.

Also PMC is planning to achieve a higher work participation ratio of 0.6. So in Scenario 4, a hypothetical scenario has been developed wherein the work participation ratio is considered as 0.6. As a result of which 23% increase in the trips has been observed. There will be significant impact Impact on the transport network due to this increase in household employment. Metro rail system with proper coordination with BRT and bus system as planned will be able to take such increase in trips.

Implementation of an integrated master plan of high capacity transit systems planned with last mile connections of walk, bicycle, bus and IPT modes in that order is recommended for Pune region as a sustainable urban transportation system.

Transit oriented land use planning with densification along metro corridors is highly recommended for achieving sustainability.

Adoption of the concept of mixed land use, in the large IT and ITES employment centres and other employment and growth centres that are being currently implemented and the ones planned in the future, minimizing commuter trips is highly recommended.

Estimated Travel for Base year and Forecast Years (Daily passenger trips)								
Mode	**scenario 1**		**scenario 2**		**scenario 3**		**scenario 4**	
	2021	**2031**	**2021**	**2031**	**2021**	**2031**	**2021**	**2031**
PT	**3050631**	**3900096**	**3307700**	**3941537**	**5045786**	**6170485**	**3639251**	**4663259**
PV	**3361606**	**3985096**	**3104541**	**3500441**	**1366444**	**1714699**	**4261023**	**4981778**
CV (PCU)	**15338**	**16005**	**15395**	**15548**	**15395**	**15548**	**15395**	**15548**
	6427575	**7901197**	**6427636**	**7457526**	**6427625**	**7900732**	**7915669**	**9660585**

Table No. 14-3 Peak Hour Passenger boardings and passenger distance for all modes for horizon year 2021								
2021	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	(Usual land use)		(Increasing FSI)		(PT share as 80%)		(Work participation ratio of 0.6)	
Mode	Passenger Boarding	Passenger Distance(km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)
BUS	107899	422375	104818	374739	214854	2236964	187520	2144029
IPT	30807	100084	19713	55340	35438	114027	37081	119440
TRAIN	326	4945	8.8	125	282	4291	477	7113
BRTS	32234	93222	24465	62388	67621	184887	42663	120255
METRO	217654	1528152	222356	1370980	336481	2319802	257602	1816065
MONO RAIL	35160	157410	32759	119726	66754	295954	43948	196852
TOTAL	424080	2306187	404111	1983182	721431	5155924	569290	4403753

Peak Hour Passenger boardings and passenger distance for all modes for horizon year 2031								
2031	Scenario 1 (Usual land use)		Scenario 2 (Increasing FSI)		Scenario 3 (PT share as 80%)		Scenario 4 (Work participation ratio of 0.6)	
Mode	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)
BUS	119804	456826	112311	394997	234821	2291674	200564	2191081
IPT	36244	114333	24437	69465	49710	150637	46468	140228
TRAIN	372	5610	9	135	1438	21027	522	7661
BRTS	49098	140537	27090	68528	97204	252908	63928	175685
METRO	289960	2135564	245623	1533537	401953	2779827	335871	2435751
MONO RAIL	47050	214506	36635	137043	91977	447707	62277	290209
TOTAL	542528	3067376	446096.9	2203705	877103	5943780	709630	5240615

. Peak Hour Passenger boardings and passenger distance for different P.T. modes for horizon year 2021								
2021	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	(Usual land use)		(Increasing FSI)		(PT share as 80%)		(Work participation ratio of 0.6)	
Mode	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)
BUS	107899	422375	104818	374739	214854	2236964	187520	2144029
BRTS	32234	93222	24465	62388	67621	184887	42663	120255
METRO	217654	1528152	222356	1370980	336481	2319802	257602	1816065
MONO RAIL	35160	157410	32759	119726	66754	29594	43948	196852

Peak Hour Passenger boardings and passenger distance for different P.T. modes for horizon year 2031								
2031	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	(Usual land use)		(Increasing FSI)		(PT share as 80%)		(Work participation ratio of 0.6)	
Mode	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)	Passenger Boarding	Passenger Distance (km)
BUS	119804	456826	112311	394997	234821	2291674	200564	2191081
BRTS	49098	140537	27090	68528	97204	252908	63928	175685
METRO	289960	2135564	245623	1533537	401953	2779827	335871	2435751
MONO RAIL	47050	214506	36635	137043	91977	447707	62277	290209

Peak hour Metro Loading for the year 2021													
		Scenario 1- Usual Land Use			Scenario 2- Increasing FSI			Scenario 3- PT Share of 80%			Scenario 4 -Work participation ratio 0.6		
LINE NAME	Length (km)	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD
AC to Nigdi	15.86	41133	21861	18418	37255	16811	16160	63971	32520	27662	50262	26406	21777
AC to Hinjewadi	15.65	41711	27950	19521	40813	22633	16221	67332	44334	30378	52083	35109	24205
AC to Katraj	12.01	36449	21157	15992	40558	23201	16860	49567	25622	20906	39091	21807	16943
Chandini Chowk to Ramwadi	17.96	54677	15773	23629	54057	14291	19485	89603	25997	35747	66101	19229	27702
Deccan GymKhana to Yerawada Bridge	13.94	45040	15410	14700	49672	16575	15073	66007	24126	19066	50065	17293	16214

