LAND USE TRANSPORTATION INTERACTION MODEL DEVELOPMENT FOR URBAN AREA

A thesis submitted to Gujarat Technological University

for the award of

Doctor of Philosophy

in

Civil Engineering

by:

RENA NARENDRABHAI SHUKLA
Enrollment No.: 159997106014

under

supervision of

Dr. L. B. ZALA
&
Late Dr. P. J. Gundaliya

GUJARAT TECHNOLOGICAL UNIVERSITY

AHMEDABAD

[February - 2024]

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I declare that the thesis entitled **Land Use Transportation Interaction Model Development for Urban Area** submitted by me for the degree of Doctor of Philosophy is the record of research work carried out by me during the period from **20/10/2016 to 27/02/2024** under the supervision of **Dr. L. B. Zala** and this has not formed the basis for the award of any degree, diploma, associateship, fellowship, titles in this or any other University or other institution of higher learning.

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LANDUSE TRANSPORTATION INTERACTION MODEL DEVELOPMENT OF URBAN AREA A thesis submitted to Gujarat Technological University
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ABSTRACT

Since many cities are expanding quickly, creating livable cities is a constant problem for urban and transportation planners. Increasing population, more compact use of land, and a surge in motorization results in number of negative effects, including congestion, air pollution, greenhouse gas emissions, and economic losses. Due to its accessibility and the economic opportunities it offers to the nearby land and activities, the transportation system serves as one of the primary forces behind urban growth. Land use and transportation interaction are fundamental concepts in the study of land development and the formulation of transport links. Land use and transportation planning have been done separately in most scenarios, which means that the impact of any changes in transportation policies on the land use patterns is frequently ignored. Urban sprawl is one of the consequences that occur due to ignoring such bilateral impacts in the planning process. Land use and transportation interaction (LUTI) models are designed to predict the interrelations between economic growth and transport demand and vice versa. This research presents a land use and transport interaction model for the urban area. The proposed system of interaction models based on regression techniques for land use and transport for selected parameters. The regular produced trips from residential land use are transport parameter. Innovative approaches are required in developing cities to adapt to situations where limited information is available. Home interview survey for 2400 households is conducted for socio-economic characteristics and travel characteristics of residents in study area. The land use for 2011 and 2017 is used to observe change in Ahmedabad urban area. Change in population and increase in number of households is observed along with density. From the collected data 66.67% is training data to develop model and 33.33% is test data to validate model by looking to relationship among observed data and estimated data. Calibration parameter estimation is the most crucial factor in LUTI models. The stastical techniques have been conventionally used to calibrate LUTI models. The correlation among independent variables is verified to develop multivariate regression model. The correlation is not zero and observed acceptable. The discrepancy between actual and modeled data is verified to validate the developed model. The calibrated model with Root Mean Squared Error (RMSE) and Analysis of Variance (ANOVA) is studied

along with residuals and standard error. ANOVA test showing Significance F is less than 0.05 for developed models which is indicating that model is acceptable. The family size is reducing day by day and it is observed that number of persons working and going for education is contributing to regular daily trip generation. There is acceptable difference between actual/observed/surveyed trips and modelled/estimated/predicted trips. The Multiple R, R^2 and Adjusted R^2 is more than 0.67 for developed LUTI models. The produced trips depending on population, number of households, density, household characteristics and land use. The developed LUTI models for study area West zone, Ahmedabad is calibrated and validated, which have application for similar kind of study area.

Keywords: Households, LUTI model, Land use, RMSE, Transport

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Rena Narendrabhai Shukla

Dedicated to My

Beloved Grandfather

Shri P. K. Shukla

and

Family

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List of Abbreviation

Abbreviation	Particulars
AI	Accessibility Index
AMC	Ahmedabad Municipal Corporation
AMTS	Ahmedabad Municipal Transportation System
ANOVA	Analysis of Variance
ASCE	American Society of Civil Engineers
AUDA	Ahmedabad Urban Development Authority
AWT	Average Waiting Time
BRTS	Bus Rapid Transit System
BUA	Built Up Area
Cabs	Hired Taxies
CBD	Central Business District
CCA	Cross Category/Classification Analysis
DMIC	Delhi Mumbai Industrial Corridor
DP	Development Plan
DPR	Draft/Detailed Project Report
EDF	Equivalent Doorstep Frequency
EMP	Employed Persons in Household
f	Frequency
FSI	Floor Space Index
GIDC	Gujarat Industrial Development Corporation
GIFT	Gujarat International Finance Tec
GIS	Geographic Information System
Ha.	Hectare
HH	Household
HIS	Home Interview Survey
IPT	Intermediate Public Transport
K	Reliability Factor
km	Kilometer
kmph	Kilometer per Hour
km^2	Square Kilometer
LU	Land Use

LUR	Land Use Residential
LUT	Land Use Transport
LUTI	Land Use Transportation Interaction
m^2	Square Meter
MEGA	Metro link Express Gandhinagar Ahmedabad
MNL	Multinomial Logit
NMT	Non-Motorised Transport
OHH	Other than Households
PCU	Passenger Car Unit
POI	Point of Interest
PT	Public Transport
PTAL	Public Transport Accessibility Level
RMSE	Root Mean Squared Error
ROW	Right of Way
RTO	Road Transport Authority
SAP	Service Access Point
SC	School/College going Children
SIR	Special Investment Regions
sqft	Square Feet
SWT	Scheduled Waiting Time
TAT	Total Access Time
TC	Travel Cost
THH	Trips Produced per Household
TL	Travel Length
TPS	Town Planning Scheme
TT	Travel Time
2W	Two Wheeler
3W	Three Wheeler
4W	Four Wheeler
VO	Vehicle Ownership
WT	Walk Time
%	Percentage

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CHAPTER - 1

Introduction

1.1 General

According to 2001 census of India, the urban population of the country was 286.11 million, living in 5161 towns, which constitutes 27.81% of the total population of country. However, the same as per 2011 census has risen to 377.16 million viz. 32.16% of the total country's population and at the same time number of towns has gone up to 7935. The rate of urban growth in the country is very high as compared to developed countries, and the large cities are becoming larger mostly due to continuous migration of population to these cities. By 2050, over half of India's population is expected to be urban dwellers. This creates enormous pressure on existing urban infrastructure. (*Census of India Website:Office of the Registrar General & Census Commissioner,India*, n.d.)

Worldwide cities are expanding more quickly now than they did in the past. Cities are experiencing population growth owing to migration in addition to the natural increase in population. In addition to placing strain on the people's access to natural resources, the growing population also causes cities to physically grow and expand. Need of study: In India, the scenario is gradually leading to a spread of built-up areas in new and expanding cities. The high population a city has, the increased demand for housing, transportation, and other land use functions. The transportation and land use interaction studies reflected literature worldwide and incorporated in transportation planning. The same is need of hour for Indian cities growing fast. Hence the Ahmedabad and other cities need similar studies.

Due to rapid rate of Urbanization, the various problems such as, congestion and pollution has great impacts on urban transportation planning as these problems not only caused by transportation system design, but also relate to land use planning. Land use or

location creates activity and that demands for accessibility which is provided by transportation. Everything that happens to land use has transportation implications and every transportation action affects land use. The interaction between transport and land use in the way cities develop and the need to use a fully integrated land use and transportation model to assess the impact of urban policies. Lack of integration between land use and transportation planning leads to an improper development and inefficient transport services distribution. The importance of interaction between land use and transportation has been increasing during the course of urban development. As a new road will encourage the development of adjacent vacant land, as land is developed, travel demand will increase, leading traffic congestion on new roads. As traffic increases, the road needs to be improved or a new road will have to be built. The new road will then encourage additional land development adjacent to it and the urban planning cycle continue.

Cities evolve in multiple dimensions: their size, density (jobs, population), land use, and travel patterns being some of these dimensions. New housing developments and transport infrastructure are key triggers for the process of change. As cities grow from new infrastructure and land cover changes. The economic and demographic growth, combined with migration into cities from rural areas, is producing a low quality urban expansion. The rapid growth of our cities inevitably leads to an increase in the demand for land and mobility, as more resources are consumed and more congestion and pollution are generated. Land use and transport planning must be closely related and play an important role in the diagnosis of present problems and the solutions to future problems. (Guzman, 2019)

1.1.1 Land Use

Land Use (LU)development refers to use of the earth's surface by human activities including the location, type and design of infrastructure such as roads and buildings. LU is defined broadly to include new development and the type and intensity of use of existing development. Hanson model, Lowry model and Saturation density gradient model are basic models of land use. The types of LU based on activities on the parcel of land is as listed below:

i.	Agricultural	iv.	Institutional	vii.	Residential	x.	Waterbody
ii.	Commercial	v.	Mixed	viii.	Transport		
iii.	Industrial	vi.	Recreational	ix.	Vacant		

The urban change processes identified and eight types of major urban subsystem are distinguished. They are ordered by four groups of the speed by which they change, from slow to fast processes;

I. Very slow change: Networks, Land Use
II. Slow changes: Workplaces, Housing
III. Immediate change: Goods transport, Travel
IV. Fast change: Employment, Population

Urban change process is very slow change for networks and land use. Urban transport, communications and utility networks are the most permanent elements of the physical structure of cities. Large infrastructure projects require a decade or more, and once in place, are rarely abandoned. The land use distribution is equally stable; it changes only incrementally. (Wegener, 2004) At existing residential land use, it occurs by change in pattern i.e., bunglow is demolished and flat is constructed. Residential to commercial or mix LU i.e., bunglow or flats are demolished and shopping complex is constructed. Residential to recreational i.e., mall or sports complex or multiplex theater is constructed by demolishing flat or bunglow. Recreational to commercial i.e., ponds are earth filled and buildings are constructed. Agricultural to residential.i.e.by procedure farmlands are converted to introduce society or flat scheme.

More concentration in Central Business District (CBD) leads to evolution in land use. The space availability is limited; hence density is more. Congestion and pollution increase. The space for business and parking is not available. To control it, there is high price of land observed. Rents and deposit for the properties also increase. Ultimately, it is attracted and diverted to new land in outskirts of urban area.

For land use planning there are two concepts. Law for evolution and law for growth. Evolution and growth both affects land use differently. The land use planning is based upon spatial interaction and land use interaction for transportation field. Spatial interaction is based upon growth factor methods, gravity model, opportunity model, entropy model etc. The models work on concept of space occupied by population and spatial separation. The data are collected by home interview method. It is tedious and long-term work. It is followed by 4 stage modeling-trip generation, trip distribution, modal split and route assignment. Land use interaction is suitable for fast growing urban area. Based upon defined and assumed criteria mathematical models can be developed. Regression analysis can be carried out. By

prediction of growth factor and trip contours modification in land use is easy. Validation of land use models can be carried out by screen line and cordon line checks and survey.

1.1.2 Transportation

Transportation is defined as the movement of people, goods and service from one place to another under a desirable condition. Transportation planning is concerned with the development of a plan with respect to social, economic and environmental impacts of the populace to enhance positive goals. The fundamental goal of transportation planning is to accommodate the need for mobility in order to provide efficient access to various activities that satisfy human needs. (Makinde, 2009)

Transportation planning processes have been intensively used to estimate the demand for travel encountered in the future. The estimated travel demand is utilized as a basis to plan for future transportation facilities and services. As for the transportation system, it is necessary to quantify the inputs and the outputs for the system. The system inputs are the quantum of demand for transportation in the future years, while the system outputs are system characteristics that are planned for meeting the demand on the horizon years. (Hutchinson, 1974)

1.1.3 LUTI-Land Use Transport Interaction

The models are basic /conceptual models, descriptive/analytical models and mathematical models. Land-use–transportation models belong to the mathematical family of models. They are composed of independent land use and travel models, with mechanisms for coupling the two either loosely or in a more integrated fashion. The validity of mathematical models can then be evaluated by comparing their predictions against observed data. (Torrens, 2000)

LUTI models are categorised as of history of LUTI. First-generation models, the models that appeared during the 1960s and 1970s. Second-generation models appearing in the 1980s and 1990s. Third-generation models appearing more recently around the second half of the 1990s. It is important to note that research is moving forward with the three generations of models and none of them has successfully managed to replace any of the others. (Coppola et al., 2013)

Land use transport interaction models classified in 3 categories. as: Descriptive models, Explanatory models and Predictive models. (Adhvaryu, 2010)

Lowry model is first land use transport model born as a result of pioneering researches conducted by Era S. in 1964.She concluded that the model developed for Pittsburg is not finished product and considered as a best prototype with a promising future. She presented ambiguities, there emerge some valuable insight into the spatial structure of metropolis and trends of change. Since then, several models were born. As modelling techniques and technology evolved new LUT or LUTI models became more and more complete and sophisticated. However, commonly used uniformed LUTI models are not available yet. (Gaál, 2015)

Land use and transportation are mutually interdependent. (Moore et al., 2007) Land use and transportation interaction are fundamental concepts in the study of land development and the formulation of transport links (Manheim, 1979)

Land-use and transportation planning have been done separately in most scenarios, which means that the impact of any changes in transportation policies on the land-use patterns is frequently ignored. Urban sprawl is one of the consequences that occur due to ignoring such bilateral impacts in the planning process (Wegener, 2004)

In order to achieve better understanding of the Land use transportation interaction (LUTI) various land use and transportation interaction models will be helpful to investigate the interrelationship between land use and transportation. The output of model will be used for decision makers to assess the impact of land use development on transportation system and transportation policies. The interaction between land use and transportation and can be conceptualized as a potential flow of activities. A particular zone with specific land use activity creates socio-economic field, which causes attraction forces with other complementary land use activities. An employment center attracts workers from the different surrounding residential zone. The force of attraction is the movement of people commuting between residential area and place of work which is reason for generation of travel demand. The creation of new housing by the developers is supply and the location of households is the demand.

The city’s urban form is nothing but a form of buildings and channels. The buildings are land use and channels are transportation network. Activities like residing, working, shopping and recreation, are functions which are the aggregate action of the population and

it is performed in channels through “flows”. The land use model is an equilibrium system that equals the demand and supply forces and model the process that affects the activities of households & firms whereas the transport model produces “flow of activities to decide “channels” and mode of transport. Hence the LUTI is used to modelling land use activities and transport to find efficient planning alternative and land use transport capabilities as shown in FIGURE 1.1. A land use and transport interaction model to simulate the overall equilibrium of an urban system.

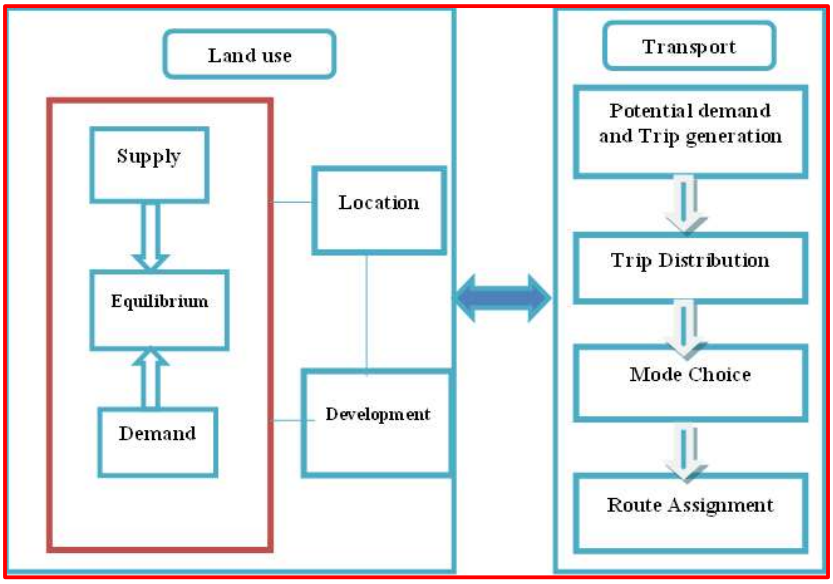

FIGURE 1.1: LUTI Modeling

(Source: (Torrens, 2000)**)**

LUTI models have been used to examine the impact of transport and land-use policies such as the implementation of transportation infrastructures (e.g. highway development, underground systems), dwelling and business improvements, improvement of public transport and fare changes, the expenses of private transport, and the development of socio-demographic and economic scenarios as well.(Hellman, 1982)

American Physical planners also realized at a very early stage that trip generation and location decisions co-determine each other and thus there is a need to co-ordinate transport and land-use planning. Later the ‘land-use transport feedback cycle’ became common place in the American planning literature as shown in FIGURE 1.2.

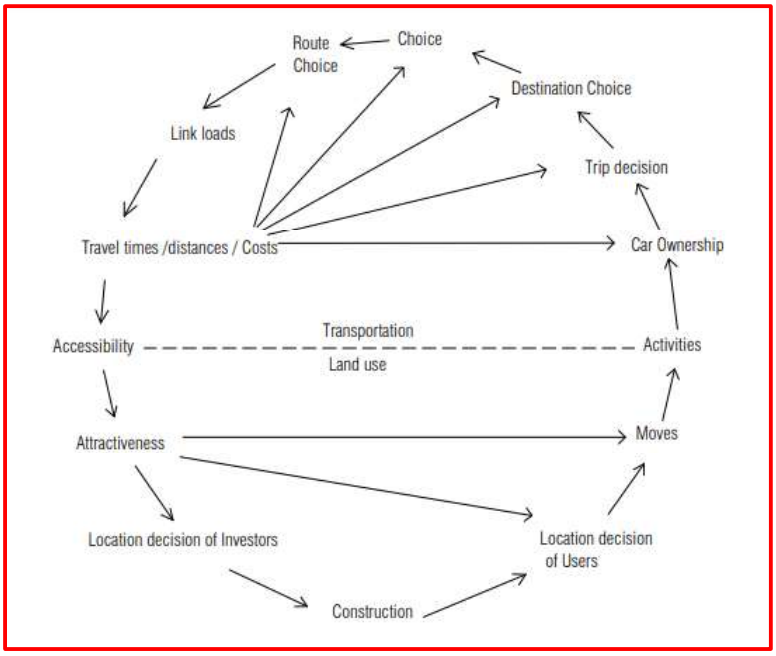

FIGURE 1.2: The Land Use Transport Feedback Cycle

(Source:(Wegener, 2004))

Reasons for a lack of coordination vary from having multiple jurisdictions, each with its own policy board; to regional planning organizations with little or no enforcement authority; to the historic separation of highway and road departments, land-use planning departments, and transit agencies. These circumstances may not be easy or even possible to change in certain regions.(Kraft, 1989)

LUTI models simulate the two-way relationship between land use and transport systems in urban areas. LU-to-T relationship influences transport, in the component of travel demand. On the other side, the T-to-LU relationship plays a prominent role in the spatial organization of the area, influencing activity location and land prices (Russo & Musolino, 2007). Components of transportation and land use system are as shown FIGURE 1.3.

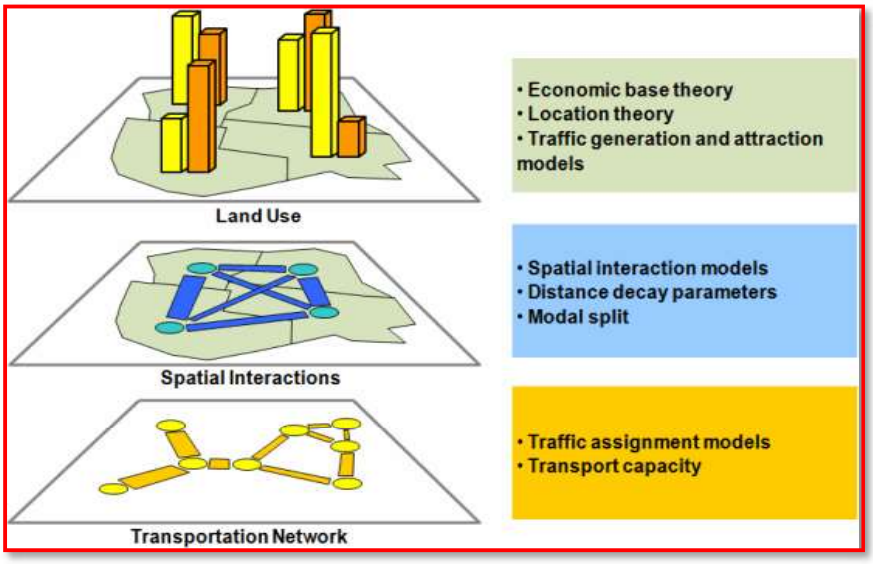

FIGURE 1.3: Components of Transportation and Land Use System

(Source: (Rodrigue et al., 2006))

1.2 Problem Definition

Large number of land use transport interaction models are in use today. There are significant variations among the models with respect to comprehensiveness, model structure, theoretical foundations, modelling techniques, dynamics, data requirements, calibration and validation. Despite the achievements in developing these models further, there remain some challenges to be met. Data disparity, differences in information and very limited information are the biggest challenges when implementing the model. It is practically observed that different pockets in urban area is not growing in same pace. The population change is not same throughout urban area. The new land introduced for development is not same throughout urban area. The transport network and public transportation facility is not same as of route and frequency throughout urban area. The development age of different pockets of urban area is different. The real estate price for land and built-up area are different. The idea of research is preliminarily found to be a missing link with no past efforts studied in such a manner. In past studies the study area is whole urban area- large size city. The study on LUTI is very limited in Indian context, The present study tries to develop LUTI for part of Ahmedabad City.

1.3 Aim and Objectives of Research

Aim of the work is "To explore the interaction of land use and transportation resulting in relationship among socio-economic parameters, transportation parameter and land use parameter for different purposes in urban area."

To expedite the aim and concept of doctoral research to establish relationships and define a novel approach for urban areas, below objectives, are defined. Objectives of the research study are defined as below:

1. To develop trip production models.
2. To develop utility functions.
3. To develop accessibility index.
4. To develop Land Use Transportation Interaction model for selected study area.
5. To calibrate and validate the developed model.

1.4 Scope of Work

As the land use change, urban development and transportation system include for a vast number of parameters affecting remarkably; the scope of work to carry out the exploration is narrowed down. Selectively a limited parameters and interrelationships are brought under focus of the study. As the parameters have a complex interrelationship and dependencies. The proposed research work includes scope of work as below.

- To explore household characteristics of study area, which includes the area of West zone of Ahmedabad city which consists of 9 wards- Paldi, Vasna, Navrangpura, SP Stadium, Naranpura, Nava Vadaj, Sabarmati, Ranip and Chandkheda. The total area of West zone in Ahmedabad city is 65.68 km^2. Only residential land use is considered. Sample size as per standards is minimum 1%. (Hogg et al., 2009) (Kadiyali, 2013) for Home Interview/Information Survey (HIS).
- To determine number of trips produced from sample households, The trips produced from households for work and education purpose is focused for analysis and model development. To determine trip rate by cross category analysis, home based work trip & home-based educational trips are considered as regular trips from Household (HH).

- To study and analyze the extent of spatial trends for West zone, Ahmedabad. The land use map of 2011 and 2017 is taken under study.
- To develop utility function and Multinomial Logit (MNL) model for mode choice. To determine vehicle ownership Non-Motorized Transport (NMT) bicycle, motorized Two-Wheeler (2W) and Four-Wheeler (4W) per household is incorporated.
- To analyze use of public transport system bus transit system is taken under study. Public transport accessibility level and accessibility index are worked out.
- To explore and understand change in population, density and land use area, the land use data of year 2011 and 2017 are taken in study. Identification and exploration of the relationship among urban land use and transport parameters resulting in application for similar kind of socio-economic development to be modelled and be calibrated.

However, these aspects of scope considered are not exhaustive as the study might bring in more insightful understanding through the exploration and research of further detailed variables.

1.5 Structure of the Thesis

Chapter 1 discusses in general and background of the research theme along with brief history, identifies a need to conduct the study. Problem definition is described for the current work. It also narrates the statements of aim and objectives along with the scope of the current research. The chapter ends with structure of the thesis and a significant contribution from the research.

Chapter 2 is a compilation of literature review blended with research outcomes published in books, reputed journal articles, conference papers, government reports and documents of multilateral organizations.

Chapter 3 details the characteristics of the study area. Ahmedabad city is chosen urban region for the study. West zone of Ahmedabad having spread of 65.68 km^2 is adopted as the study area. The chapter includes demographic dynamics, land use and other features existing in the study area.

Chapter 4 discusses methodology with flow diagram and steps in sequence for performing research activity. The adopted methodology for research is as shown in FIGURE 4.1.

Chapter 5 mentions about different data collected for performing research work. It includes secondary data of land use map and demographic information for the study period. The primary data collected by HIS and Public transport user's survey. Digitization of land use map with shape file for area computation for different land use in study area is shown in the chapter. The data analysis performed, results obtained and interpretation of the results reported. Cross category analysis is adopted for trip rate estimation. Mode choice analysis and development of MNL model is included in the chapter. The Public Transport Accessibility Level (PTAL) and Accessibility Index (AI) is calculated based on public transport bus user's survey.

Chapter 6 includes developed LUTI models showing relationship between land use and transport parameters. Calibration and validation of developed models are included.

Chapter 7 draws the conclusions from the research. It also lists limitations of the research study carried out, major contribution and scope for future research.

1.6 A Significant Contribution from the Research

Generally, four stage modeling is carried out for transportation planning. Land use models are developed for urban planning. Here, researcher have tried to make combination of urban and transportation planning. Here, researcher have kept emphasis on making land use and transportation interaction models: LUTI model. Number of models developed. In future as per availability of data, applicable model can be used for horizon year.

1.7 Closure

This chapter provides the introduction in general about LUTI as title of the research. It also covers problem definition with the Aim, Objectives and Scope of the study. The Organisation of report, as structure of thesis, is provided here. The chapter ends with a significant contribution from the research.

CHAPTER - 2

Literature Review

2.1 General

India, with almost 1.39 billion people, comes second after China in population. It is the largest democracy in the world. Furthermore, it is the largest country by area in South Asia and the seventh largest in the world, with a geographical area of about 329 Million Hectares.(*An Introduction to India - English (General Studies) - NDLA*, n.d.) Gujarat is the established administrative state in the western part of India. The urbanization cycle of Gujarat state is continuously changing with more urbanites in the state. Toward the start of the century, Gujarat's population was 9.09 million, of which 22 percent were living in urban regions. The citizens living in urban areas increased from 27.33 per cent in the year 1951 to 42.6 per cent in the year 2011 (*Census of India*, n.d.). The density of population in Gujarat was 83 people for each km^2 in the year 1951 that has been expanded during the most recent couple of decades. In the year 2011, the density was reportedly mentioned as 308 people for each km^2, showing expansion of 3.71 times in the population density in Gujarat. The Gujarat state has 33 administrative divisions as Districts. In some of these districts, the district headquarter has emerged as a major urban center of the State. These urban centers are highly populated compared to population density 2011 as 308 persons per km^2 of state. Ahmedabad in the northern part of the state has population density 2011 as 890 persons per km^2 is higher than state average value. (Jariwala, 2017). Ahmedabad, the largest city in the state of Gujarat and the fifth most populous city in the country. Ahmedabad is the seventh largest metropolitan area and third fastest growing cities of India. Ahmedabad has a key geographical location in Gujarat and is well connected with other major cities of the state as well as the country with road, rail and air. It has great potential for future development, in hotel development and medical tourism. It has availability of service land. The city's

expansive infrastructure, strong industrial base, and strategic location continue to attract significant number of businesses, investments and new residents. (*AMC (Website)*, n.d.)

Developing habitable cities is a continuing challenge for urban and transportation planners. Congestion, air pollution, unavailability of parking space, accidents are few of the negative effects of rising populations. The transportation infrastructure is one of the main drivers of urban growth due to accessibility and the economic opportunities it provides to the neighboring land and activities. In the study of land development and the creation of transportation links, the relationship of land use and transportation is an important idea.

As the number of vehicles are expected to continue increase in the future, the need of transportation planning appears to be essential for urban areas. To provide strong basis for the transportation planning process, this research considers the need for studies in this area, through studying the trip production and trip generation stage and its various categories.

For different purpose, the mode chosen is noted to generate modal split analysis. In the travel demand forecasting process, mode usage comes after trip distribution. However, mode usage analysis can be done at various points in the forecasting process. Mode usage analysis are also commonly done within trip generation analysis.

Transport planners generally focus on mobility, particularly vehicle travel. Whereas land use planners generally focus on geographic accessibility (distances between activities). In roadway engineering, *access* refers to connections to adjacent properties. Accessibility can be defined in terms of *potential* (opportunities that could be reached) or in terms of *activity* (opportunities that are reached). An automobile is a machine for mobility. A city is a machine for accessibility. When people say, “location, location, location,” they really mean “accessibility, accessibility, accessibility.”

As per the defined aim and objectives of the study literature review is conducted in major four sections. Books, Website, Reports, Conference proceedings and Journal papers are searched related to research work. Visit of local authority is carried out frequently to understand about land use and transportation scenario of proposed study area. The four major sections of literature review are as under:

(1) Land Use Transportation Interaction models

(2) Trip production

(3) Mode choice

(4) Accessibility

Trip rate is trip production per capita originated from households to reach economic -social-educational activity center to participate important transport network parameters used to develop LUTI model. Traffic Volume measured in Passenger Car Unit (PCU) depends upon mode choice of citizens. Use of public transport as mode choice depends upon accessibility to public transport system. Real estate and affordability to dwelling units depends upon land and built-up area available in city. More accessible area has more land, built up value and rent. Population always like to live in vicinity of activity center.

2.2 Literature Review

The literature reviewed are presented in the following paragraphs section wise:

2.2.1 Land Use Transportation Interaction Models

(1) (Skandary et al., 2021) : In this paper a generic calibration approach proposed for the parameters of the land use model using a differential evolution algorithm. A global sensitivity analysis was performed to identify the most important land use model parameters. These parameters were then calibrated using the differential evolution algorithm with the Root Mean Square Error (RMSE) and Mean Absolute Normalized Error (MANE) as multi-objective functions. Five key capabilities provided in the suggested technique for calibration of LUTI models:

1) Global estimation rather than local estimation

2) Consideration of multi-objective functions

3) Continuously improving the results

4) Easily adaptability

5) Involving multi parameters in the calibration process.

Author summarized that LUTI models are decision-making aid tools, that simulate complex dynamic bilateral feedback between transportation and land use within a territory. The

TRANUS land use model was used to test the performance of the suggested calibration technique. The validation and consolidation of the approach were tested based on convergence, minimization of errors, and modeled/observed data ratio by comparing with the genetic algorithm and particle swarm optimization techniques. Using the deferential evaluation algorithm, the suggested approach out performed both genetic and particle swarm optimization techniques and provided the most stable and diverse solutions. There is no standard approach to calibrate LUTI models, and neither is there a consensus on which objective function to use. Complexity makes the calibration a very expensive, time-consuming, and challenging process. Important parameters such as elasticity, price factor, and shadow prices of the land use model were obtained through sensitivity analysis. The suggested technique for Calibration of LUTI model was tested only on a developed model with three zones and five sectors. GA (Genetic Algorithms) and DE (Differential Evolution) continuously improved RMSE values and ended almost near 1000 iterations.

(2) (Guzman, 2019) : This paper suggested a first approach of a dynamic and strategic land use and transport interaction (LUTI) model aimed at addressing these challenges by simulating land use and transport system performance simultaneously. The model is intended to cover the entire city of Bogotá and 12 surrounding municipalities. It aims to support decision-making around high-level strategic policies. The tool's design was based on a qualitative analysis using causal loop diagramming (CLD) and subsystem diagrams, between socioeconomic, mobility, and policy variables. This model was inspired on the basic framework of the metropolitan activity relocation simulator, known as the MARS model. With the Bogotá-LUTI model, it is not necessary to complete the route assignment stage, given that it works with volume delay relationships rather than a complete network. It is designed for fast execution, using the information available in the city. The Bogotá model is a new development that goes beyond the traditional static and peak hour models. It is not an equilibrium model. It is assumed that land use is not constant and that it constitutes a dynamic system which is influenced by transport infrastructure. This planning tool is made up of two main models: the land use model and the transport model. These two elements are related by a time interval, which allows each sub model to work in different timescales. This means that if changes are made in the transport system, it will have an impact on the land use system after a time period. In turn, if there are changes in the land use system, there will be quicker reactions in the transport system. The availability and accuracy of data are not uniform for the entire study area was a challenge. For the case of the Bogotá Region, data

disparity was one of the biggest challenges when implementing the model. Growth patterns and the activities they produce are likely to be significantly different, and proper adjustments are needed. The area of the Bogotá case study was divided into 127 zones: 112 zonal planning units (UPZ) in the city of Bogotá, which occupy about 400 km^2 in 2015, the Bogotá city area has 7.9 million people. Additionally, the 12 surrounding municipalities comprised of an area that extends across 1194 km^2 with a population of 1.34 million inhabitants. Transport model simulates the transport of passengers on a working day and incorporates trip generation, the spatial distribution of trips, and modal split. These elements are the first three stages of the classic transport model. This sub model not included a traditional assignment step. The model is based on the analysis of speed versus Origin & Destination (OD) demand relationships and includes speed-flow functions that simulate the existing transport network over time. These functions were calibrated for the Bogotá region network using a transport model developed with the PTV-VISUM commercial modelling software. The assessment of accessibility levels by zone involved the use of a potential accessibility model that incorporates daily trips by motorised transport modes (car, bus, and BRT). A validation attempts of the Bogotá-LUTI model, which simulated and compared changes by zone between 2011 and 2015, shows a significant correlation. There is not enough official information to make a complete model validation. For this reason, the comparison between 2011 and 2015 will only be shown for two results of trips generated and population. LUTI-Bogotá with the base year 2011 was set up, and its results in 2015 were compared to empirical data observed in the period of 2015. However, validation could not be done at the zonal level, because the last mobility survey (2015) did not have the same level of statistical significance at UPZ level. Estimated OD specific speed-flow relationships at the aggregate LUTI-Bogotá level. Compared speeds versus Bogotá-LUTI modelled speeds for all OD pairs with an R^2 value of 0.55 and an intercept of 10.2 kmph. There were differences between the Bogotá-LUTI model and VISUM results.

(3) (Petri et al., 2019) : The paper presented the first results of the LUTI model built to analyse territorial impact of future project in the area around Florence, starting from the province of Pistoia, and arriving to Florence through Prato province. Starting with the collection, homogenization and comparison of actual most important planned measures at different scale, from the single involved municipalities to the Tuscany Regional Plan. The LUTI model to evaluate different evolution scenario joining complementary infrastructure and territorial evolution measures. The obtained results show the importance of the LUTI

model to support territorial planning at a multidisciplinary level. There was not so satisfactory level of sustainability in mobility relative to the objective of the general Environmental policies and objectives. The study area includes the whole Florence city urban area and the metropolitan area linking Florence to the city of Prato and Pistoia, the so-called "Piana Fiorentina". The area is approximately 681 km^2 and it is a high tourist attractive city. The area was divided into 71 zones. Daily schedule public transport program where collected, both of rail and bus service. Around 400 lines with frequency scheme and their mileage rates were loaded in the model. There are a greater number of households having retired persons as per income category. The Land use model implement two main markets, namely the housing market and that of economic activities. The generation and distribution model step has built within Cube Voyager. The calibration of the generation phase reported an R^2 index of 0.59, Which needs to be checked and corrected and finally stopped at R^2 =0.89. Author significantly concluded that the LUTI models specifically consider the interaction between population, land use/distribution of activities/gravitation of the individual areas and existing transport services.

(4) (Litman, 2016) : This report examined ways that transportation decisions affect land use patterns, and the resulting economic, social and environmental impacts. These include direct impacts on land used for transportation facilities, and indirect impacts caused by changes to land use development patterns. In particular, certain transportation planning decisions tend to increase sprawl (dispersed, urban-fringe, automobile-dependent development), while others support smart growth (more compact, infill, multi-modal development). These development patterns have various economic, social and environmental impacts. This report described specific methods for evaluating these impacts in transport planning.