Peak hour Metro Loading for the year 2031													
		Scenario 1- Usual Land Use			Scenario 2- Increasing FSI			Scenario 3- PT Share of 80%			Scenario 4 -Work participation ratio 0.6		
LINE NAME	Length (km)	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger distance	PPHPD	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD
AC to Nigdi	15.86	55823	29796	24253	42394	280532	17410	79450	40550	31691	67757	35546	28325
AC to Hinjewadi	15.65	58452	40403	28296	50819	453573	21742	84656	51677	35694	71565	46829	32234
AC to Katraj	12.01	49996	33000	21728	42061	283870	17345	60956	34695	24356	53532	33433	22493
Chandini Chowk to Ramwadi	17.96	68876	20105	29927	57333	271666	20545	99085	27707	37735	81158	23750	33429
Deccan GymKhana to Yerawada Bridge	13.94	56812	19635	18547	53014	243893	15890	77804	29729	21906	61858	22356	18951

Ridership Estimation on Monorail Corridor													
		Scenario 1- Usual Land Use			Scenario 2- Increasing FSI			Scenario 3- PT Share of 80%			Scenario 4 -Work participation ratio 0.6		
YEAR	Length (km)	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD	Passenger Boardings	Passenger km/km	PPHPD
2021	32	35160	4919	9149	32759	119726	4748	66754	9249	16859	43948	6152	11391
2031	32	47050	6703	11246	36635	137043	5177	91977	13991	21283	62277	9069	14002

Peak Hour Passenger Boarding and Passenger Distance for BRTS								
	Scenario 1- Usual Land Use		Scenario 2- Increasing FSI		Scenario 3- PT Share of 80%		Scenario 4 -Work participation ratio 0.6	
YEAR	Passenger Boardings	Passenger Distance (Km)	Passenger Boardings	Passenger Distance (Km)	Passenger Boardings	Passenger Distance (Km)	Passenger Boardings	Passenger Distance (Km)
2021	32234	93222	24465	62388	67621	184887	42663	120255
2031	49098	140537	27090	68528	97204	252908	63928	175685
	81332	233759	51555	130916	164825	437795	106591	295940

ANNEXURE 1

Zonal Planning Variables

Table A1.1 Zonal Planning Variables for year 2008

Zones	Population	Employment	Student Enrollment
1	23362	180	1840
2	22128	9966	4457
3	21947	180	1840
4	25486	180	1840
5	20539	2516	3559
6	26640	2530	4401
7	38433	13225	6110
8	33190	9966	4457
9	37938	13051	5619
10	19729	3362	3279
11	28185	3362	3279
12	23489	3362	3279
13	35936	3376	4120
14	13969	14	842
15	15134	14	842
16	12235	2516	3559
17	31515	11440	2152
18	20149	11440	2152
19	34242	4757	1088
20	28015	4757	1088
21	15564	4757	1088
22	6235	34103	4628
23	4155	34103	4628
24	11081	14675	1828
25	2674	14675	1828
26	66015	48778	6456
27	3649	5638	2360
28	37953	5638	2360
29	18742	5716	1785
30	29638	5716	3556
31	31385	5638	2360
32	6831	0	1771
33	7217	2131	3623
34	35696	1407	13408
35	29544	710	8882
36	25509	8649	12517
37	29896	2928	1596
38	20991	2928	1596
39	12721	2928	1596
40	48819	6992	1262
41	56714	6278	7782
42	27359	857	8310

43	43980	857	8310
44	10918	288	6656
45	1821	288	6656
46	18528	29420	7825
47	87381	19987	5003
48	18847	7939	3635
49	10096	7939	3635
50	3029	7939	3635
51	14377	10726	1287
52	30551	17242	5753
53	57948	1358	12670
54	4946	698	4525
55	3008	2131	3623
56	49917	2131	3623
57	6885	1330	6203
58	28918	1330	6203
59	26853	1330	6203
60	5712	10269	3599
61	37376	881	2909
62	68889	11151	5655
63	29359	11151	5655
64	6528	10269	3599
65	6197	1330	6203
66	25896	660	8144
67	25759	1369	17027
68	12787	6515	4466
69	10741	6515	4466
70	24920	10726	1287
71	11501	10726	1287
72	41566	31613	8709
73	20796	10332	5242
74	15185	9433	2823
75	25591	18340	2112
76	28118	18954	2373
77	11521	9433	2823
78	20858	899	2419
79	37206	1943	4148
80	14322	6515	4466
81	27182	40114	14327
82	25615	40114	14327
83	54925	40114	14327
84	39137	4857	1567
85	24804	1943	4148
86	23986	4857	1567
87	106947	38639	4406

88	1765	615	262
89	10035	1780	5508
90	13044	1780	5508
91	10485	569	1654
92	9023	569	1654
93	17514	23286	6042
94	28575	22717	4388
95	11535	547	1530
96	8759	2349	7162
97	26090	1780	5508
98	31916	7089	2013
99	5318	7089	2013
100	66812	2341	8125
101	8334	2027	3699
102	10681	3078	9429
103	6689	1051	5729
104	12370	3078	9429
105	18625	18330	1689
106	4897	10269	3599
107	18625	18330	1689
108	4557	11151	5655
109	62321	3157	3745
110	35410	3157	3745
111	43908	3157	3745
112	16297	18330	1689
113	24056	18330	1689
114	56156	3078	9429
115	6000	2027	3699
116	13550	558	5112
117	24452	1784	3013
118	32675	7089	2013
119	6080	7089	2013
120	41838	9153	6232
121	39134	1780	5508
122	28686	4526	3995
123	15220	4628	2237
124	7609	4628	2237
125	3344	558	5112
126	47889	1784	4861
127	10636	2426	2969
128	23727	2426	2969
129	5727	2426	2969
130	21272	2426	2969
131	20454	2426	2969
132	30618	1784	4861