(5) (Aljoufie et al., 2016) : Author discussed that there are 3 types of land use classes namely active, passive and static. Cellular automata based Metronamica model were developed in which trip production, trip attraction, mode choice and route assignment are transport models in LUTI structure. Accessibility is the land use element which considers local, implicit and zonal accessibility. Residential, commercial, vacant lands, roads, green areas, industrial, airport, port, informal settlements and public places extracted as land use classes. Residential land use considered with low, medium and high density as per population.TAZ map comprising 311 zones were taken for transport model. The developed LUTI model calibrated for the duration of 1980 to 2007. The developed model validated for

the period from 2007 to 2011. The paper focused on framework for policy and impact assessment in urban area. The developed model act as a tool for integrated land use transport planning. The developed model replicates the past and current urban growth, change in land use and interaction between 1980 and 2011.The developed model is used for next 20 years forecast up to 2031.There was continuous support from Jaddah's municipality staff for the model development. The four policy interventions are considered for Jeddah are BAU (Business As Usual), Compact growth, transport improvement and interaction of land use and transport. Transport intervention considers public transport promotion and expansion.

(6) (Litman, 2015) : This paper investigated the transport impacts of various land use factors, and evaluates land use management strategies called smart growth, new urbanism or compact development achieving planning objectives such as,

- Transport Impacts: Vehicle Ownership, Vehicle trips and travel (mileage), Walking, Cycling, Public transit travel, Ridesharing, Telecommuting, Shorter trips
- Land use factors**:** Regional accessibility, Density, Land use mix, Centeredness, Road and path connectivity, Roadway design, Active transport (walking and cycling) conditions, Public transit service quality, Parking supply and management, Site design, Mobility management, Integrated smart growth programs
- Planning Objectives**:** Congestion reductions, Road and parking facilities, Consumer savings and affordability Improved mobility for non-drivers, Traffic safety, Energy conservation, Pollution emission reductions, Improved public fitness and health, Community liveability objectives

Most land use factors have modest individual impacts, typically affecting just a few percent of total travel, they are cumulative and synergistic. Integrated smart growth programs that result in community design similar to what developed prior to 1950 can reduce vehicle ownership and travel by 20-40%, and significantly increase walking, cycling and public transit, with even larger impacts if integrated with other policy changes such as increased investments in alternative modes and more efficient transport pricing.

Land use impacts depending on definitions, geographic and time scale of analysis, perspectives and specific conditions, such as area demographics. Most factors only apply to subset of total travel, such as local travel or commute travel. Density tends to receive the

greatest attention, although alone its travel impacts are modest. Density is usually associated with other factors such as regional accessibility, mix, transport system diversity, parking management that together have large travel impacts.

(7) (Gaál, 2015) : This paper discussed about status of Land Use and Transport modeling in Hungary. In Hungary there is no history of joint planning of transport systems and land use. One of the territorial goals of the Concept – linked spaces: ensuring accessibility and mobility – is directly interconnected with transport. Developing an LUTI model applied to Hungarian circumstances was in the urban context. A mixed strategy involving land-use planning, pricing schemes, efficient public transport services and infrastructure for non-motorized modes and charging/refueling of electric vehicles was needed to reduce congestion and emissions. By application of LUTI models, resources could be focused on the most profitable investments. For Hungarian practice a LUTI framework was needed to give a powerful tool to planners. The model should be able to operate in two level, regional and urban/agglomeration levels. LUTI models like TIGRIS XL or MARS (Metropolitan Activity Relocation Simulator) were suggested.

With the application of suitable LUTI models inefficient investments could be avoided, succession of actions could be determined and resources could be concentrated on projects better serving government policies and sustainability.

(8) (Mayerthaler et al., 2015) : This paper presented an attempt to set up the land-use transport interaction model MARS (Metropolitan Activity Relocation Simulator) for a nationwide case study of Austria. The purpose of the model was to capture the most important interactions and feedback mechanisms between the land use and the transport system. Particular attention was paid to the structural changes of the model and the estimation of the transport model parameters as well as the land use model parameters, which are modelled with a gravity model approach. For this purpose, the build-in optimizer of the modelling software Vensim by minimizing the sum of squared deviations between observed and predicted data was used. MARS LUTI model, developed to support decision at strategic level transport policy issues in metropolitan areas in the late ’90s. Although originally developed for metropolitan areas, MARS was tested on nationwide scenario to investigate generality. Results were reasonable without external interventions, showing the possible wider range utility of the model.

(9) (Coppola et al., 2013) : This paper had presented a land use and transport interaction (LUTI) model that can perform estimations of changes in the location of population, real estate prices, and economic activities as a result of the introduction of policies and projects relating mainly to transport. This model was classified as a LUTI simulator between first and second generation as it combines certain aspects of spatial interaction models with random utility theory and hedonic regression techniques for predicting real estate prices. The model was later applied to the metropolitan area of Santander(Spain) where its parameters were calibrated and the goodness of fit evaluated using observed data from the base year but fit of the model could definitely be improved by further disaggregating the types of households and economic sectors and by data collection to allow for more complex specification of the utility functions. The parameters estimated using the different sub models showed theoretically consistent signs like travel times from home to work were shown to have an explanatory role in household location, causing more disutility for people with incomes more than2,500€. Other aspects such as property prices and the income levels of the households also agreed with theoretical expectations. In the case of Santander, the active accessibility of each zone did not prove to have significant impact in explaining residential location but it affects the transport costs. Passive accessibility along with other factors showed significant impact in determining the location of economic activities.

The four sub models making up the main structure of the LUTI model for Santander are as follows:

- *Transport Model* that, given a location pattern for residents and activities, simulates the simultaneous equilibrium between supply and demand in the transport system.
- *Residential Location Model* that, gives a journey time between zones, an activity location pattern, a set of real estate prices, and a residential supply, simulates the location of workers and residents in the study area disaggregated by income classes.
- *Economic activity location Model* that, gives each zone's accessibility and the residential location pattern, simulates the distribution of these activities disaggregated by an economic sector.
- *Real Estate Price Prediction Model* that, given the structural characteristics of the properties, the environmental characteristics, the demand/supply of location, and the transport conditions of each zone, simulates the property price.

(10) (Aljoufie et al., 2013) : Author said that understanding the interaction between urban land use change and transport is critical for urban planning as well as transport planning, particularly in the case of rapidly growing and motorising cities. A CA-based land use transport interaction model was applied to the city of Jeddah, in Saudi Arabia. Author had concluded that dynamic land use and transport interaction models provide a good platform to study this mutual interaction. Metronamica Land Use Transport Interaction model (Metronamica-LUTI), which integrates a cellular automaton (CA) based land use model and a four-step transport model into one system. CA models typically exist on a lattice of grid cells, where the state of each grid cell represents one of a limited number of land uses. Land use is a primary input in the four-step transport model and transport accessibility is an important input in the land use model, the two can be integrated in a straightforward manner. Both models were evaluated per yearly time step; therefore, each year, the result from the land use model feeds into the transport model and vice versa. This resulted in a dynamic model that included the mutual feedback between both systems.

(11) (Iacono et al., 2008) : This paper reviewed some of the frameworks for modeling transportation and land use change, illustrating each with some examples of operational models that have been applied to real-world settings. Authors had reviewed various land use and transportation model starting from late 1960's to till 2008 and classified as below:

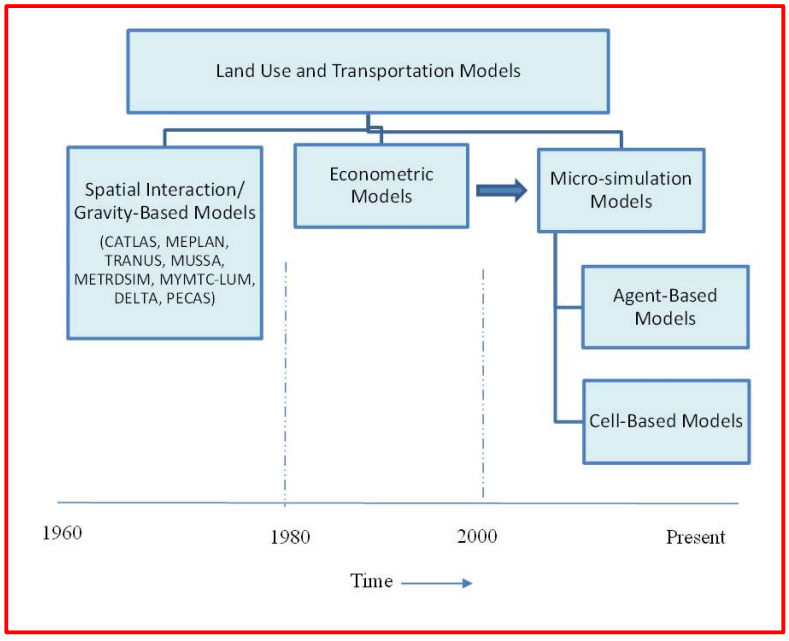

FIGURE 2.1: Chronological Development of Land Use and Transportation

Newer models represent in greater detail the dynamics of the transportation–land use change process. Experiments with bottom-up approaches to modeling urban systems, especially those that recognize the interactions between agents, provides an alternative mean for understanding their complexity. Most of the newer generations of micro simulation models are designed with the objective of making them more policy sensitive. This paper also addressed limitations and issues of various land use models.

(12) (Russo & Musolino, 2007) : As the title of the paper, it included state of the art and applications of urban Land Use Transport Interaction modelling. LUTI modelling can support strategic planning, policy making, public and private investment decisions. At the urban scale, land use has an important role in determining the process of activity generation and location. The model was applied to forecast changes in transport and land use patterns at an urban strategic scale. It included definition of a state of the art on LUTI models, activity models, formalization of a LUTI model and description of all modelling components and connections; model application to forecast changes in transport and land use patterns at an urban strategic scale. Many urban LUTI models refer to the Multi-Regional-Input-Output (MRIO) framework, estimating transport demand, generation and location of activities, land use, as a result of interaction between a transport system of models and an activity model. The proposed LUTI model has two interacting modelling components: the transport model and the activity model. The LUTI model applied to the town of Reggio Calabria (Italy), to forecast changes in transport and land use patterns induced by an integrated transit-oriented transport system. Reggio Calabria is a coastal town of about 1,80,000 inhabitants, located in the south of Italy. Current transit system is composed by urban and regional bus services; regional rail services, connected with bus services through the bus terminal located beside the main rail station in the central district; inter-regional maritime services. The Sustainable Mobility System to be implemented is a funicular travelling in a reserved right-of-way, with stops every 400 to 500 meters. Vehicles guidance is fully automated and the control system is centralized. The study area has been subdivided in 35 zones comprised of 11 peripheral zones and 24 central zones. The activity system is segmented in 8 sectors to match available census residential and employment location data. Transport demand is estimated through a three-step system of demand models that simulate emission, mode and path choices. Transport demand during morning peak hour estimated and forecasted. Individual trips for each transport service (car, bus, rail) estimated and forecasted for the study area. Activity's location and land use patterns were estimated and forecasted for each district. Activity's

location patterns were observed in line with forecasted average floorspace prices in each district. Challenges concern data unavailability at the urban scale for general validation of the whole model. Calibration of some model parameters was difficult due to the difficulty to get appropriate observed data.

(13) (Sivakumar, 2007) : As the title of paper, it gives overview of LUTI models. The paper is about Synthesis of Transport Modelling Methodologies. The author discussed the approach to modelling an urban system in its entirety, with specific focus on the issue of energy consumption. The framework of land use and transport related policies that a LU-T model should ideally be able to address is pointed. Underpinning all the models of land use transport interaction discussed in this report are models describing the decision-making behavior of individual agents e.g., travelers, developers, employers etc. Operational integrated LU-T models were active and dynamic models. The authors discussed about aggregate, disaggregate and activity-based model. Complexity of functional linkages in urban system dynamics was shown in research. Urban planners in the 1950s and 1960s initiated the development of integrated land use-transport (LU-T) models in recognition of the complex dynamics of an urban system. The first of these models to gain popular notice was Lowry's model of Metropolis in 1964. Since then, there have been several integrated LU-T models developed worldwide such as ITLUP (Putman, 1983), MEPLAN (Echenique,1985), MUSSA (Martínez, 1992), and UrbanSim (Waddell, 2002). While the land use components of these LU-T models have been rapidly evolving from simple aggregate representations to complex economic and econometric models of the market processes, the four-step model continues to represent the transport modelling component.

(14) (Wegener, 2004) : This paper described the recent and future developments in the field of operational land-use transport interaction models and has analyzed with special emphasis on their ability to check land-use and transportation policies with their impacts. The models analyzed the most essential processes of spatial development in urban areas which implies that they forecast urban land use, where land use indicates a range of land uses as residential, industrial and commercial. This excludes partial models addressing single subsystem such as housing or retail.

It is essential that the links from transport to land use are considered and transport itself may be modelled by endogenous/exogenous transport model. The models are operational in the sense that they have been implemented, calibrated and used for policy

analysis for metropolitan area. For the evaluation of operational urban models, the urban change processes to be modelled are identified. Eight types of major urban subsystem are distinguished. They are ordered by the speed by which they change, from very slow to immediate processes. For the overview, twenty contemporary urban land-use transport models were selected for a comparative review which represent the current state of the art of urban modelling. This paper emphasis on the spatial revaluation of existing land use transport models based on activity-based travel behavior or neighborhood scale travel demand management policies rather than traditional four step travel model sequence models. As of title this paper gives Overview of land-use transport models.

(15) (Patnam, 2003) : In this research paper, an effort has been made to model the mutual interaction between urban transportation system and the urban land use pattern and its change with time. The major factor influencing the location of the middle-class population is the travel time to their places of interest and the state of the transportation facilities available for this travel.

Author works on the model which is applied as part of the LEAM (Land Use and Evolution Impact Assessment Model) in the Peoria region and in the greater St. Louis region. LEAM was designed to simulate land use change over space and time. This simulation makes use of National Land Cover Data (NLCD) (with a resolution of 30m x 30m) classification and other extensive local geographic and demographic data. 25 ramps (actual entry point) for an interstate have been chosen, it has been assumed that proximity to a ramp would help in development for a locality. The volume over capacity ratios for the entire region was then compared with an optimal volume to capacity ratio of 0.80. The road links which had a V/C ratio above this threshold of 0.8 were identified as potentially congested links.

(16) (Lerner-lam et al., 1992) : Author discussed that successful land development depends as much on the ability of the public sector to operate efficiently and innovatively as it does on the ability of the private sector to do so. In particular, it is essential that public agencies responsible for land use and transportation policy and planning decision making coordination among themselves and efficiently channel scarce public resources so that transportation infrastructures-road and transit systems- can be planned and implemented effectively. Coordinated land use and transportation planning can enhance the development process and, therefore, the quality and profitability of the end products.

OUTCOME OF THE LITERATURE REVIEW FOR LUTI:

Several past efforts of research and studies performed in the past depicts for the uniqueness and novelty of the research work, its aim and objectives along with a scope. The GIS applications are used for understanding the spread of land and preparing base maps using boundaries for land use data. LUTI model is relationship among transportation and land use using mathematical models. Developing a full flanged LUTI model is problematic and constrained due to non availability of spatially disaggregated land use data, data collection cost and time. Huge quantity of data is required for validating models. Calibration (parameter estimation) is the most crucial factor in LUTI models. (Bonnel et al., 2014). LUTI models are not optimizing models, their function is prediction. The estimation and adjustment of model parameters using a numerical method to minimize discrepancies between actual and modeled data. The literature reveals that there is no standard approach to calibrate LUTI models. Trial and errors techniques have been conventionally used to calibrate LUTI models. (Gilquin et al., 2017). There is change in land value due to accessibility for transport facility. LUTI is a cycle showing cyclic relationship of predictive nature as shown in FIGURE 2.2 below.

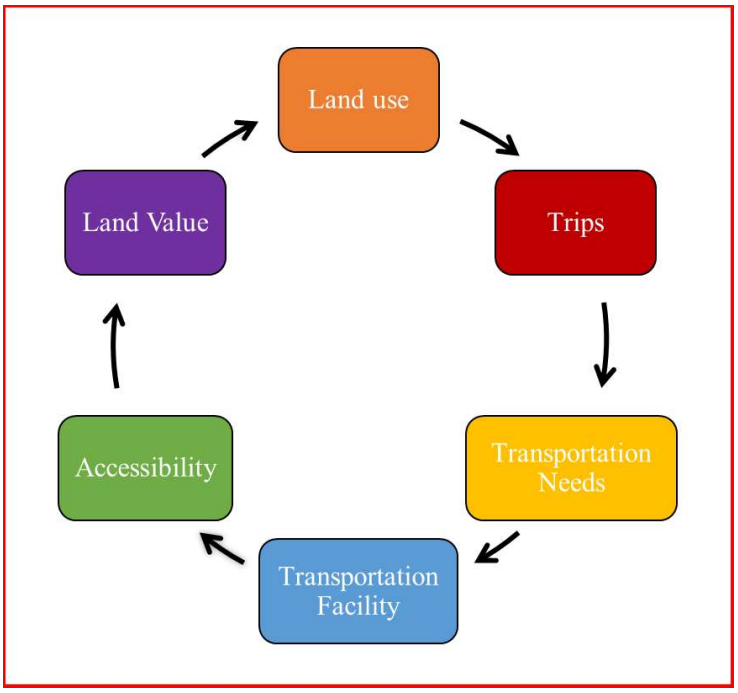

FIGURE 2.2: Land Use Transportation Cycle

(Source:(Khisty, 1990)

Calibration is expensive, time consuming and challenging process. LUTI modelling can support strategic planning, policy making and public and private investment decisions. Various land use models, transport models and their limitations and issues are addressed in literature review. Four stage modeling is explained as transport model. LUTI model does not include traditional route assignment step. Transport model includes transport of passengers on a working day and incorporates trip generation and modal split. LUTI models specifically consider the interaction between population, land use and existing transport services. There are changes in real estate prices as a result of the introduction of transport projects. i.e. Indication of impact on land use. The research reported in context of Indian cities are very less. This is gap in research in Indian policy and decision making.

2.2.2 Trip Production

The travel demand is continuously growing due to rapid development of infrastructure, business opportunity, spatial distribution work place and residences, and higher education. Estimating the number of trips generated in the city is basic and the most important step in travel demand forecasting. Transport generated trips are considered with an aim to improve the accuracy of transport trip production models. Trip production model can be developed by two methods- Regression Analysis and Cross Classification Analysis/category analysis. Trip production models in India have traditionally been developed using simple regression analysis.

(1) (Ashenagar, 2017) : Author compared empirical trip rates modelled by way of multivariate regression and category analysis in Skudai town in state of Johor in Malaysia. Origin and Destination interview surveys were conducted to determine the mode used for traveling. From the data collection, correlation analysis carried out with trips as dependent variable and independent variables to test the ability of those variables in estimating the observed trip generation. Then it was used to determine how well the trip generation equation output matches the surveyed data. By Category and multivariate regression household trip generation analysis techniques compared and contrasted. Although according to previous researches it is expected that regression and category models will be yielded equivalent results, having a fixed formula predicting the future travel, using regression model seems much better and easier than Category Analysis. The study recommend that the household regression approach should be further investigated since it has advantages as a model building procedure and makes better use of sample data.

(2) (Shinya Kikuchi & Jongho Rhee, 2015) : Authors discussed about trip production rates, presented in cross classification tables, which are essential data for the planner's understanding of the travel characteristics of a region. They find that the trip rates obtained from surveys, often show a pattern that is not consistent with what is expected by the analyst. For example, the greater the household size and auto ownership, the greater the number of trips generated. This pattern may not be found in the trip rates that are obtained directly by the survey. In such cases, analysts commonly adjust the irregularities manually. The way in which the values are adjusted affects the credibility of the trip table and, ultimately, the forecasted travel demand. A method that adjusts the values of the trip table systematically was presented. The process used the fuzzy linear programming method. The objective was to make the adjusted value as close to the observed value as possible. The constraints are to make the adjusted values adhere to the analyst's general expectations about the pattern of the values in the table, and to match the number of trips estimated from the adjusted trip table with the actual number of trips surveyed. An application example that uses real-world data was given.

(3) (Chang et al., 2014) : Authors Compared the performance of trip generation models in this paper. Trip generation estimates the number of trips to and from a traffic analysis zone. Six representative models namely regression, Tobit, Poisson, ordered logit, category, and multiple classification analysis were applied to the home-based work trips in the Seoul metropolitan area. In this process, the measures of correlation, variance, and coincidence were compared. The category type model was superior in overall performance. The performance comparison between the models was conducted based on validation. The measures of correlation, variance, and coincidence were utilized for the quantitative assessment of this process. In the cross validation, the models show similar RMSEs while the category type approaches achieve slightly better performance. The data for household characteristics and trip generation rates was taken from a household travel dairy survey of the Seoul metropolitan area and regional characteristics were based on the data from the Korea Regional Development Total Information System (REDIS). The Regression model had R^2 value of 0.4. The comparison of six models based on RMSE and NRMSE(Normalized Root Mean Square Error), measures of difference between observed value and model value revealed category type models to be superior of all. Further, regression model also produced acceptable performance.

(4) (Aloc et al., 2013) : Authors aimed to create models for the first of the four-step model of travel demand forecasting i.e., trip generation for Lipa City. Two modelling techniques used, namely: (1) regression analysis; and (2) trip rate method. For the regression analysis, fifteen independent variables and two dependent variables namely trips produced and trips attracted considered by trip purpose. Eight trip purposes were identified: To Home; To Work; To School; To Private Business; To Employer's Business; To Medical; To Shopping; and To Church. Results of regression analysis showed that the population per zone, number of households per zone, workers per zone, and students per zone and household head monthly income per zone were significant parameters for a particular zone to produce and attract trips.

(5) (Montealegre, 2010) : The technique of cross classification was very useful for studying the quantity of generated trip on household for each trip purpose. To validate this technique was necessary rely on. All the base information as historical data and other samples allowed to check the sound index of technique. It shows also some difficulty on the incorporation and interrelation of new variables. This limits the precision of estimation of future demands but stability of supposed relations acceptable.

(6) (Makinde, 2009) : Author concluded by study in Ado – Ekiti that people with higher income and more automobile availability make more trip than people with low income and less automobile availability. He observed that home based other trip purpose took the largest percentage (52%) of people while non-home based and home-based work contributes 31% and 17% respectively. The result of the regression analysis of trips as dependent variable as against other independent variables such as age, family size, income and car ownership amongst others gives average value of R and R^2 as 63.5% and 40.45% respectively.

(7) (M. Taher & Khalik Al-Taei, 2006) : The authors used a cross-classification technique to predict trip production travel among 20 traffic analysis zones located within Dohuk city residential area. Two and three level cross-classification matrices had been used to describe disaggregated trip rates, total vehicle trips and total private trips. Car ownership was considered as the main factor causing trip production related to other household characteristics like family size, income level and number of workers. Based upon this study it was concluded that data can be used directly in the prediction analysis of trip rates. Family size and number of workers in the family were the most effective independent variables.

Number of cells could be reduced if larger sample size were used in the prediction analysis as well.

(8) (Abdel-Aal, 2004) : The author developed a trip production model using cross classification technique for the city of Alexandria. He used the data-efficient Multiple Classification Analysis (MCA) for modelling trip production. Due to non-availability of recent travel survey for the city of Alexandria, an application of the proposed model was carried out using a recently collected sample data. A weighing procedure was applied and proved to be effective in offsetting the bias of small collected sample. The two-dimensional MCA model showed the model sensitivity to reflect the effect of changes in socioeconomic household attributes on trip rates in the future. Different household attributes were tested and their suitability was discussed as well. The model accuracy was affected by the small sample size in terms of a wide confidence interval. A discussion was given about the sufficient sample size. The proposed model suggested that there was an indication that the average trip rate had increased by about 10% during the last two decades. More significantly, the motorized trips had largely increased while walk trips had decreased.

(9) (Satyakumar, 1995) : Author discussed about structuring category analysis and derives the methodology which is suitable in situations where there are cells having insufficient or no data. The simplicity of the procedure lies in the fact that raw data can be effectively used for calibrating the models. Computations become less voluminous once the normal equations are derived. From the analysis it may also be concluded that

- The models produced generally fit adequately.
- Only cells with insufficient data show significant discrepancies in the trip rates.
- Household structures were found to be more significant for explaining the variations in work-trip rates.
- Since the models calibrated with data available from the entire scheme, the reliability of trip rate estimates in cells with insufficient or no data were high.
- The analysis helps to identify the variables that most influence the trip rates.

(10) (Takyi, 1990) : Author used cross-classification technique to investigate household trip rate analysis in Kumasi, Ghana and presented it as a developing country context. Four independent variables were selected for the analysis namely, household income, household size, the number of cars owned per household, and the number of employed persons per household. Household income and size were each classified into six groups, and the number of employed persons and car ownership were classified into three and four groups respectively.

(11) (Wootton & Pick, 1967) : In this paper author discussed about model for trips generated by households. At the end of the 1960's an alternative method for modelling trip generation appeared and quickly became popular and it is widely used. The method is known as category analysis in the UK and cross-classification in the USA. It originally developed in the Puget Sound Regional Transportation Study (1964) and it is based on reporting trips rate per household for any trip purpose as a function of household attributes. In this method, households are categorised into categories on the basis of a cross classification of their characteristics and applies a constant trip generation rate for each category. The advantages of category analysis that it is easy to understand and no prior assumptions about the shape of the relationship are required.

OUTCOME OF LITERATURE REVIEW OF TRIP PRODUCTION:

Based upon literature review, researcher has framed the data to collect and analyze. The method of data collection, suggested, is home interview survey by selecting sample size. The data of household characteristics and trip information is to be collected using HIS form as designed and presented in Appendix-A. Trip production is the first stage of transport model for LUTI model. There are two modelling techniques, regression analysis and trip rate estimation for data analysis. Home based work trips and home-based study trips are major contributor in trip production. Trip production rates presented in cross classification tables are essential data for the understanding of the travel characteristics of an urban area. Cross Category Analysis (CCA) for trip production using household data is superior compared to other methods.

2.2.3 Mode choice

Mode choice for urban residents to perform various activities is also known as mode shift or modal split. It is the stage of four steps in transportation planning followed by trip generation stage.

(1) (Jin et al., 2018) ; This paper included the case study of Suzhou city, China and mode choice behavior of citizens derived using Multinomial logit model. Under the rapid development of public transportation, a case study was processed to study the citizens mode choice behavior. A stated preference survey was carried out to analyse the mode choice pattern of citizen under different scenarios and MNL model were developed. The conclusion shows that in-vehicle time, non-in-vehicle time, cost and number of transfers has affect on mode choice pattern of citizen. Middle and young aged people favor public transportation. People with higher income uses car and hired taxi as a mode of travel. Some of the policy implications also suggested for increasing the use of public transportation mode like use of bicycle to reach the metro station would have increase the use of public transportation.

(2) (Jana & Varghese, 2017) : The paper analysed mode choice for inter-regional travel in India. This paper considered the four types of trips namely social trips, pilgrimage trips, health trips and shopping trips. The information was collected on domestic tourism through a countrywide household survey in 2008-2009 in India. Sample size for the survey were 1,53,308 households and data collected from 8,109 samples from village and 4,719 samples from urban areas. For the analysis of the data binary logit model were developed from collected data and mode of travel considered were by walk, bus, trains, air travel, own private vehicle and rental transportation. The data for individuals were segregated for residents from urban and rural areas and the trips were segregated into overnight and same day trips. Binary logit model analysed the Socio-economic parameters, Individual characteristics, Trip characteristics, Time of year, Purpose by Destination and Type of stay were influencing factors which derived from the model. Results shows that trips within district and urban areas made by bus and trips outside the district made by the trains. In rural areas rental transportation mostly used for Health trips. Pilgrimage trips made by walk and as distance increases private and public transportation also increases. Land use in urban and rural area has impact on different type of mode choice.

(3) (Juremalani & Chauhan, 2017) : Comparison of different mode choice models for work trip has been carried out using data mining process. Personal characteristics and trip characteristics which were taken as independent variable and have been considered for development and analysis of different models. Study considers the development of three models namely Boost tree, MNL and SVM models.

(4) (Sekhar et al., 2016) : This paper mainly aims at modelling the mode choice behavior of commuters in Delhi using Random Forest (RF) Decision Tree (DT) model and Multinomial Logit (MNL) model. For this purpose, household survey was carried out and 5000 individual sampled for data collection from Delhi. In this study mode of transportation considered were Two wheelers, Private car, Bus, Metro, Auto Rickshaw and Bicycle. For mode choice analysis purpose WEKA6.3.9 software has been used. The results show that Random forest-based decision tree model have the higher prediction accuracy of 98.96% and Logit model have accuracy of 77.31% which shows that RFDT model has higher accuracy and superiority.

(5) (Lekshmi et al., 2016) : This paper considered trip-based approach and tour-based modelling were the methods used for travel demand modelling. Thiruvananthapuram, capital of Kerala was considered as study area and data of socio-economic and travel characteristics were collected by household survey method. Utility functions were developed for each mode of travel and analysis shows that variables such as age, income, vehicle ownership, time of day and cost of travel were identified as significant variables. Based on all variables MNL model was developed using SPSS software package tool. Result shows that socio-economic and travel characteristics have higher influence on selection of travel mode. The model developed can be used to predict the types of activity patterns and generating the mode preference of the population.

(6) (Wang et al., 2015) : The paper analysed the factors influencing the travel mode choice of residents, and develops a multinomial logit model using RP (Revealed Preference) data and SP (Stated Preference) data. The paper provides a theory for using traffic policy to adjust the structure of a public transit system and improvement needed for more use of public transportation. Mode choice analysis carried out after implementation of BRT service. Based on the data of personal characteristics and trip characteristics MNL model was developed and utility function of each mode of travel has derived. The result shows that different factors

have different influencing degree on mode choice. Females were more likely to use BRT. Also ticket price and speed of BRT affect most for selection of mode of travel.

(7) (Minal & Sekhar, 2014) : This paper focused on review of mode choice study and analysed as a transportation planning process. Disaggregate model found to be most useful and accurate model and specifically Multinomial logit model gives the specific and accurate result in mode choice study. Logit model, Probit model, General extreme value model and Hybrid model has been analysed in this paper. Among all this model logit model is most useful model because of simplicity and easy interpretation of results. Hybrid model gives the better result than individual model. The conclusion of the study derives the different influencing factors like trip characteristics, comfort, convenience and characteristics of mode which affect most to the traveler. In this study comparison of use of different model given and accordingly disaggregate model has given more emphasis for mode choice modelling. Also, hybrid fuzzy model gives the most accurate results compared to any other individual models.

(8) (**Ashalatha et al., 2013) :** Author has analysed statistical mode choice models such as multinomial logit model. The study used multinomial logistic regression to analyse the mode choice behavior of commuters in Thiruvananthapuram city. Data of Socio-economic and trip characteristic were collected. Total 739 data sets in sample were collected and the data analysis were carried out. In survey data collected like age, gender, income, trip purpose, trip length, travel time and travel cost. MNL model developed and influencing factor on trip were determined. Author concluded that lower age group uses bus whereas preference to car is higher among higher age group. Male commuters give preference to a car and female commuters give preference to bus as a mode of travel. As income increases the use of bus as transportation mode decreases and a greater number of car users were shown. It is observed that increase in travel time and shifting from one bus to another bus in the case of public transport affect most and a greater number of commuters shift to car as transportation mode. The person who have their own two-wheeler and four-wheeler, uses two-wheeler for reaching at a working place rather to use public transport. Shifting of a greater number of people from public transport to private transport reduce the efficiency of road transport so, final suggestion was given that improvement and different schemes need in public transport facilities for higher use of it.

(9) (Yin et al., 2012) : The authors had used the binary logit model for selecting a car and bus only two mode of travel and encourage the people to stop driving cars and start riding bus in the city of Jinan. Individual and travel attributes were considered for study like gender, age, occupation, monthly income and trip purpose, trip distance, departure time, travel hours, travel cost. Jinan resident trip survey data were used to establish impact factors on travel behavior and use of mode of travel. Travel and spatial distribution characteristics of resident travel were analysed. Binary logit model between bus and a car were developed and influencing factors were derived. This analysis found that age and gender impact choice of bus travel. Use of bus and car depend upon income of a user. People with higher income prefer to use car as mode of travel. Travel time and travel fare were major influencing factor to choose the mode of travel. As increase in travel time and travel fare in public transport a greater number of people uses car than bus. Suggestion was given that reduction in travel time and travel cost attract the greater number of people to use public transport as a bus.

(10) (Zhou & Lu, 2011) : This paper analysed the factors influencing the trip mode choice of urban residents. This study was done for effective implementation of traffic demand management and traffic control strategies. The prediction model was built respectively based on multinomial logit model and probabilistic neural network. Using these two models, probability of each mode choice is calculated and final choice was estimated. The result shows that probabilistic neural network has overall higher accuracy and MNL model gives better results for some extent. Estimation of error was observed less in probabilistic neural network model.

(11) (Yang Zhongwei et al., 2010) : The main study of this paper compared the two mode of transport, subway and bus, in the city of Beijing. Effect of fare on traffic structure was studied and mode split analysis was done. Effect of traveler's personal attributes, trip information, and traffic mode level of service on mode split studied. Different variables were determined and based on that disaggregate model, MNL model were developed. Utility function for both mode of travel was determined. Traveler choose the mode which has higher utility. Influencing factors on subway and buses were analyzed and results show that trip time, cost, gender, age, occupation, income and trip purpose have remarkable influences on trip mode selection.

OUTCOME OF LITERATURE REVIEW OF MODE CHOICE:

Home Interview Survey (HIS) is a method of data collection for mode choice analysis and model development. MNL model gives the specific and accurate result in mode choice study. MNL is found most useful. Utility functions to be develop for each mode of travel. Traveler choose the mode which has higher utility. Probability of each mode choice is to be calculated for traffic control strategies. The identified variables such as age, income, occupation, trip purpose, vehicle ownership, travel distance, trip time and cost of travel are significant. Socio-economic and travel characteristics have higher influence on selection of travel mode. Mode choice is useful for improvement in public transport facilities to reduce shift from public transport to private transport. The developed MNL model suggests that reduction in travel time and travel cost attract higher number of persons to use public transport as a bus. Travel time and travel cost depends on spatial distribution of intensive land use and transport network. Mode of trip affects land use and transport activities.

2.2.4 Accessibility

Accessibility is the suitability of the public transport network to get individuals from their system entry point to their system exit location in a reasonable amount of time. A comprehensive analysis of accessibility in planning expands the scope of potential solutions to transportation problems. Accessibility is the main parameter which contributes to the effective transportation system.

(1) (Thu & Tun, 2017) : This paper explains public transport accessibility level (PTAL) Madalya city (second largest city of Myanmar) with the help of an indexing system. The software ArcGIS10.1 has been used. Daily transportable number of passengers of 93 wards is obtained from Bus Line Control Committee. Land use and population density map is taken from department of remote sensing, Mandalay Technological University. Locations of bus routes are taken as spatial data. Population and bus routes taken as attribute data. LONDON PTAL Methodology is used.

(2) (Litman, 2016a) : This paper discussed the concept of *accessibility* and how it can be incorporated in transport planning. Accessibility refers to people's ability to reach goods, services and activities, which is the ultimate goal of most transport activity. Many factors affect accessibility, including mobility (physical movement), the quality and affordability of transport options, transport system connectivity, mobility substitutes, and land use patterns.

Accessibility can be evaluated from various perspectives, including a particular group, mode, location or activity. Conventional planning tends to overlook and undervalue some of these factors and perspectives. More comprehensive analysis of accessibility in planning expands the scope of potential solutions to transport problems.