133	22701	6423	4163
134	14646	6423	4163
135	12448	6423	4163
136	29280	7516	4968
137	7609	4628	2237
138	6088	4628	2237
139	7609	4628	2237
140	18031	4526	3995
141	19521	7516	4968
142	23425	7516	4968
143	10495	13939	9130
144	38315	13939	9130
145	82988	25976	49725
146	80296	7752	30586
147	7076	2499	832
148	2358	2499	832
149	2358	2499	832
150	18968	4101	6380
151	5951	2605	1559
152	7076	2499	832
153	11902	2605	1559
154	11902	2605	1559
155	22941	8123	2742
156	26067	4694	2955
157	6277	6779	1213
158	24015	306	994
159	6821	6471	219
160	10794	1783	402
161	16191	1783	402
162	21628	40389	2941
163	13641	12943	438
164	8413	12943	438
165	12949	2821	1280
166	6589	9293	1499
167	3239	1783	402
168	21581	2821	1280
169	5397	1783	402
170	5397	1783	402
171	17345	5518	1183
172	21244	6555	2061
173	8465	3735	781
174	24785	3509	4850
175	70124	3509	4850
176	8298	3346	1451
177	8935	3338	1368

178	26802	3338	1368
179	2766	3346	1451
180	30409	2501	1372
181	9603	569	4323
182	6277	3001	2454
183	10260	3439	3207
184	31274	843	2057
185	22338	843	2057
186	17871	843	2057
187	17544	3250	4294
188	33488	911	3254
189	2570	258	491
190	2663	10654	1628
191	1888	2499	832
192	1652	2499	832
193	593	7895	305
194	1184	7895	305
195	23158	344	3013
196	36989	4662	6001
197	5314	4318	2988
198	15677	4318	2988
199	7948	2596	1531
200	3180	2596	1531
201	23158	344	3013
202	3118	277	1130
203	9352	277	1130
204	26425	621	4142
205	18295	2025	3562
206	10576	1681	549
207	2643	1681	549
208	10064	27344	2649
209	19784	25663	2100
210	12964	18133	2362
211	30250	18133	2362
212	7420	25663	2100
213	18383	26070	3024
214	10963	406	923
215	9610	1685	2262
216	33749	1279	1338
217	1471	31	151
218	1471	31	151
219	1471	31	151
220	53562	1594	1742
221	20077	393	805
222	20077	393	805

223	8030	393	805
224	8030	393	805
225	8651	2580	1501
226	14005	2580	1501
227	17923	2187	696
228	11141	2136	2814
229	5570	2136	2814
230	5570	2136	2814
231	11141	2136	2814
232	3713	2136	2814
233	67528	18239	5144
234	10441	4662	3535
235	40755	4431	2806
236	8150	4431	2806
237	4328	2137	2810
238	3462	2137	2810
239	10820	2137	2810
240	12984	2137	2810
241	10820	2137	2810
242	13864	8322	5637
243	17333	6185	2827
244	12999	6185	2827
245	13870	6024	930
246	5944	4580	298
247	11274	2915	1186
248	16562	624	1037
249	16562	624	1037
250	4732	624	1037
251	1946	1547	565
252	0	33744	4920
253	8943	4862	4226
254	8185	9421	5700
255	1014	805	707
256	0	43566	0
257	0	13567	0
258	0	38073	0
259	0	55799	0
260	9250	11091	4041
261	5844	5600	3866
262	0	23392	0
263	0	61716	0
264	3332	2549	2316
265	0	27027	0
266	3364	0	2343
267	2879	1728	2002

Table A1.2 Zonal Planning Variables for year 2011

Zones	Population	Employment	Student Enrollment
1	26039	209	2506
2	24663	11577	2222
3	24462	209	2354
4	28407	209	2733
5	22892	2923	4892
6	29693	2939	3963
7	42838	15363	2925
8	36993	11577	3334
9	42286	15161	2927
10	21990	3906	2284
11	31415	3906	3263
12	26180	3906	2719
13	40054	3922	3809
14	15570	16	1303
15	16869	16	1411
16	13638	2923	2914
17	35127	13289	4565
18	22458	13289	2918
19	38166	5526	1568
20	31226	5526	1283
21	17348	5526	713
22	6949	39617	1548
23	4631	39617	1032
24	12351	17047	1531
25	2981	17047	370
26	73580	56664	13665
27	4068	6549	402
28	42303	6549	4188
29	20890	6640	2934
30	33035	6640	6086
31	34982	6549	3463
32	7614	0	0
33	8044	2475	1537
34	39787	1635	10905
35	32930	825	9260
36	28433	10047	8229
37	33322	3401	2390
38	23397	3401	1678
39	14179	3401	1017
40	54413	8122	2192
41	63214	7293	4625
42	30494	996	5779