(3) (Shah & Adhvaryu, 2016) : This paper described the public transport accessibility levels (PTAL) for Ahmedabad city. The ARCGIS mapping tool was used to generate a visual representation of PTAL. Ahmedabad city base map (satellite image) is taken from Google earth. On it square grid of 1 km in both directions prepared in a layer. GIS shape file prepared for the tasks. Average walk speed was taken as 4.8 kmph. Distances to public transport stops were measured on map in ARCGIS. Peak-hour observed is 8.15 am to 9.15 am. Route frequencies of different public transport modes-BRTS & AMTS obtained from concerned offices. Point of Interest (POI) defined as a point for which the accessibility level was to be measured with reference to a public transport stop (bus stop) known as Service Access Point (SAP). Walk access time from POI to SAP calculated. Max time 8 min for bus and 12 min for proposed rail system for the study considered. Accessibility index (AI) for each POI calculated by the formula. Range of Index means AI of the POI. Range is defined from poor to excellent accessibility.

(4) (Tuan & Son, 2015) : In this paper study area divided into 3 parts-city center, newly developed area, and rural area. The sample size was 210 bus users and non-bus users. Data collected by interviews at bus stops and terminals. Data collected are age, gender, income, occupation, vehicle ownership. Bus use frequency noted as daily, number of days per week and number of days in month. Access distance asked as less than 500m or more than 500m and up to1000m. Satisfaction levels and importance levels of respondents analyzed to calculate AI. Safe boarding, waiting time, waiting comfort, access conditions were important parameters in the study. The evaluation was made in a 5-point scale. By taking the average of all the indicators, it gives the value of the comprehensive accessibility index. The bigger the values are the better accessibility conditions.

(5) (Harnadh & Prasad, 2014) : In this paper author has worked out present and future trip generation and accessibility. The population of study area was 7480, who involved in agricultural activity. Rural areas were suffering from insufficient transportation facility and problems of accessibility. Data collected by HIS with sample size from 18% to 53% of total HH for 13 villages from Srikakulam district of Andhra Pradesh. Average HH size was 6.

Average trip length was 20 km. Data analyzed as per trip purpose and income. Weightage for each and every activity calculated by dividing the total trip by 2600 from sample size Wi = Weightage for each activity taken as: Office = 0.22, College = 0.26, Work = 0.21, Entertainment = 0.15, Others =0.14. Overall Accessibility Levels (OAL) are calculated by using the and OAL Range as per ARASAN Study adopted. OAL more than 50 is categorised as good. OAL less than 45 is poor and in the range of 45 to 50 is moderate.

(6) (Coppola & Papa, 2013) : The paper focused on sustainable accessibility planning in urban areas that can be defined as the integration of transport and land use planning to achieve sustainable development. The study proposes a tool to support the choices of activities location indicator: Marginal Activity Access Cost (MAAC) measures the impacts on mobility costs of locating an activity in a given zone. The proposed indicator validated through an application to the urban area of Rome. Accessibility planning includes mobility planning. Integrated LUT planning entails minimizing the generalized transportation costs. To compute MAAC, spatial Land Use Transport Interaction (LUTI) models, particularly residential location models, trip generation-attraction and modal split models are needed. MAAC takes into account Individual Travel time and Costs (ITC) and External Costs (ETC) in Euro.

(7) (Rajendran et al., 2013) : Authors considered that accessibility as the main parameter which contributes to the effective transportation system. Public Transport Accessibility Level (PTAL)is one of the criteria for evaluating the accessibility. There is a quantitative assessment method with simple basic tools of GIS.13 wards are of CBD out of 100 wards of Thiruvanthpuram as study area. They have direct access from selected stretch (NH-47 & M.G.Road).560 HHs was the sample size for Home Interview Survey. The questionnaire included the trip information and the household data. An Equivalent Doorstep Frequency (EDF) measured with reliability factor. Total Access Time (TAT) is calculated. Public Transport Accessibility Level (PTAL) for all 13 wards calculated as per LONDON model and presented graphically. The accessibility was classified as poor, fair, good, very good and excellent.

(8) (Jędrzej Gadziński, 2010) : The study is for Poznan city in Poland. It is an industrial and academic center. There is good public transportation system even though 56% trips by CAR observed during study period. Reason found is travel time by bike and car is half than public transportation. The migrations into surrounding communes were created many

transport problems. Travel time less than 40 min., direct routes-no transfer stations, space for cycle is emphasized for efficient public transportation. New routes, rapid routes, common routes for bus and tram were analyzed and proposed. As per guidelines given by author in 2008, accessibility was considered to solve the problem. Analysis was carried out by using advanced GIS and GPS tools.

(9) (Gent & Symonds, 2005) : This study suggested a quantitative assessment method for public transport network accessibility as an alternative to PTAL. An attempt has been made to identify the best methodology, within the constraints of the available data, software and time. This paper reviews the PTAL and GIS based accessibility modeling tools, such as Accession. Home and Origin was considered as Point of Interest and bus stops/metro stations were considered as Service Access Point. Frequency of bus used to find out waiting time. Access time obtained by summation of walk time and waiting time. Accessibility Index (AI) categorized as poor, moderate, good, very good and excellent.

OUTCOME OF LITERATURE REVIEW OF ACCESSIBILITY:

Literature discusses concept of accessibility and how it can be incorporated in transportation planning. Accessibility to public transportation is determining usage of bus transit as mode choice in urban area. The literature study helps to put use of accessibility chain as shown in FIGURE 2.3 below.

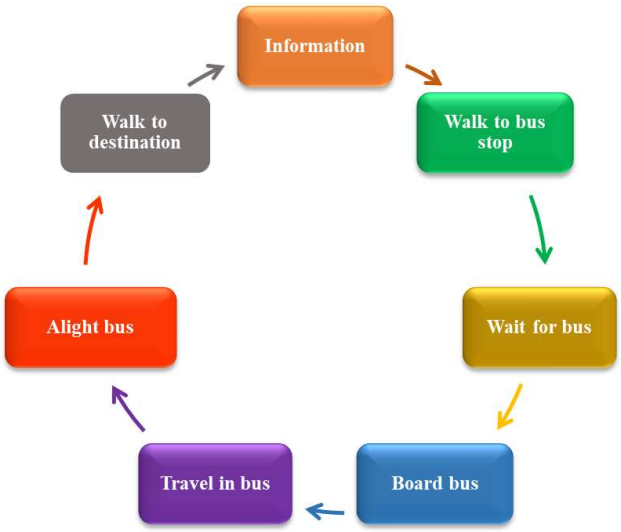

FIGURE 2.3: Accessible Journey Chain

(Source:(Tyler, 2002))

Less accessibility to public transport affects congestion and associated problems in urban area. Data is collected by interview survey at bus stops which are known as Service Access Point (SAP). Sample size is calculated and during morning peak hour survey is conducted. Data collected are age, gender, income, occupation, vehicle ownership, bus frequency, waiting time, comfort, safe boarding, access condition etc. Public Transport Accessibility Level (PTAL) is one of the criteria for evaluating accessibility. Maximum time of walk is 8 minute and average walk speed is taken as 4.8 kmph. Accessibility index for each Point of Interest (POI) is calculated. Range of AI is defined from poor to excellent. AI for selected POI is computed. Equivalent Doorstep Frequency (EDF) is measured with Reliability Factor (RF). Total Access Time (TAT) is calculated.AI for various wards are computed.AI for selected SAPs in study area. Various terminology used in accessibility is studied with steps for calculation of AI and PTAL.

2.3 Research Gap

The literature review revealed that the studies in Indian context, synthesis of LUTI, category analysis for trip rates, mode choice and PTAL; but the LUTI incorporating all the above for holistic approach is missing. Present study is taken up for all models together.

2.4 Closure

This chapter includes literature review from various sources in domain section of the research. This leads to frame methodology of work to achieve aim and objectives to justify title of the research. It may be anticipated that the current research work carried out keeping the study is of West Zone of Ahmedabad shall be useful for the planners to a larger extent. Next chapter discusses the study area in detail.

CHAPTER - 3

Study Area Profile

The area for which research work done, is known as study area. For the research work urban area, West zone of Ahmedabad, is selected. There are 5 basic zones namely North, South, East, West, and Central in Ahmedabad. The new development is towards west side and New West (NW) zone is introduced in 2011 onwards. Hence, study area is chosen as West zone of Ahmedabad.

3.1 Ahmedabad City

Urban area in Ahmedabad City is chosen as study area. Ahmedabad of Gujarat state was founded in 1411 AD is in existence from 600 and more years. Ahmedabad Municipal Corporation (AMC) is established in July 1950. Upto 2008 there are 43 wards and 5 zones. Central, North, South, East and West with area of 190 km^2. Since 1980's western periphery has grown rapidly. In the year 2008 around 180 km^2 area has been added on the western side of the city. In 2011, AMC with 450 km^2 area and Ahmedabad Urban Development Authority (AUDA) with 1866 km^2 area with 6 zones North(N), South(S), East(E), West(W), Centre (C) and New West (NW) and 64 wards. West zone of 54.51 km^2 area was observed as 65.68 km^2 area in 2011.New west zone given 199.23 km^2 land area. AMC has 101 Town Planning Scheme (TPS) and AUDA has 137 TPS in 2021.Development Plan (DP) in 1987 was handmade map. CAD base DP is prepared in 2002. DP in GIS with Geo referencing with satellite imaginary is prepared in 2011 onwards. There is hot and dry climate in city. There is flat plain topography in city. Sabarmati river bank is 22 km long passing through Ahmedabad and act as natural screen line. There are 1519 small and large size lakes and ponds in Ahmedabad. Waterbodies in Ahmedabad is spread in 3500 Hectare (Ha.). There are 11 bridges over river Sabarmati to connect old city with new city.

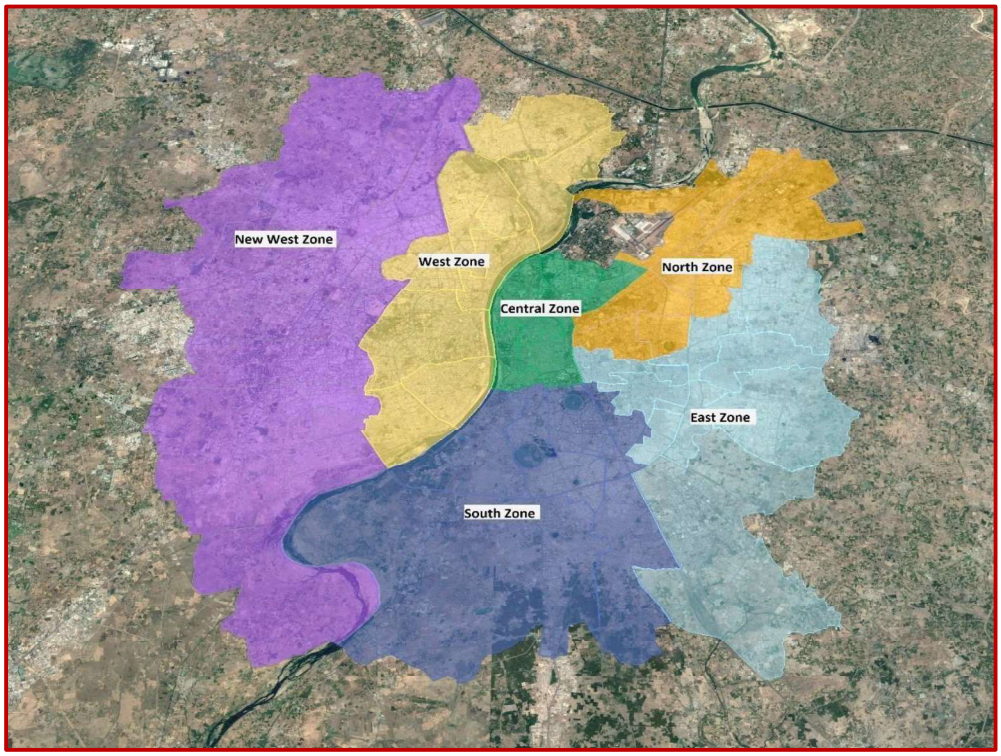

FIGURE 3.1: Map of Ahmedabad (Source: Google Map)

3.1.1 Growth in Ahmedabad city

Ahmedabad known as Manchester of India in history has grown from textile markets as backbone of economy. Heritage city Ahmedabad have potential to attract population in tourism and medical sector.0.24% Primary, 2.16% Secondary and 97.59% Tertiary economic sectors in Ahmedabad and a lot potential to attract population from surrounding. Total 255 colleges with 26 Engineering & Technology colleges in existence in Ahmedabad. Number of state level universities established in Ahmedabad attract population as education hub from all over India and abroad. Population is increasing and concentric growth of city expanding in the form of ring enclosing CBD. Density increase leads to demand for households and land area is provided by authority as supply. There is rising trend of population in Ahmedabad. Details are as shown in TABLE 3.1.

Average size of household was 5.15 persons in 1991, which is reduced to 5.02 in 2001. Within AMC number of households are 6,63,577 in 1991, which is increased to 8,98,027 in 2001. In Ahmedabad total number of households were 7.80 lacs in 1991 and 10.44 lacs in 2001.Increase in number of households is 35% by decade as per 1991-2001

census data. Number of zones in 2001 was five (North, South, East, West, Central), in 2011 sixth (North West) added and seventh (South West) added in 2021.

TABLE 3.1: Growth of Ahmedabad

Year	Population	Area (km^2)	Density (per km^2)	Radius(km)
2021	82,53,000	464.00	16,000	12.15
2011	56,33,927	356.00	13,508	10.65
2001	45,25,013	190.84	18,445	7.80
1991	33,12,200	190.84	15,074	7.80
1981	25,12,200	98.15	20,985	5.60
1971	19,50,000	92.98	17,053	5.44

Source: (*Draft Comprehensive Development Plan 2021(Second Revised)Part I:Existing Conditions, Studies & Analysis*, n.d.)

Special Investment Regions (SIR) at Changodar with 319 km^2 and Viramgam with 139 km^2 increasing employment opportunity in Ahmedabad. Gujarat International Finance Tec (GIFT) City in 500 Acre and Dedicated Freight Corridor and Delhi Mumbai Industrial Corridor (DMIC) have potential to attract migration from surrounding states at Ahmedabad. Out of total length of 1483 km of DMIC, 564 km is passing from Gujarat and 38 km through AUDA area. On both side of rail corridor, a band of 150 km is feeder rail or road corridor under consideration for future plan. GIFT city may generate employment for minimum 4 lacs. There are 4 Gujarat Industrial Development Corporation (GIDC) Estates in 1007 Ha. land: Naroda, Odhav, Vatva and Behrampura. There are 4859 industries. Types of Industries are Engineering products, Chemical & Petrochemical, Metallurgy, Textile, Wooden, Paper, Food & Beverages in Ahmedabad. In search of employment as labour, supervisor, engineer, technical assistant etc. people migrate to Ahmedabad.

3.1.2 Land Use Intensity

Ahmedabad has concentric growth and 2 km radius area is added per decade. If the current growth trends continue, the total population in the AUDA area is expected to go up to 88 lacs by 2021 and 108 lacs by the year 2031.Census count for 2021 is not done due to CORONA and lockdown. To accommodate 51 lacs upto 2031, 230 million m^2 built up space will be required. The land demand for zones will be 204 km^2. Land available as vacant land is 137 km^2 and scarcity of 67 km^2 land is to balance supply & demand. Ahmedabad has an urban structure that is compact with high densities and mixed land use.

Residential land use types in Ahmedabad is categorized in 3 heads. R1 (bunglow), R2 (Twin bunglow, Duplex) and R3 (Row house, flat, Apartments). The open to sky land area is as Agriculture land, Undeveloped land, Vacant land, Open Space (Margin), Green belt and Garden. There is land use for Road, Railway, Airport and Waterbody. There is land use for Commercial and Industrial development. There is Gamtal and mix land use for multipurpose for public. The FIGURE 3.2 shows land use development proposal along with different land use for horizon year 2021.

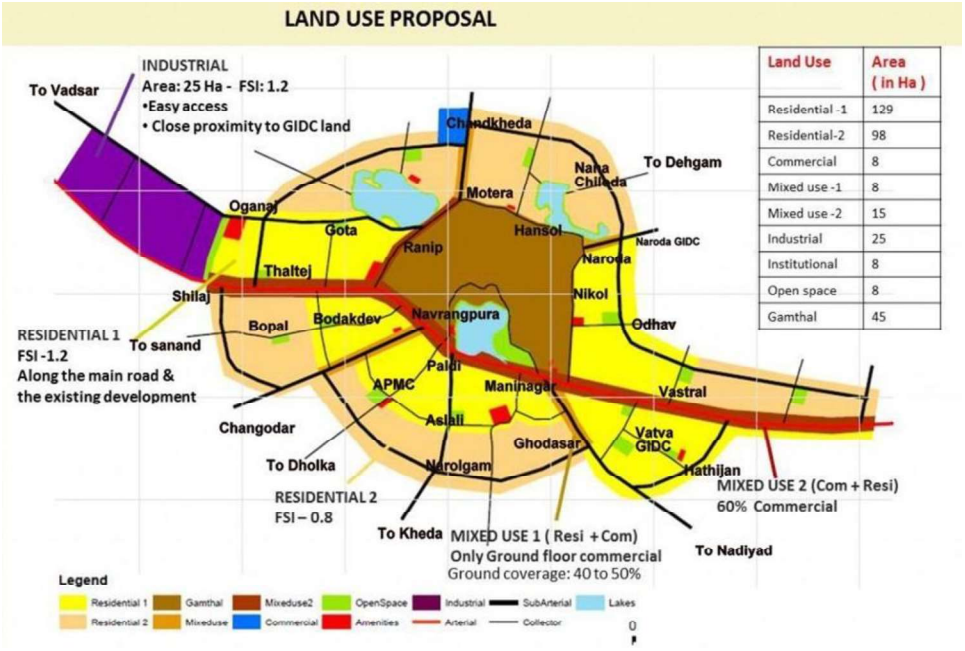

FIGURE 3.2: Land Use Proposal

(*AUDA Website*, n.d.) https://portfolio.cept.ac.in/archive/wp-content/uploads/2014/05/Proposal-Landuse-1024x689.jpg

3.1.3 Transportation System

Like other large cities in India, Ahmedabad is grappling with the challenges of rapid urban expansion, mounting motorization, congestion and uncoordinated land and transportation development. Transport mode share observed is as shown in FIGURE 3.3. Non Motorized Transport (NMT), Personal/ Private vehicle transport, Intermediate Public Transport (IPT) and Public Transport are major categories. People of Ahmedabad are more dependent on private vehicle transportation (42%), which results into the problem of traffic congestion, accidents, air pollution, noise pollution and delay. There is 16% mode share of

bus transit public transportation. Urban roads in Ahmedabad are classified as shown in TABLE 3.2.with road width.

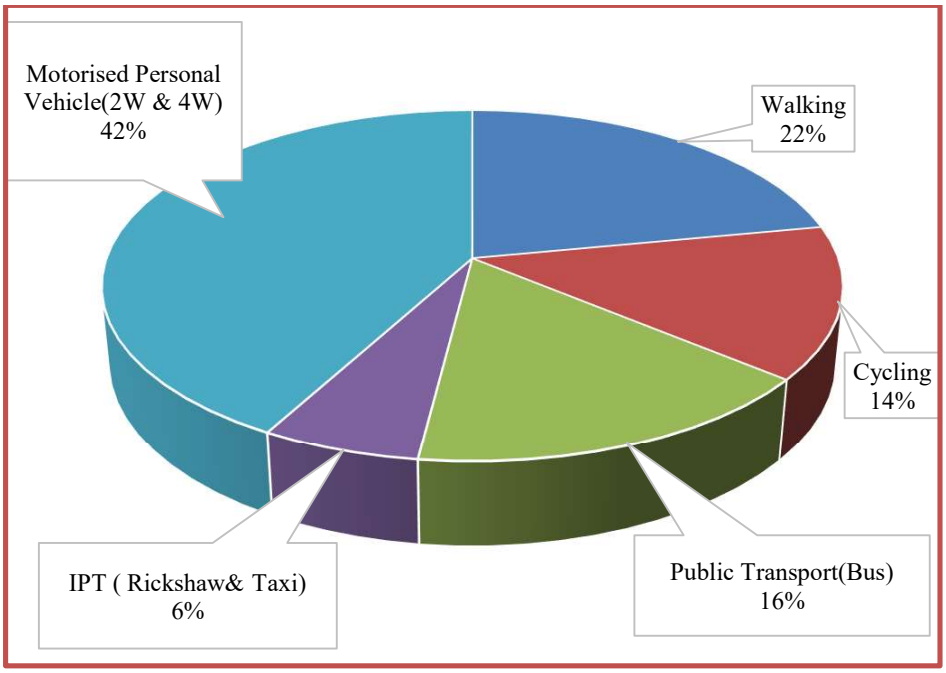

FIGURE 3.3: Mode Choice of Ahmedabad Residents

(Source: DPR for Ahmedabad Metro Rail Project)

TABLE 3.2: Urban Road Classification in Study Area

(Source: *Draft Comprehensive Development Plan 2021(Second Revised)Part II:Planning Proposals & Recommendations*, n.d.)

Type of Urban Road	Right of Way (ROW) Widths
Arterial road (Major)	28.0 to 60.0 m
Arterial road (Minor/sub arterial)	22.0 to 30.0 m
Major Street (Collector Street)	16.0 to 24.0 m
Minor Street	9.0 to 18.0 m
Local Street	3.0 to 12.0 m

Vehicle ownership in Ahmedabad as per vehicle registration at Road Transport Authority (RTO), Ahmedabad. The year is considered as 1st April 2021 to 31st March 2022.Likewise the year and new vehicle registration from 1st April 2010 to 31st March 2022

is as shown in FIGURE 3.4 below. The total number of registered motor vehicles are 31,63,206 upto 31st March 2022. Total new vehicles added in traffic stream in addition to vehicle registered before 31st March 2010. Registration of private motorised vehicles like 2 wheelers and cars for last 10 years are 1769648 and 513205 respectively. (https://parivahan.gov.inParivahan)

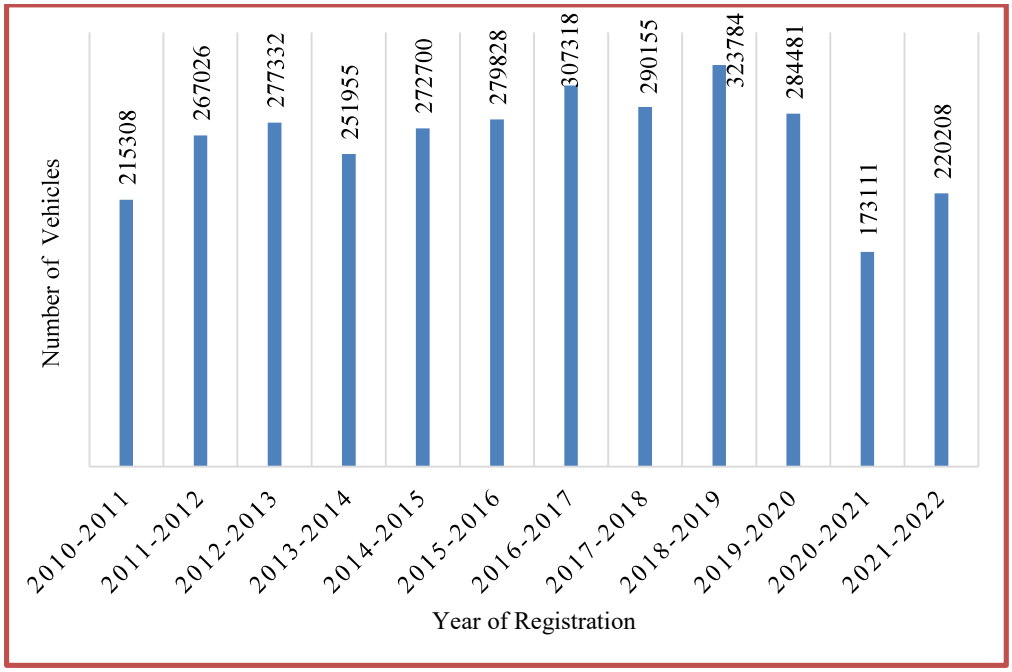

FIGURE 3.4: New Vehicle Registration in Ahmedabad

(Source: *RTO,Ahmedabad(GJ-1) & ARTO,Ahmedabad(GJ-27)*, n.d.)

Ahmedabad has two major public transport systems: The Ahmedabad Municipal Transport Service (AMTS), a bus service running in mixed traffic, and the Bus Rapid Transit system (BRTS), operated by Ahmedabad Janmarg Ltd (AJL), which runs on dedicated corridors (except junctions and a few other links). Both AMTS and BRTS are wholly owned subsidiaries of the Ahmedabad Municipal Corporation (AMC). AMTS has 1227 buses serving the city. 977 runs under AMTS in mix traffic condition & 250 under Janmarg in exclusive lane for bus transit. AMTS covers about 88% of developed AMC area and moving in interior areas and on narrow internal roads. There are 162 BRTS stations along BRTS routes and provisions of cabins on extended routes. There are 14 (11 bi-directional, 2 circular routes, 1 shuttle) BRTS lines. A metro rail system called the Metro link Express Gandhinagar Ahmedabad (MEGA) has been proposed and is in the advanced stages of

implementation. AMTS, BRTS and Metro Routes as in google image is as shown below in FIGURE 3.5.

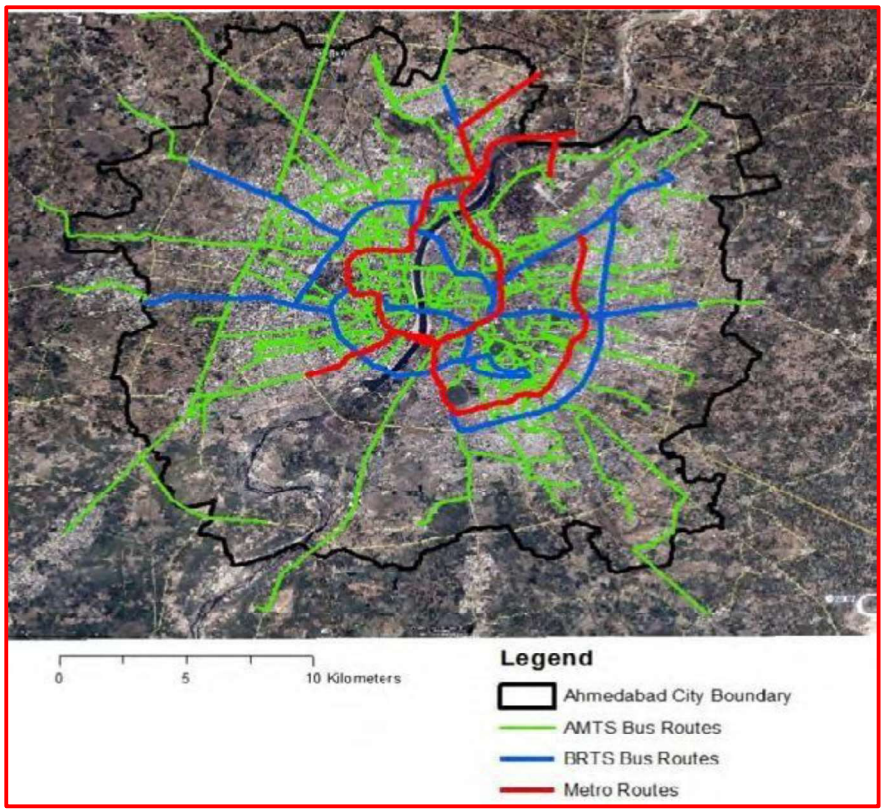

FIGURE 3.5: AMTS, BRTS and Metro Routes

(Source: Google Map)

3.1.4 FSI Scenario in Ahmedabad

Permissible and chargeable Floor Space Index (FSI) as per type of land use in Ahmedabad is as shown in TABLE 3.3. Ahmedabad has an urban structure that is compact with high densities and mixed land uses. The arterial roads of the city that accommodate the AMTS in the city exhibit higher densities with intensified activities. With the commencement of BRTS in the city, similar land use development is observed along the first phase corridor. The land use transformations along the BRTS corridor of Ahmedabad in terms of increase in built-up area, land use and density changes has proved that further intensification will have positive impact on the transit patronage. The area along the mass transit network be intensified by increasing the FSI and encouraging transit supportive land use. As shown in FIGURE 3.6.

TABLE 3.3: Proposed FSI for Various Zones of AUDA Area for 2021

(Source:(*Draft Comprehensive Development Plan 2021(Second Revised)Part II:Planning Proposals & Recommendations*, n.d.))

Sr. No	Types of Land Use	Codes	Permissible FSI	FSI Chargeable	Max FSI
1	Residential zone 1	R1	1.8	0.9 – Within SP Ring Road	2.7
				0.45 – Outside SP Ring Road	2.25
2	Residential zone 2	R2	1.2	0.6 – Within SP Ring Road and for Bopal TP1, TP3	1.8
				Nil – Outside SP Ring Road	1.2
3	Residential zone 3	R3	0.3	Nil	0.3
4	Residential- Affordable Housing zone	RAH	1.8	0.9	2.7
5	Core walled city	CW	2.0	Nil	2.0
6	Gamtal	GM	2.0	Nil	2.0
7	Gamtal extension	GME	1.2	Nil	1.2
8	Central Business District	CBD	1.8	3.6	5.4
9	Transit oriented zone	TZ	As per base zone	As applicable	4.0
10	Commercial and logistic zone	C	1.8	0.9 – Within SP Ring Road	2.7
				0.45 – Outside SP Ring Road	2.25
11	Industrial Zone-General	IG	1.0	Nil	1.0
12	Industrial Zone-Special	IS	1.0	Nil	1.0
13	Knowledge and Institutional Zone	KZ	1.8	Nil	1.8

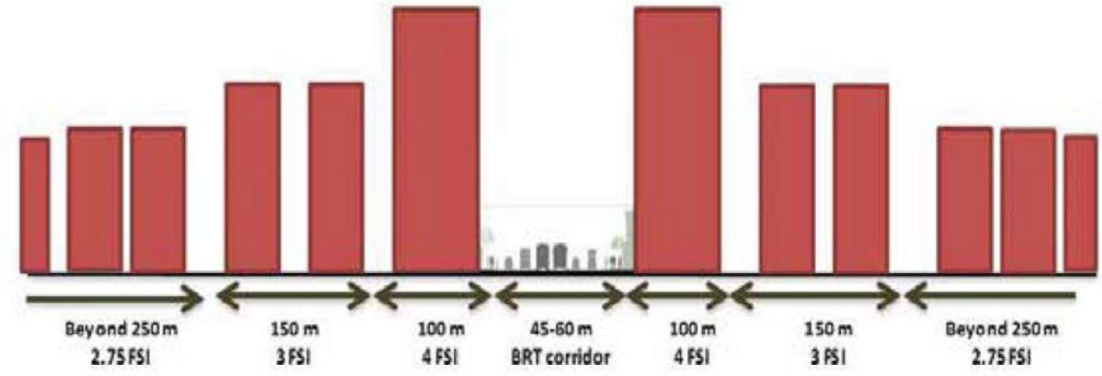

FIGURE 3.6: FSI along Mass Transit Network

Source: (***Draft Comprehensive Development Plan 2021(Second Revised)Part I:Existing Conditions, Studies & Analysis*, n.d.**)

Promotion of redevelopment is to balance environmental preservation and development priorities. Height restrictions are removed. Minimum floor height is specified. 51% ground coverage instead of existing 30% is allowed. Extra 2.2 FSI at highly concessional rates above the FSI of 1.8 for providing affordable houses is introduced. Increased parking space from 5% to 20% of total utilizable space for residential areas. For commercial construction, this limit has been raised to 50% of permissible maximum FSI from the existing 30%. Improvement of green cover is from 4% to 15%. Highest 5.4 FSI for 10 km^2 area surrounding the Sabarmati riverfront, allowing nearly 22 storey buildings. FSI provision for CBD area in Ahmedabad in redevelopment plan is 4.5 to 5.

3.2 West Zone, Ahmedabad

West Zone of Ahmedabad city have been considered as a study area. The map is digitized in TransCAD software as shown in FIGURE 3.7. On one side of west zone, there is Sabarmati river. Total area of 9 different wards namely Paldi, Vasna, Navrangpura, SP Stadium, Naranpura, Nava Vadaj, Sabarmati, Ranip and Chandkheda is 65.68 km^2 and Total population is 7,87,753 as per census 2011. Ward wise population, area and number of HHs are as shown in TABLE 3.4.

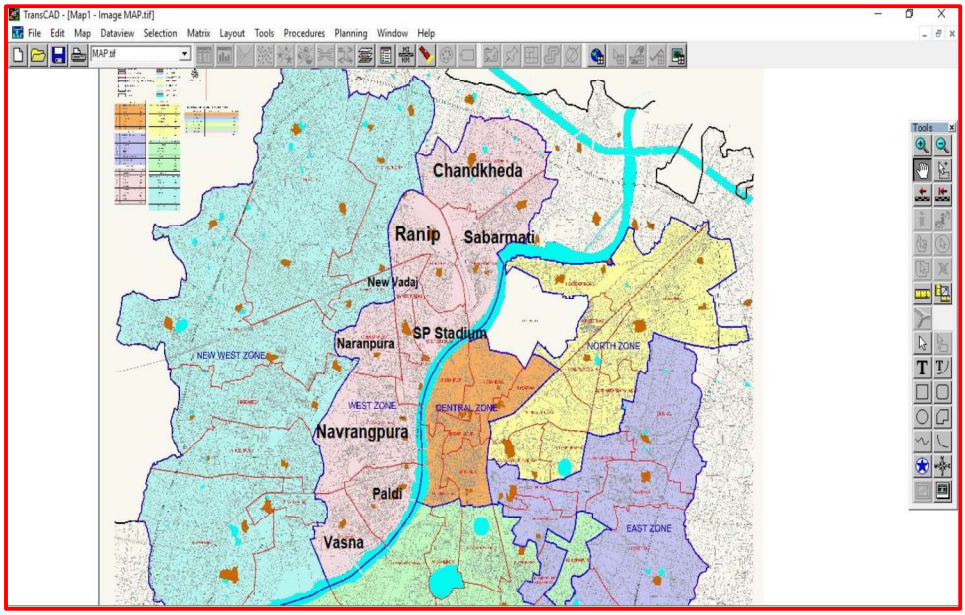

FIGURE 3.7: Digitize Map of Wards of West Zone, Ahmedabad

(Source: Prepared by Researcher in TransCAD)

TABLE 3.4: Details of Study Area as per Census 2011

(Source:(*AMC (Website)*, n.d.)

Sr.No.	Name of Ward	Ward no.	Area (km^2)	Number of House Holds	Population
1	Paldi	07	5.58	18855	83109
2	Vasna	08	5.57	27754	123116
3	Navrangpura	10	11.98	12839	55647
4	SP Stadium	11	5.24	16979	75051
5	Naranpura	12	4.91	20829	88032
6	Nava Vadaj	13	3.17	17237	77814
7	Sabarmati	15	9.78	14362	68566
8	Ranip	45	7.55	24960	120152
9	Chandkheda	57	11.90	20436	96266
	Total		65.68	174251	787753

Population distribution and employed persons among gender along with children is as shown in TABLE 3.5 below for west zone. It is also known as Cohort analysis.

TABLE 3.5: Demographic Details of Study Area as per Census 2011

(Source:(*AMC (Website)*, n.d.)

No.of male	No.of female	Male child (0-6 year)	Female child (0-6 year)	Male worker	Female worker	Total worker
403299	373813	39832	34018	289407	51387	340794

On one side of study area there is waterbody and on other side new west zone. The distance from CBD is about 4.6 km. As per AUDA report West zone have only 12% open space within AMC limit. New west zone has 309 Ha. and 642 number of spaces which is 41% of total land. There are 82 number of chawls with 14,120 units and 159 number of slums with 43,312 units in west zone. Rehabilitation and chawl slum removal is under process.

The census information is displayed in FIGURE 3.8 below for the year 2011.Ward area and density also displayed graphically. Number of households in ward is displayed.