43	49020	996	9280
44	12170	335	2046
45	2029	335	341
46	20651	34177	3087
47	97395	23219	15913
48	21007	9222	5266
49	11253	9222	2821
50	3376	9222	847
51	16025	12460	700
52	34052	20029	3629
53	64589	1578	20668
54	5512	811	1390
55	3353	2475	640
56	55638	2475	10628
57	7674	1545	1741
58	32232	1545	7312
59	29931	1545	6790
60	6367	11930	739
61	41659	1023	4132
62	76784	12954	9537
63	32724	12954	4770
64	7277	11930	844
65	6907	1545	1567
66	28864	767	11312
67	28711	1591	8916
68	14252	7569	3474
69	11972	7569	2918
70	27775	12460	1214
71	12819	12460	561
72	46329	36724	5180
73	23180	12002	3930
74	16926	10958	2550
75	28524	21305	3232
76	31341	22018	3131
77	12841	10958	1934
78	23249	1044	4350
79	41470	2258	8413
80	15963	7569	3891
81	30297	46599	10246
82	28551	46599	9650
83	61219	46599	20610
84	43622	5642	3110
85	27646	2258	5609
86	26735	5642	1906
87	119203	44886	12046

88	1967	714	20
89	11185	2068	1730
90	14539	2068	2249
91	11686	661	2580
92	10057	661	2219
93	19521	27051	5307
94	31850	26389	8725
95	12857	635	6282
96	9763	2729	1558
97	29080	2068	4498
98	35573	8235	2475
99	5928	8235	412
100	74469	2720	7572
101	9289	2355	2912
102	11905	3576	3374
103	7456	1221	1665
104	13788	3576	3005
105	20759	21293	1228
106	5458	11930	633
107	20759	21293	1228
108	5079	12954	645
109	69463	3668	6319
110	39468	3668	3591
111	48940	3668	4452
112	18164	21293	1074
113	26813	21293	1585
114	62591	3576	14106
115	6687	2355	2096
116	15102	648	11218
117	27254	2073	2478
118	36420	8235	2534
119	6776	8235	471
120	46632	10633	6175
121	43618	2068	6747
122	31973	5257	4322
123	16965	5377	2187
124	8481	5377	1093
125	3727	648	2768
126	53378	2073	10228
127	11854	2818	1375
128	26447	2818	3066
129	6383	2818	740
130	23710	2818	2749
131	22798	2818	2643
132	34126	2073	6539

133	25303	7461	4540
134	16324	7461	2929
135	13875	7461	2489
136	32636	8731	4472
137	8481	5377	1093
138	6785	5377	874
139	8481	5377	1093
140	20098	5257	2716
141	21758	8731	2982
142	26109	8731	3577
143	11697	16192	1888
144	42706	16192	6636
145	92498	30175	44853
146	89498	9005	34763
147	7887	2903	899
148	2629	2903	300
149	2629	2903	300
150	21141	4764	1921
151	6633	3026	544
152	7887	2903	899
153	13266	3026	1088
154	13266	3026	1088
155	25570	9436	1529
156	29054	5453	2257
157	6996	7875	497
158	26767	356	2193
159	7603	7517	194
160	12031	2072	267
161	18046	2072	400
162	24106	46919	1624
163	15205	15036	388
164	9377	15036	239
165	14433	3277	1566
166	7345	10795	581
167	3610	2072	80
168	24054	3277	2610
169	6016	2072	133
170	6016	2072	133
171	19333	6410	757
172	23679	7615	1367
173	9435	4338	421
174	27625	4076	3901
175	78160	4076	11545
176	9249	3887	1138
177	9959	3878	1053

178	29874	3878	3159
179	3083	3887	379
180	33894	2905	5108
181	10704	661	1030
182	6996	3487	634
183	11436	3995	911
184	34858	980	2540
185	24898	980	1814
186	19920	980	1451
187	19554	3775	3708
188	37325	1058	7054
189	2865	300	317
190	2968	12376	462
191	2104	2903	240
192	1841	2903	210
193	660	9171	262
194	1320	9171	524
195	25812	399	4754
196	41228	5415	6293
197	5923	5016	1003
198	17474	5016	2955
199	8859	3016	1780
200	3544	3016	711
201	25812	399	4754
202	3475	322	443
203	10424	322	1329
204	29454	721	4923
205	20392	2352	1871
206	11788	1953	687
207	2946	1953	172
208	11217	31765	1438
209	22051	29812	3337
210	14450	21064	2483
211	33716	21064	5794
212	8270	29812	1251
213	20490	30284	2155
214	12220	472	947
215	10712	1957	1518
216	37617	1486	6798
217	1640	36	278
218	1640	36	278
219	1640	36	278
220	59701	1852	11728
221	22378	457	1271
222	22378	457	1271

223	8951	457	509
224	8951	457	509
225	9642	2997	566
226	15610	2997	947
227	19977	2541	1149
228	12418	2481	3954
229	6208	2481	1977
230	6208	2481	1977
231	12418	2481	3954
232	4139	2481	1318
233	75266	21188	14887
234	11637	5415	1739
235	45426	5147	5236
236	9084	5147	1047
237	4824	2482	1064
238	3858	2482	851
239	12060	2482	2659
240	14472	2482	3191
241	12060	2482	2659
242	15453	9667	3280
243	19319	7185	4065
244	14489	7185	3049
245	15460	6998	1119
246	6625	5320	1312
247	12566	3386	1078
248	18460	725	1138
249	18460	725	1138
250	5274	725	325
251	2169	1798	1436
252	0	39199	4920
253	9968	5648	4460
254	9123	10944	6015
255	1131	935	747
256	0	50610	0
257	0	15760	0
258	0	44228	0
259	0	64820	0
260	10310	12884	4242
261	6514	6505	4081
262	0	27174	0
263	0	71694	0
264	3713	2961	2445
265	0	31396	0
266	3749	0	2473
267	3209	2007	2113