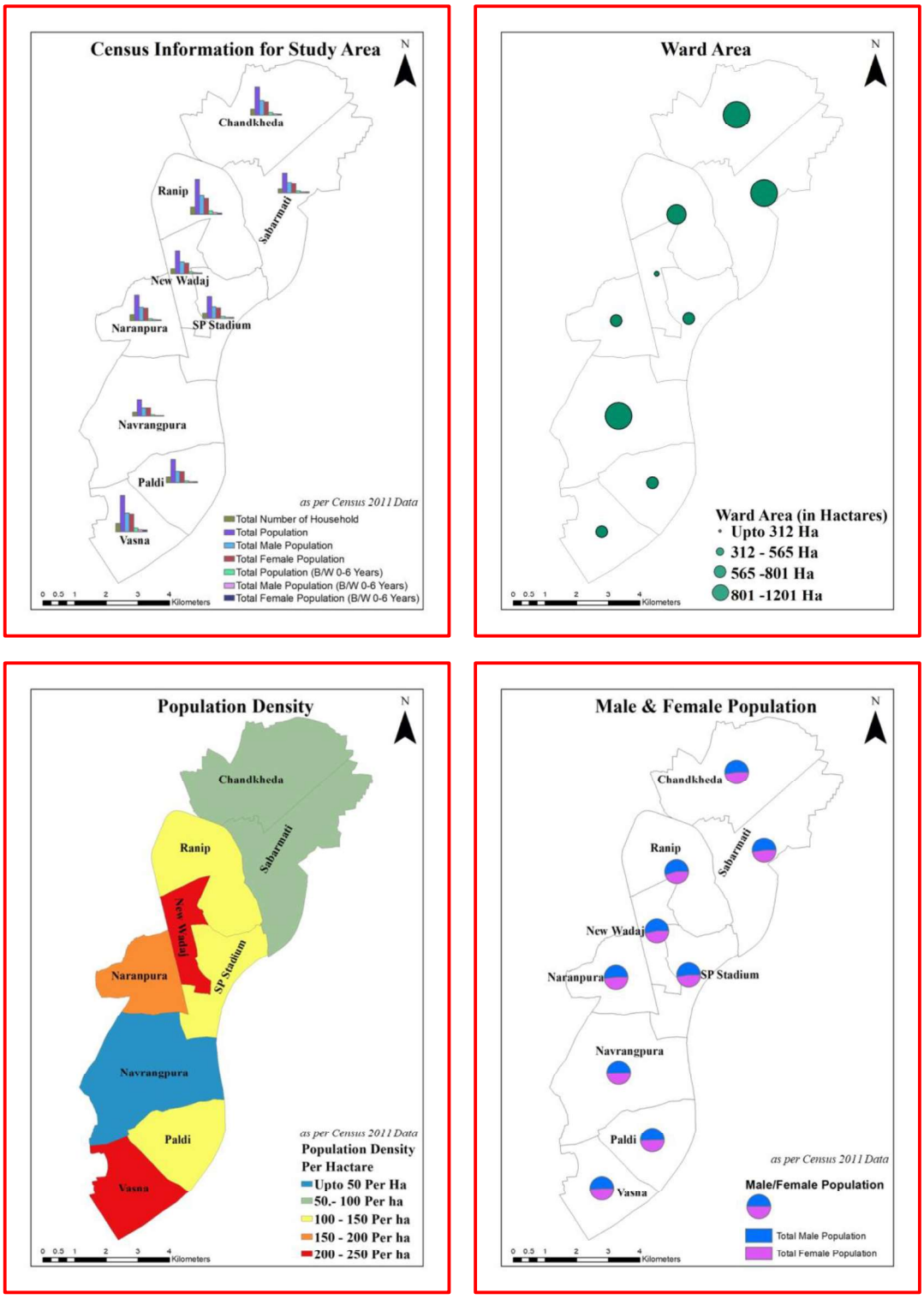

FIGURE 3.8: Ward Wise Details of Study Area

When researcher have started the work after PhD registration, In the year 2017-18 data collection started. The census data available was of 2011 only during the journey of PhD. Due to CORONA, Census count not updated for the year 2021. For election and record keeping the booklet *Urban Profile 2017, Ward Patrak, Patrak-B*, 2021b was collected from AMC office. The data is compiled and presented as shown in TABLE 3.6.The educational facilities in study area is as shown in TABLE 3.7.The area and ward number for all 9 wards are same as shown for 2011.

TABLE 3.6: Details of Study Area

(Source:((*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021,AMC)

Name of Ward	Number of HHs	Population	Population Density (per km^2)
PALDI	31325	117301	21022
VASNA	26054	115936	20814
NAVRANGPURA	27971	121091	10108
S.P. STADIUM	32574	132625	25310
NARANPURA	37437	133456	27180
NAVAVADAJ	28666	130388	41132
SABARMATI	25741	121060	12378
RANIP	26181	124790	16528
CHANDKHEDA	27098	126607	10639
Total	**263047**	**1123254**	**Average Density:20568**

TABLE 3.7: Details of Education Facilities in Study Area

(Source:((*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021,AMC)

Ward Name	Anganwadi	School	Primary School	Secondary School	Higher Secondary School	College University
Paldi	12	20	20	14	14	4
Vasna	31	16	16	8	4	3
Navrangpura	7	28	28	25	21	40
SP Stadium	42	26	26	13	11	5
Naranpura	20	22	22	16	13	0
Nava Vadaj	10	28	28	4	11	1
Sabarmati	41	24	24	16	11	1
Ranip	28	16	16	12	8	0
Chandkheda	23	48	48	26	22	3

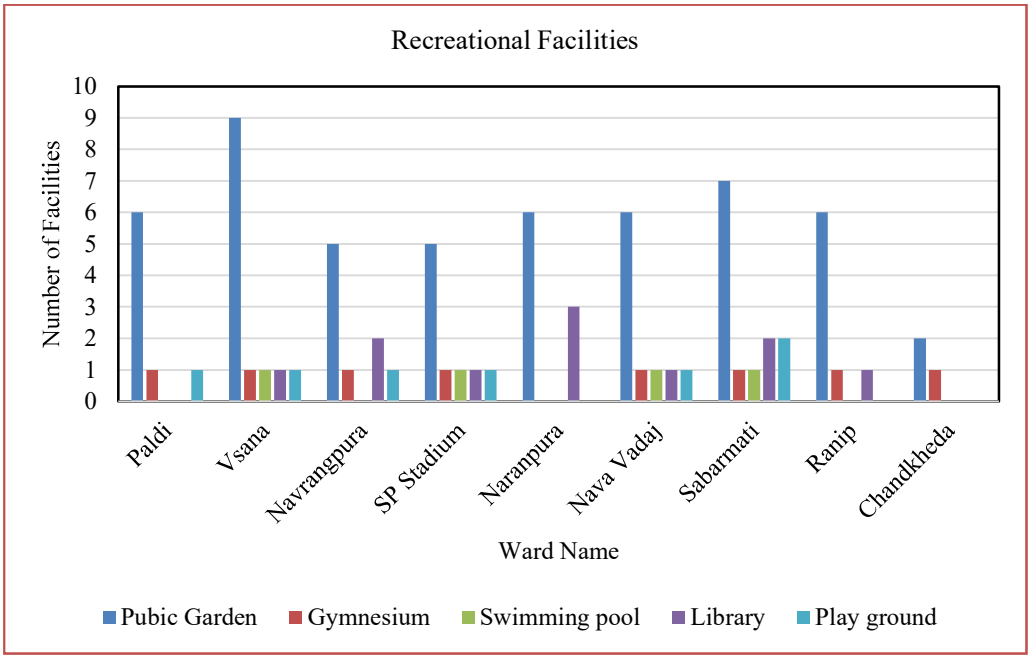

FIGURE 3.9: Ward Wise Recreational Facilities in Study Area

Source:(*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021)

The general facilities like Hotel, Guest house (GH), Restaurant (Rest), Dharmshala (DS) including health facilities is as shown in TABLE 3.8. All the data is in numbers. Community hall for social gatherings, rationing shops and vegetable markets also included in table.

TABLE 3.8: Details of General Facilities in Study Area

(Source:(*AMC (Website)*, n.d.)**(*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021,AMC)**

Ward Name	Govt. Hospital	Private Hospital	Shops	Hotel/Rest/GH/DS	Rationing shop	Vegetable market	Community hall
Paldi	2	70	1153	119	8	3	5
Vasna	2	49	1402	15	5	5	6
Navrangpura	4	29	7211	84	12	1	10
SP Stadium	3	88	2992	28	13	2	5
Naranpura	1	58	3214	34	13	4	8
Nava Vadaj	1	42	2909	8	15	5	5
Sabarmati	2	38	4143	46	19	3	5
Ranip	1	41	5860	2	18	8	8
Chandkheda	2	31	3898	30	17	5	3

3.3 Closure

In this chapter giving historical development of Ahmedabad city, the study area is presented with detail information. Education institutions, health facilities, recreational facilities and general facilities in the study area is presented. The study area information is collected from various sources of AMC & AUDA offices. By referring reports and visiting website the necessary information is retrieved. The information ranges from ward name, ward area, population, density and the same is presented on spatial ward map.

CHAPTER - 4

Research Methodology

4.1 Methodology Framework for the Study

In the field of Urban land use and Transportation Planning, Land Use and Transportation Interaction is effective for existing situation and future prediction in urban area. Literature Review is done by searching the research papers, reports, articles and books. Based on the literature reviewed, the research proposal was identified as "Land Use Transportation Interaction Model Development for Urban Area". To justify title the two objectives are defined. To develop LUTI model and to calibrate and validate model. Keeping the aim in the center of thought process and need of study formulation of the research framework in the form of research methodology is as shown in FIGURE 4.1 Based on problem and discussions among the research team, the study area was finalized. Land use, transportation and socio-economic inventory for its existing condition is performed with the focus on aspects as land use and transportation. The study area is Ahmedabad urban area. Instead of considering Ahmedabad as a whole, west zone of Ahmedabad is finalized as urban area for study. The literature review and exploration assisted for the identification of sources of data collection, analysis methods, results, and interpretations. West Zone of Ahmedabad as per Cencus 2011 and AMC map 2014-15 comprising of 9 wards namely- Paldi, Vasna, Navrangpura, SP Stadium, Naranpura, Nava Vadaj, Sabarmati, Ranip and Chandkheda. The land use map for 2011 and 2017 is delineated for area computation of various land uses. Understanding of the study area for its existing condition was performed with the focus on aspects as socio-economic condition and land use development in the area. The facilities available in study area is searched and listed to understand scenario of trip generation and attraction as activities performed by citizens.

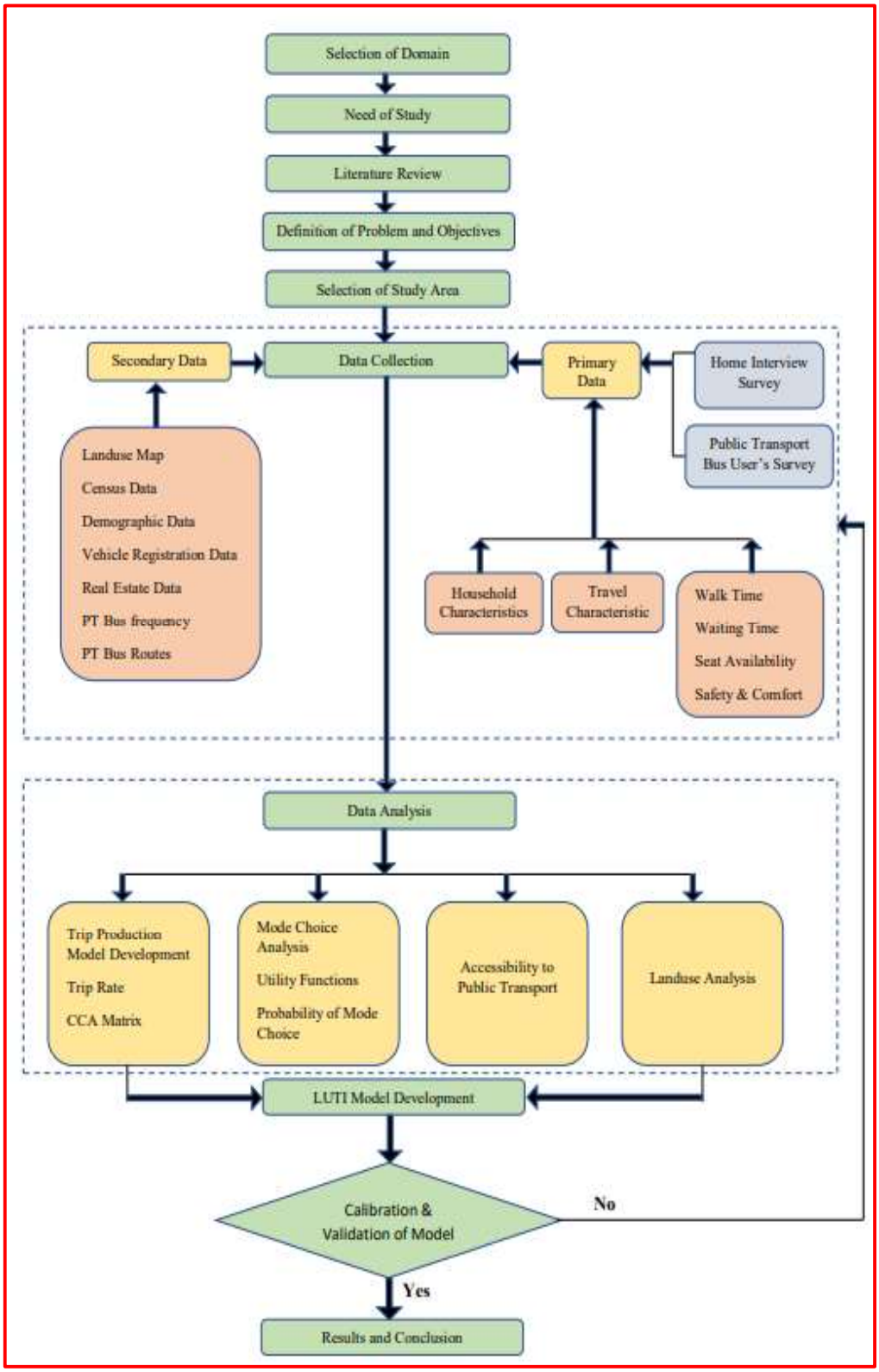

FIGURE 4.1: Research Methodology

Trip production model is developed by Cross Category Analysis (CCA) and regression analysis. The socio-economic characteristics and travel information is analyzed from primary data collected by HIS. Based upon same database of HIS, mode choice model development by MNL (Multinomial Logit) along with utility functions and probability analysis carried out. Public Transport Accessibility Level (PTAL) and Accessibility Index (AI) for bus transit system in study area is derived based on primary data collected for public transportation system. For this Public Transport User's Survey was conducted. Land use map of 2011 and 2017 analyzed for 10 different land use in study area. Land use Residential, Commercial, Industrial, Institutional, Agricultural, Mixed, Vacant, Waterbody, Transport and Recreational. The land use maps were used for extracting the information about land use land cover surface area within the study area and for quantification of the same over the study duration. LUTI models Univariate and Multivariate regression, developed and calibrated using MS Excel. Validation of model was done on 33.33% of collected total data. Discussion of results along with scope of study and limitation of study concluded. The research steps presented in FIGURE 4.1 as flow diagram.

A regression model provides a function that describes the relationship between one or more independent variables and a response, dependent, or target variable. Regression analysis is a reliable method of identifying which variables have impact on a topic of interest. The process of performing a regression allows you to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other. Considering the results obtained from the statistical model development the interpretations were made. Using the insightful understanding of the interrelationship among the parameters, calibrated and validated LUTI models are ready for application.

4.2 Definition of the Problem

Large number of land use transport Interaction models are in use today. There are significant variations among the models with respect to comprehensiveness, model structure, theoretical foundations, modelling techniques, dynamics, data requirements, calibration and validation. Despite the achievements in developing these models further, there remain some challenges to be met. Data disparity, differences in information and very limited information are the biggest challenges when implementing the model. It is practically observed that different pockets in urban area is not growing in same pace. The population change is not

same throughout urban area. The new land introduced for development is not same throughout urban area. The transport network and public transportation facility is not same as of route and frequency throughout urban area. The development age of different pockets of urban area is different. The real estate price for land and built-up area are different. The idea of research is preliminarily found to be a missing link with no past efforts studied in such a manner. In past studies the study area is whole urban area- large size city.

The research problem hypothesis is as under:

Research Hypothesis: There is relationship between /among land use parameters with transport parameter.

vs

Null Hypothesis: There is no relationship between /among land use parameters with transport parameter.

4.3 Data

Data Collection is categorised in two sections as primary data and secondary data. For primary data collection survey is conducted by researcher and secondary data is taken by exploration of secondary sources of information by several means to use for analysis work. The secondary data is taken from Census website, AMC office, AMC website and AUDA report.

4.3.1 Secondary Data

Land use map, Census 2011 data, demographic data, vehicle registration data, real estate data, public transport bus frequency and bus route information is included here.

4.3.2 Primary Data

Household characteristics, travel characteristics, walk time from Point of Interest (POI), waiting time for bus at Service Access Point (SAP), seat availability in bus, safety in bus travel and comfort in public transport bus information is included here.

4.4 Home Interview Survey

Home interview survey (HIS) also known as Household Information Survey (HIS). It is carried out for primary data collection in study area by determining sample size. The home interview survey is most important but it is expensive and time-consuming data collection exercise in any urban transportation system study. The questionnaire is designed and survey form prepared as shown in Appendix-A. Based upon HIS questionnaire following data obtained.

a) Information on the socio-economic characteristics of the HH in the study area:
   Family size, Working and non-working members in family (Number of employed persons), Number of persons going for education (School/College/University), Income of household, Vehicle ownership, Age, Gender etc. information has been collected by conducting interview at residents of citizen.
b) Inventory of the trips made by the family members in the HH:
   Daily household trips, Purpose of trip, Mode of travel, Origin of trip, Destination of trip, Travel route etc. information has been collected
c) Inventory of mode choice by the family members:
   Mode choice, travel time, travel distance, travel cost etc. information has been collected

Derivation of relationship between the trips made by the members of household and the characteristics of the household for the area in which they reside. The data collected are analysed in category. which are considered as explanatory variables. These variables are used in the attempt to build the models, which will be examined statistically and logically to adopt the most appropriate model that can predict the produced trips in West zone, Ahmedabad city.