Table A1.3 Zonal Planning Variables for year 2021

Zones	Population	Employment	Student Enrollment
1	36057	303	3368
2	34152	16827	2576
3	33873	303	3164
4	39336	303	3675
5	31700	4249	5703
6	41118	4272	4601
7	59319	22329	3391
8	51226	16827	3864
9	58556	22036	3393
10	30451	5677	2817
11	43502	5677	4024
12	36253	5677	3353
13	55465	5700	4598
14	21561	23	1500
15	23359	23	1625
16	18885	4249	3397
17	48641	19315	4850
18	31099	19315	3101
19	52850	8031	1827
20	43240	8031	1495
21	24022	8031	831
22	9623	57581	1687
23	6413	57581	1124
24	17103	24777	1835
25	4127	24777	442
26	101890	82359	15272
27	5633	9519	617
28	58579	9519	6412
29	28927	9650	3687
30	45745	9650	7383
31	48441	9519	5302
32	10544	0	0
33	11139	3598	1816
34	55094	2376	12666
35	45600	1199	10875
36	39372	14603	9602
37	46143	4944	2510
38	32399	4944	1762
39	19634	4944	1068
40	75349	11805	2598
41	87535	10601	5493
42	42227	1447	6875

43	67881	1447	11044
44	16852	487	2437
45	2810	487	406
46	28597	49674	3219
47	134867	33747	16557
48	29089	13404	5499
49	15582	13404	2946
50	4675	13404	884
51	22190	18111	735
52	47153	29111	3809
53	89440	2293	22964
54	7633	1178	1573
55	4642	3598	756
56	77044	3598	12561
57	10627	2246	1962
58	44633	2246	8239
59	41446	2246	7651
60	8816	17339	940
61	57687	1488	5299
62	106325	18828	12033
63	45314	18828	5912
64	10076	17339	1073
65	9564	2246	1766
66	39969	1115	12413
67	39757	2312	10192
68	19736	11001	3648
69	16579	11001	3064
70	38462	18111	1275
71	17751	18111	588
72	64154	53377	5421
73	32098	17445	4103
74	23438	15927	2661
75	39498	30966	3545
76	43399	32003	3445
77	17782	15927	2018
78	32194	1518	4541
79	57425	3281	8820
80	22105	11001	4085
81	41954	67730	10903
82	39535	67730	10270
83	84772	67730	21951
84	60405	8200	3350
85	38283	3281	5881
86	37021	8200	2053
87	165066	65240	14947

88	2724	1038	25
89	15488	3005	2227
90	20132	3005	2895
91	16182	960	2976
92	13926	960	2561
93	27031	39318	6678
94	44104	38356	11013
95	17803	923	7366
96	13519	3966	1980
97	40268	3005	5790
98	49260	11970	2942
99	8208	11970	490
100	103120	3953	7968
101	12863	3423	3390
102	16485	5198	3873
103	10325	1775	1837
104	19093	5198	3353
105	28746	30948	1527
106	7558	17339	806
107	28746	30948	1527
108	7033	18828	813
109	96189	5331	8338
110	54653	5331	4737
111	67770	5331	5874
112	25153	30948	1336
113	37129	30948	1972
114	86673	5198	15803
115	9260	3423	2441
116	20913	942	12157
117	37740	3013	2602
118	50432	11970	3012
119	9384	11970	560
120	64574	15455	7790
121	60400	3005	8685
122	44275	7641	5524
123	23492	7815	2558
124	11743	7815	1279
125	5161	942	3000
126	73914	3013	12002
127	16415	4096	1775
128	36622	4096	3960
129	8839	4096	956
130	32832	4096	3549
131	31569	4096	3413
132	47256	3013	7673

133	35038	10845	5770
134	22605	10845	3723
135	19213	10845	3165
136	45193	12690	5948
137	11743	7815	1279
138	9396	7815	1023
139	11743	7815	1279
140	27830	7641	3472
141	30130	12690	3965
142	36154	12690	4758
143	16198	23535	2436
144	59137	23535	8632
145	128086	43858	48057
146	123931	13089	34763
147	10921	4220	1145
148	3640	4220	382
149	3640	4220	382
150	29275	6924	2403
151	9185	4398	682
152	10921	4220	1145
153	18369	4398	1365
154	18369	4398	1365
155	35408	13714	1835
156	40232	7926	2935
157	9688	11446	655
158	37066	517	2971
159	10528	10926	204
160	16661	3011	280
161	24989	3011	420
162	33381	68195	2094
163	21055	21854	407
164	12985	21854	251
165	19986	4763	1644
166	10170	15690	610
167	4999	3011	84
168	33309	4763	2740
169	8330	3011	140
170	8330	3011	140
171	26771	9317	795
172	32789	11069	1435
173	13065	6306	442
174	38253	5924	4090
175	108232	5924	12116
176	12808	5650	1189
177	13790	5637	1093

178	41368	5637	3278
179	4269	5650	396
180	46934	4223	6201
181	14822	960	1137
182	9688	5068	791
183	15835	5807	1161
184	48270	1424	3016
185	34478	1424	2155
186	27583	1424	1723
187	27078	5487	4968
188	51686	1538	9001
189	3967	436	389
190	4110	17988	575
191	2914	4220	305
192	2550	4220	267
193	915	13330	321
194	1828	13330	643
195	35743	581	5390
196	57090	7871	6862
197	8202	7290	1198
198	24196	7290	3516
199	12268	4383	2549
200	4908	4383	1019
201	35743	581	5390
202	4812	468	586
203	14435	468	1759
204	40786	1049	6267
205	28237	3418	2412
206	16323	2838	1045
207	4080	2838	261
208	15533	46169	2042
209	30536	43331	4680
210	20009	30616	3586
211	46689	30616	8366
212	11452	43331	1755
213	28373	44017	2817
214	16921	686	1113
215	14833	2845	1708
216	52090	2159	7537
217	2270	52	397
218	2270	52	397
219	2270	52	397
220	82670	2692	12613
221	30987	664	1704
222	30987	664	1704

223	12394	664	681
224	12394	664	681
225	13352	4356	806
226	21616	4356	1315
227	27664	3693	1683
228	17196	3606	4245
229	8597	3606	2123
230	8597	3606	2123
231	17196	3606	4245
232	5731	3606	1415
233	104225	30795	19244
234	16115	7871	2617
235	62903	7481	8468
236	12579	7481	1694
237	6680	3608	1332
238	5343	3608	1066
239	16701	3608	3331
240	20040	3608	3997
241	16701	3608	3331
242	21399	14051	4308
243	26752	10443	5356
244	20063	10443	4017
245	21408	10172	1175
246	9174	7732	1377
247	17401	4922	1129
248	25563	1054	1191
249	25563	1054	1191
250	7303	1054	340
251	3003	2613	1561
252	0	56975	4920
253	13803	8209	6258
254	12633	15907	9194
255	1565	1359	1142
256	0	73559	0
257	0	22907	0
258	0	64284	0
259	0	94213	0
260	14276	18726	5995
261	9020	9455	6236
262	0	39497	0
263	0	104204	0
264	5142	4304	3297
265	0	45633	0
266	5192	0	3779
267	4444	2917	3230

Table A1.4 Zonal Planning Variables for year 2031

Zones	Population	Employment	Student Enrollment
1	42643	384	4232
2	40391	21295	2930
3	40061	384	3975
4	46521	384	4616
5	37490	5377	6515
6	48628	5406	5238
7	70154	28258	3856
8	60583	21295	4396
9	69251	27887	3860
10	36013	7185	3349
11	51448	7185	4785
12	42875	7185	3987
13	65596	7214	5388
14	25499	29	1697
15	27626	29	1838
16	22334	5377	3881
17	57526	24444	5136
18	36779	24444	3284
19	62504	10164	2086
20	51138	10164	1707
21	28410	10164	948
22	11380	72871	1826
23	7585	72871	1218
24	20227	31356	2137
25	4881	31356	516
26	120501	104227	16880
27	6662	12046	830
28	69279	12046	8635
29	34211	12213	4438
30	54101	12213	8680
31	57289	12046	7140
32	12469	0	0
33	13174	4553	2095
34	65158	3007	14426
35	53929	1517	12489
36	46563	18480	10976
37	54571	6256	2629
38	38317	6256	1846
39	23221	6256	1119
40	89112	14940	3003
41	103524	13415	6360
42	49940	1831	7971

43	80280	1831	12808
44	19930	616	2829
45	3323	616	471
46	33820	62864	3352
47	159502	42708	17202
48	34402	16963	5733
49	18429	16963	3071
50	5529	16963	921
51	26243	22920	770
52	55766	36841	3989
53	105777	2902	25260
54	9027	1491	1755
55	5490	4553	873
56	91117	4553	14494
57	12568	2842	2182
58	52785	2842	9165
59	49017	2842	8511
60	10426	21944	1140
61	68224	1883	6465
62	125747	23828	14529
63	53592	23828	7056
64	11917	21944	1303
65	11311	2842	1964
66	47269	1411	13514
67	47019	2926	11468
68	23341	13922	3822
69	19607	13922	3210
70	45487	22920	1334
71	20993	22920	616
72	75873	67551	5663
73	37961	22077	4275
74	27719	20156	2772
75	46713	39188	3859
76	51326	40500	3758
77	21030	20156	2103
78	38074	1921	4733
79	67914	4153	9228
80	26143	13922	4280
81	49617	85714	11559
82	46757	85714	10889
83	100257	85714	23292
84	71438	10378	3589
85	45276	4153	6152
86	43784	10378	2200
87	195217	82563	17848

88	3221	1314	31
89	18317	3803	2725
90	23810	3803	3541
91	19138	1215	3373
92	16470	1215	2902
93	31969	49758	8049
94	52160	48540	13301
95	21055	1168	8450
96	15988	5019	2403
97	47623	3803	7083
98	58258	15148	3409
99	9708	15148	568
100	121957	5002	8363
101	15213	4332	3868
102	19496	6578	4374
103	12210	2246	2009
104	22580	6578	3701
105	33997	39166	1825
106	8938	21944	977
107	33997	39166	1825
108	8318	23828	979
109	113759	6746	10355
110	64636	6746	5883
111	80149	6746	7295
112	29747	39166	1597
113	43911	39166	2358
114	102505	6578	17501
115	10952	4332	2785
116	24733	1192	13098
117	44634	3813	2726
118	59644	15148	3490
119	11098	15148	649
120	76369	19558	9404
121	71433	3803	10624
122	52362	9670	6728
123	27783	9890	2931
124	13889	9890	1465
125	6103	1192	3231
126	87416	3813	13777
127	19414	5183	2175
128	43311	5183	4852
129	10454	5183	1172
130	38829	5183	4350
131	37335	5183	4183
132	55888	3813	8808

133	41438	13724	7001
134	26734	13724	4517
135	22723	13724	3839
136	53448	16060	7423
137	13889	9890	1465
138	11112	9890	1173
139	13889	9890	1465
140	32914	9670	4229
141	35634	16060	4949
142	42758	16060	5939
143	19157	29784	2984
144	69939	29784	10630
145	151483	55504	6512
146	146569	16565	3367
147	12916	5341	1392
148	4305	5341	464
149	4305	5341	464
150	34623	8762	2886
151	10862	5565	822
152	12916	5341	1392
153	21725	5565	1643
154	21725	5565	1643
155	41876	17356	2139
156	47581	10030	3613
157	11457	14485	811
158	43836	654	3748
159	12451	13827	213
160	19704	3811	293
161	29554	3811	440
162	39479	86303	2564
163	24901	27657	428
164	15357	27657	263
165	23637	6028	1723
166	12028	19856	639
167	5912	3811	88
168	39393	6028	2871
169	9852	3811	147
170	9852	3811	147
171	31661	11791	833
172	38778	14008	1503
173	15452	7980	463
174	45241	7497	4278
175	128002	7497	12687
176	15147	7150	1239
177	16309	7134	1133

178	48924	7134	3398
179	5049	7150	413
180	55507	5344	7294
181	17529	1215	1244
182	11457	6413	947
183	18728	7349	1410
184	57087	1802	3493
185	40776	1802	2495
186	32622	1802	1996
187	32024	6943	6227
188	61127	1947	10947
189	4692	552	461
190	4861	22764	688
191	3446	5341	371
192	3015	5341	325
193	1082	16870	381
194	2162	16870	761
195	42271	735	6027
196	67519	9961	7430
197	9700	9226	1392
198	28616	9226	4077
199	14509	5547	3317
200	5804	5547	1327
201	42271	735	6027
202	5691	592	730
203	17072	592	2189
204	48236	1327	7612
205	33395	4326	2953
206	19304	3591	1403
207	4825	3591	351
208	18370	58428	2644
209	36113	54837	6024
210	23664	38746	4687
211	55217	38746	10938
212	13544	54837	2259
213	33556	55705	3480
214	20012	868	1279
215	17542	3601	1898
216	61605	2732	8276
217	2685	66	515
218	2685	66	515
219	2685	66	515
220	97771	3407	13498
221	36648	841	2136
222	36648	841	2136

223	14658	841	854
224	14658	841	854
225	15791	5512	1045
226	25565	5512	1684
227	32717	4673	2217
228	20337	4564	4538
229	10167	4564	2269
230	10167	4564	2269
231	20337	4564	4538
232	6778	4564	1512
233	123263	38972	23601
234	19058	9961	3496
235	74394	9468	11700
236	14877	9468	2340
237	7900	4566	1601
238	6319	4566	1281
239	19751	4566	4002
240	23700	4566	4803
241	19751	4566	4002
242	25307	17782	5335
243	31639	13216	6646
244	23728	13216	4985
245	25318	12873	1231
246	10850	9786	1442
247	20579	6229	1180
248	30232	1334	1243
249	30232	1334	1243
250	8637	1334	355
251	3551	3306	1688
252	0	72103	4920
253	16324	10389	7261
254	14941	20130	10711
255	1851	1720	1330
256	0	93091	0
257	0	28989	0
258	0	81353	0
259	0	119229	0
260	16884	23698	6959
261	10667	11966	7265
262	0	49984	0
263	0	131873	0
264	6082	5447	3815
265	0	57750	0
266	6140	0	4402
267	5255	3692	3857

Table A1.5 Zonal Planning Variables Land use scenario 2 (Increasing FSI along Metro Corridor)

Zones	Population	Employment	Student Enrollment
1	24009	197	3368
2	23156	10930	2576
3	22260	197	3164
4	25422	197	3675
5	25315	2760	5703
6	48547	8534	4601
7	27565	14505	3391
8	27058	10930	3864
9	25200	14314	3393
10	24832	3688	2817
11	26436	3688	4024
12	47994	20817	3353
13	90228	45087	4598
14	69090	38362	1500
15	25221	15	1625
16	22794	2760	3397
17	22712	12547	4850
18	21927	12680	3101
19	22630	8784	1827
20	22292	5217	1495
21	22719	5217	831
22	51176	41737	1687
23	162958	94236	1124
24	69132	40294	1835
25	27041	17062	442
26	144583	104471	15272
27	51270	27288	617
28	24444	6183	6412
29	27757	6269	3687
30	26654	6269	7383
31	56669	26783	5302
32	105066	49489	0
33	33175	8343	1816
34	67501	34644	12666
35	85492	49439	10875
36	52754	29196	9602
37	58263	21377	2510
38	77066	40892	1762
39	111712	59276	1068
40	62693	31970	2598
41	23455	6886	5493
42	23183	940	6875

43	26944	940	11044
44	26623	316	2437
45	38185	435	406
46	90897	58672	3219
47	58868	31236	16557
48	37350	11989	5499
49	19331	9856	2946
50	26995	13056	884
51	24161	13355	735
52	31581	18263	3809
53	24897	1490	22964
54	26241	766	1573
55	23571	2337	756
56	56671	24329	12561
57	37634	12414	1962
58	40704	15891	8239
59	23448	1459	7651
60	63113	35471	940
61	40398	1330	5299
62	55697	27341	12033
63	35373	18770	5912
64	48208	24386	1073
65	64545	28799	1766
66	59494	18305	12413
67	102886	52075	10192
68	39334	14442	3648
69	21991	9698	3064
70	18979	10975	1275
71	16455	9516	588
72	37747	47742	5421
73	37484	15603	4103
74	24043	10346	2661
75	23167	20115	3545
76	22721	20789	3445
77	26152	10346	2018
78	25261	986	4541
79	15995	6930	8820
80	20718	8970	4085
81	27390	43078	10903
82	29559	17094	10270
83	17383	10052	21951
84	11711	6772	3350
85	24834	2131	5881
86	26373	5327	2053
87	22442	19341	14947

88	13782	5431	25
89	26874	1952	2227
90	26659	1952	2895
91	24502	624	2976
92	25613	624	2561
93	24972	25540	6678
94	26067	24916	11013
95	22979	599	7366
96	25428	2576	1980
97	24806	1952	5790
98	32146	15087	2942
99	34431	15432	490
100	60290	34865	7968
101	22073	2223	3390
102	22652	3376	3873
103	24019	1153	1837
104	24092	3376	3353
105	35502	27681	1527
106	37115	15509	806
107	37494	27681	1527
108	36300	16840	813
109	38825	4768	8338
110	35638	4768	4737
111	37492	4768	5874
112	38086	27681	1336
113	39657	27681	1972
114	23796	3376	15803
115	24686	2223	2441
116	32315	11499	12157
117	65533	37897	2602
118	23952	7775	3012
119	24934	7775	560
120	26014	10039	7790
121	26779	1952	8685
122	26615	4964	5524
123	23467	5076	2558
124	53200	30765	1279
125	67490	27108	3000
126	38949	2695	12002
127	38252	3663	1775
128	37774	3663	3960
129	26420	2661	956
130	22845	2661	3549
131	34860	3663	3413
132	44217	18007	7673

133	22238	7045	5770
134	24503	7045	3723
135	25207	13660	3165
136	13843	8005	5948
137	23735	5076	1279
138	26602	5076	1023
139	25221	5076	1279
140	26067	4964	3472
141	23033	8244	3965
142	74018	42803	4758
143	63917	38218	2436
144	22673	15288	8632
145	119499	32207	48057
146	115623	9612	34763
147	10189	3099	1145
148	3396	3099	382
149	3396	3099	382
150	27313	5084	2403
151	8569	3229	682
152	10189	3099	1145
153	17138	3229	1365
154	17138	3229	1365
155	33034	10071	1835
156	37535	5820	2935
157	9038	8405	655
158	34581	380	2971
159	9822	8023	204
160	15544	2211	280
161	23314	2211	420
162	31143	50078	2094
163	19643	16048	407
164	12115	16048	251
165	18646	3498	1644
166	9488	11522	610
167	4664	2211	84
168	31076	3498	2740
169	7772	2211	140
170	7772	2211	140
171	24976	6842	795
172	30591	8128	1435
173	12189	4630	442
174	35689	4350	4090
175	100975	4350	12116
176	11949	4149	1189
177	12866	4139	1093

178	38594	4139	3278
179	3983	4149	396
180	43787	3101	6201
181	13828	705	1137
182	9038	3721	791
183	14774	4264	1161
184	45033	1046	3016
185	32166	1046	2155
186	25734	1046	1723
187	25262	4029	4968
188	48221	1129	9001
189	3701	320	389
190	3835	13209	575
191	2718	3099	305
192	2379	3099	267
193	853	9789	321
194	1705	9789	643
195	33346	426	5390
196	53263	5780	6862
197	7652	5354	1198
198	22574	5354	3516
199	11445	3219	2549
200	4579	3219	1019
201	33346	426	5390
202	4490	344	586
203	13467	344	1759
204	38052	770	6267
205	26344	2510	2412
206	15228	2084	1045
207	3806	2084	261
208	14492	33904	2042
209	28488	31820	4680
210	18668	22483	3586
211	43558	22483	8366
212	10684	31820	1755
213	26471	32324	2817
214	15787	504	1113
215	13838	2089	1708
216	48598	1586	7537
217	2118	38	397
218	2118	38	397
219	2118	38	397
220	77128	1977	12613
221	28910	488	1704
222	28910	488	1704

223	11563	488	681
224	11563	488	681
225	12457	3199	806
226	20167	3199	1315
227	25809	2712	1683
228	16043	2648	4245
229	8021	2648	2123
230	8021	2648	2123
231	16043	2648	4245
232	5347	2648	1415
233	97237	22614	19244
234	15034	5780	2617
235	58686	5494	8468
236	11736	5494	1694
237	6232	2649	1332
238	4985	2649	1066
239	15581	2649	3331
240	18696	2649	3997
241	15581	2649	3331
242	19964	10318	4308
243	24959	7669	5356
244	18718	7669	4017
245	19973	7469	1175
246	8559	5678	1377
247	16234	3614	1129
248	23849	774	1191
249	23849	774	1191
250	6813	774	340
251	2802	1919	1561
252	0	41839	4920
253	12877	6028	6258
254	11786	11681	9194
255	1461	998	1142
256	0	54017	0
257	0	16821	0
258	0	47206	0
259	0	69184	0
260	13319	13751	5995
261	8415	6943	6236
262	0	29004	0
263	0	76521	0
264	4797	3160	3297
265	0	33510	0
266	4844	0	3779
267	4146	2142	3230