4.4.1 Methods of Sample Size Determination for HIS

There is no straight forward and one objective answer to the question of the calculation of sample size. Determining the sample size is crucial.

- A too much large sample may imply a data-collection and analysis process, which is too expensive, more time consuming and its required degree of accuracy.

- A too much small sample may imply results which are subject to an unacceptably high degree of variability reducing the value of the whole exercise.

The sample size is calculated by following two methods.

I. Standards of Bureau of Public Roads (BPR):(Kadiyali, 2013)

Total population of study area (West zone, Ahmedabad city) is 7,87,753 and number of HH are 1,74,251 as per census 2011. Average family size is 5.2.

HH Size= $\frac{787753}{174251}$ = 5.2

Number of Household = $\frac{787753}{5.2}$= 151490.96

Sample size = $\frac{151490.96}{100} = 1514.91$ = 1515 HH.

Sample size as per BPR standard is 1515 Household.

II. Sample Size Statistical Formulas- Hogg and Tennis equation (Hogg et al., 2009)

Sample size can be determined using **Hogg and Tennis** (2009) equation:

$$\text{Sample size}=\frac{Z^2*p*q}{C^2} = \frac{1.96*1.96*0.50*(1-0.50)}{0.04*0.04} = 600$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)

c = confidence interval, expressed as decimal (e.g., .04 = ±4)

Confidence level: 95%

$$\text{Sample size} = \frac{Sample\ size}{1+\frac{(SS-1)}{Population}}$$

Putting Total population of study area = 7,87,753 as per census 2011

Sample size = 599.75 =600 persons.

Family size is 5.2 then final sample size = 599.75/5.2 = 115.33 HH =115 HH

Total Sample size =115*9=1035 number of households to be surveyed.

Confidence interval: It expressed as a percentage and represents how often the true percentage of population who would pick an answer lies within the confidence interval. Factors affecting the confidence interval are Sample size, Percentage and Population size. Sample size as per Hogg & Tennis Equation is 1035 Household as per Census 2011

Sample size finally taken more than required as per BPR standards, which is higher than Hogg & Tennis method. By considering population in horizon year, HIS conducted at 2423 HH and after eliminating vague & missing entries final 2400 HH is taken for data analysis. The number of HHs were selected randomly from electoral list. Ward wise sample size is as shown in TABLE 4.1.

TABLE 4.1: Ward Wise Sample Size

Sr.No.	Name of Ward	Number of House Holds (2011)	Number of HHs surveyed	% of total HHs surveyed
1	Paldi	18855	346	1.84
2	Vasna	27754	299	1.08
3	Navrangpura	12839	150	1.17
4	SP Stadium	16979	280	1.65
5	Naranpura	20829	347	1.67
6	Nava Vadaj	17237	192	1.11
7	Sabarmati	14362	160	1.11
8	Ranip	24960	335	1.34
9	Chandkheda	20436	324	1.59
	Total	174251	2433	Average=1.4%

4.4.2 Public Transport Bus User's Survey

Local accessibility is the accessibility of a particular location to a public transport system; network accessibility is the accessibility of locations in a city by the public transport system. The public transport accessibility level (PTAL) concept essentially addresses local accessibility, but indirectly also incorporates network accessibility by using route and frequency data. Interview surveys are carried out at selected AMTS & BRTS bus stops in each ward of the study area. Survey form is designed as shown in Appendix-B_1 and Appendix-B_2. A questionnaire is prepared containing basic and general scenario of Ahmedabad bus transit AMTS & BRTS. The purpose is to collect and analyze the transit requirement of the community for the route. The questionnaire survey is conducted during morning peak period, specifically between 08.00 am to 11.00 am. The number of questionnaire survey forms filled up are 2862 numbers from 33 BRTS stops. 3599 survey forms filled at **77** AMTS bus stops in the study area. Bus stops are defined as Service Access

Point (SAP). Selected stops for survey is as shown in FIGURE 4.2.Home based trips are considered and origin of trip by public transport is Point of Interest (POI). At every selected stop survey has been carried out, in which every person (passenger) who came to stop to travel in AMTS-BRTS bus were interviewed. Some questions like walking time from home to bus stop has been asked and noted. As per literature the maximum walk time for bus transit is defined as 8 minutes. Average walking time for every ward and every stop has been calculated. Waiting time at SAP for particular routes are asked/calculated.

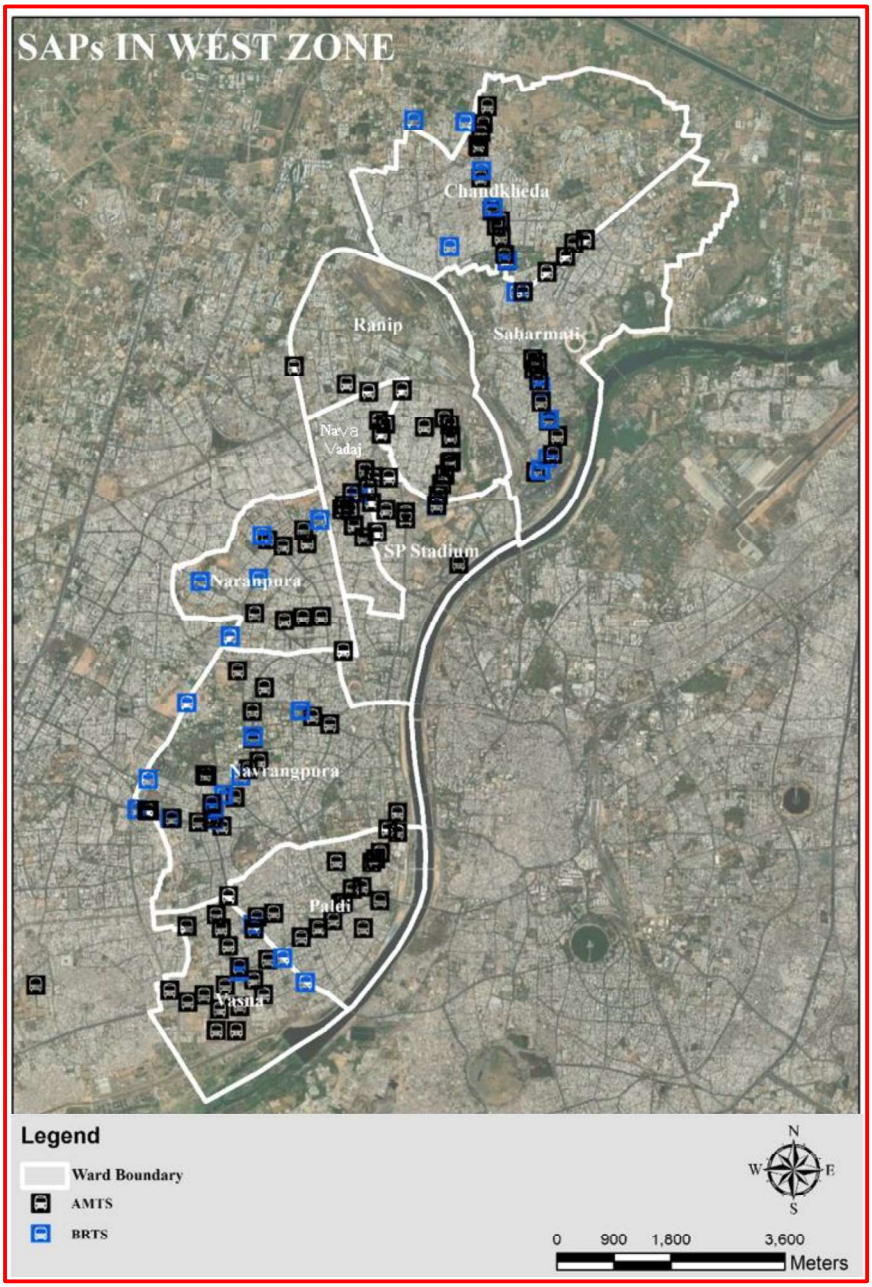

FIGURE 4.2 : Selected SAPs for Survey

The name of SAPs displayed in Chapter-5. Ward wise names in TABLE 5.4: AMTS SAPs in Study Area West Zone, Ahmedabad and TABLE 5.5: BRTS SAPs in Study Area West Zone, Ahmedabad are as shown in Chapter-5.

Route numbers and frequency of bus is collected from AMTS-BRTS office and app. *Apps on Google Play-AMTS info, Moovit: Bus&Rail Timetable, Ahmedabad BRTS-AMTS.* Reliability Factor (k) value which is obtained from literature is 2.5 for AMTS and 1 for BRTS. Weight is assigned to each SAP based on boarding and alighting data which are collected by bus occupancy survey and boarding and alighting data. Questionnaire also includes seat availability, safety and comfort of public transport users. Total 6461 public transport users are interviewed under survey for the study area from 9 wards of West zone of Ahmedabad.

4.5 Cross Classification Analysis (CCA)

In this method, households are categorised on the basis of a cross classification of their characteristics and assumed a constant trip generation rate for each category. Cross classification analysis in trip generation study is used here to estimate trip production rates due to its ability to overcome the problems of regression and traditional classic category analysis. The advantages of category analysis include that it is easy to understand and no prior assumptions about the shape of the relationship are required. The difficulty with category analysis is the lack of any effective way to choose the best groupings of household characteristics and hence the best categories. Another drawback of category analysis is the lack of inferential statistics, so there is no way to assess the statistical significance of the explanatory variables in trip generation. CCA is based on a simple extension of analysis of variance (ANOVA) provides a statistically powerful procedure for selecting the variables and their categories for cross classification models.

The goal of trip production is to estimate the total number of trips, by purpose, produced or originating in each zone. Trip production is performed by relating the frequency of trips to the characteristics of the individuals, of the zone, and of the transportation network. The estimation process for trip production follows several steps listed below:

Step-1: Selecting variables for the model.

Two bases are considered for selecting variables in trip production model. First, behavioral justification that the variable has a causal effect on the phenomenon being modelled. Second, Statistical justification that variables show a significant and measurable empirical association with the phenomenon being modelled.

Step-2: Selecting independent variable for the model.

To analyses the effect of household characteristics in trip production analysis, five variables (Independent variables) selected. The following factors have been proposed initially for consideration in many practical studies. (M. Taher & Khalik Al-Taei, 2006)

1- Total number of persons in the household (HH)/Family size

2- Vehicle ownership/ Number of vehicles in HH

3- Number of school/college going children/person in the HH

4- Number of employed person in the HH

5- Family income level

Step-3: Dependent variable for the model- It is daily produced trips from HH

Here, trips are produced trips from HH. Trips to perform regular daily activity such as work trips, business trips and education trips.

Step-4: To determine the best grouping of data to use for model development

To determine which variables appeared to have the strongest relationships to trip making. Variables analysis is carried out in two stages. The first stage is to calculate correlation between independent variables and dependent variables by determining Pearson correlation test. Second stage is Analysis of Variance (ANOVA) test. ANOVA provides a structured and statistically sound procedure for selecting both the independent variables and the best groupings of those variables from those available. F statistic is used for interaction effects. Test is conducted on grouped and ungrouped variables.

Step-5: To estimate the number of trips (Trip rate) as per group of variables.

Trip rate Matrix is generated for combination of different classes of independent variables. Formula used for calculation of average trip rate in cell is given below

$$t_h = \frac{T_h}{H_h}$$

Here t_h, is average number of trips, T_h and H_h are the total no. of trips and household for household type h.

Step-6: To estimate the number of households in each class.

The correct application of the model is to multiply the trip rates by those number of households. The aggregate Trip Production of an area is estimated.

For socio economic study of present survey trip rate estimated is average. It is dependent on HH size. Future studies can be extended based on assumption of constant trip rates as socio economic condition assumed stable.

4.6 Mode Choice Analysis

Mode choice behavior of urban residents play an important role in transportation planning decisions. Choice of a particular mode affect the general efficiency of travel within the city. To conduct different activities; urban residents make trip by choosing various mode of travel for different purposes. It is expressed in Percentage, Fraction or Ratio. Percentage (%) of different category of vehicles expressed in terms of utility function by using mode choice analysis

The MNL Model structure has been widely used for both urban and intercity mode choice models primarily due to its simple mathematical form, ease of estimation and interpretation, and the ability to add or remove choice alternatives. The MNL model estimates the choice probabilities of each alternative as a function of the organized portion of the utility of all the alternatives. The MNL model is widely used in the research related to the mode choice. The MNL model can be explained by following formula:

Probability of Mode Choice: $Pr(i)$ =Exp (vi) / $\sum$ exp (Vj) , j =1 to j

Pr(i) = probability of the decision maker choosing alternative “i”

Vj = systematic component of the utility of alternative “j”

Utility of each mode of travel can be derived by following equation:

Utility Function: $U = a_0+b_1x_1+b_2x_2+……..+ b_nx_n$

Where, a_0, b_1, …b_n are the coefficient and x_1, x_2…. x_n are the variables like trip cost, trip time, trip length etc.

4.7 Accessibility to Public Transport

PTAL is a measure of connectivity by public transport, which has been used in various planning processes in London for many years(Thu & Tun, 2017). For any selected place, PTAL suggests how well the place is connected to public transport services. It does not cover trips by car.(Shah & Adhvaryu, 2016) studied PTAL for Ahmedabad city. PTAL values are simple. They range from zero to six, where the highest value represents the best connectivity. For historical reasons, the PTAL value of one is split into two categories (1a and 1b) and the PTAL value of six is split into two categories (6a and 6b). All together there are nine possible values of PTAL: 0, 1a, 1b, 2, 3, 4, 5, 6a and 6b. We often present PTAL values in maps, where a preset set of colors represent the different values(Gent & Symonds, 2005). A location will have a higher PTAL if:

- There is short walking distance to the nearest stations or stops
- Waiting times at the nearest stations or stops are short
- More services pass at the nearest stations or stops, more frequency, more routes
- There are metro rail stations nearby (Not applicable to present study)
- Any combination of all the above.

PTAL can be seen as a measure of the density of the public transport network. PTAL does not take into account the destinations you can travel to from each location or the ease of interchange. PTAL also does not reflect levels of crowding on buses or trains.

Steps of PTAL Method:

Step 1: Define points of interest (POI) and service access points (SAP) – POI is defined as a point for which the accessibility level is to be measured with reference to a SAP, which is a public transport facility or system stop i.e. bus stop

Step 2: Calculate walk access time from POI to SAP – The actual road network distance from POI to SAP is measured and by assuming walk speed, walk time (WT) is calculated.

The maximum walk times for bus is calculated. Any SAPs beyond these distances are not taken into account to calculate PTAL for that particular POI.

Step 3: Identify valid routes at each SAP and calculate average waiting time (AWT). The valid routes are bus routes for the peak hour. Frequency of services on all these routes during this hour is used in the calculation of AWT.

AWT is the defined as the period from when a passenger arrives at an SAP to the arrival of the desired service. In the calculation, the hourly frequency (f) is halved because the scheduled waiting time (SWT) is estimated as half the headway. For example, a 10-minute service frequency (6 buses per hour) would give an SWT of 5 minutes. In addition, to make the calculations more realistic, a "reliability factor" (K) is added to the SWT depending on the transport mode

$$AWT = (0.5*60)/f + K$$

Step 4: Calculate minimum total access time (TAT) for each valid route at each SAP.

$$TAT = WT + AWT$$

Step 5: Convert TAT into equivalent doorstep frequency (EDF) – This is obtained as 30 divided by TAT. The principle is to treat access time as average waiting time and the route was available at the doorstep of the selected POI.

$$EDF = 30/TAT$$

The reason for dividing 30 minutes by TAT is that it reapplies the half the headway rule. This is applied twice because the values have different meanings. In the Step 3, frequency is converted into AWT, and in the Step 5, TAT is converted back into a frequency i.e. EDF. The first step calculates TAT, i.e., the time it takes to leave home/point of origin and get on a service. This is made up of three elements: WT+ AWT (assumed to be half the headway) +K. TAT is now converted into a number that is comparable to service frequency but that takes into account the additional walk time taken to reach the stop along with reliability. Thus, the half the headway rule is applied again to TAT in Step 5 to give the doorstep frequency.

Step 6: Obtain the accessibility index (AI) for each POI – In this step, the most dominant route, i.e., the route with the highest frequency, is assigned the weighting factor of 1.0; for

all other routes, a weighting factor of 0.5 is assigned. Thus, for a transport mode, the AI is calculated as shown below:

$$AI_{mode} = EDF_{max} + (0.5 * \sum \text{All other EDFs})$$

Then, the accessibility index for a POI is calculated, as shown below:

$$AI_{POI} = \sum (AI_{mode\ 1} + AI_{mode\ 2} + \ldots. + AI_{mode\ n)}$$

Step 7: Map PTAL – The AI obtained for each POI are allocated to eight bands of PTAL. Range of Index means AI of the POI. A POI with a value of 0 indicates no access to the public transport network.

AI for various mode is estimated separately. For bus transit and rail transit under public transportation facility. Bus transit in heterogeneous traffic and in exclusive lane is estimated separately. The considerations are different and hence derive step by step for each mode.

4.8 Land Use Analysis

Various types of land use obtained from secondary data. Land use map for the year 2011 is collected in CAD and GIS map format from local authority. Analysis of land use map in ArcGIS software is carried out. Following steps are taken to get land use area from land use map. Various stage screenshots are shown here to obtain land use area.

Step-1: Collect land use map from local authority.

Step-2: Open file “FinalLU50312”

Step-3: Open file “land use combined”

Step-4: find file with extension- .dbf,. prj, sbn,.shp,.xml, .shx

Above steps are as shown in FIGURE 4.3 screenshot in ArcMap

The World Geodetic System 1984 (WGS 84) is a datum featuring coordinates that change with time. WGS 84 is defined and maintained by the United States National Geospatial Intelligence Agency (NGA). Universal Transverse Mercator (UTM) divides the world into 60 North and South zones, 6 degrees wide. WGS 84 is a geographical coordinate system and UTM is a projected coordinate system. WGS 1984 UTM Zone 43N is used here.

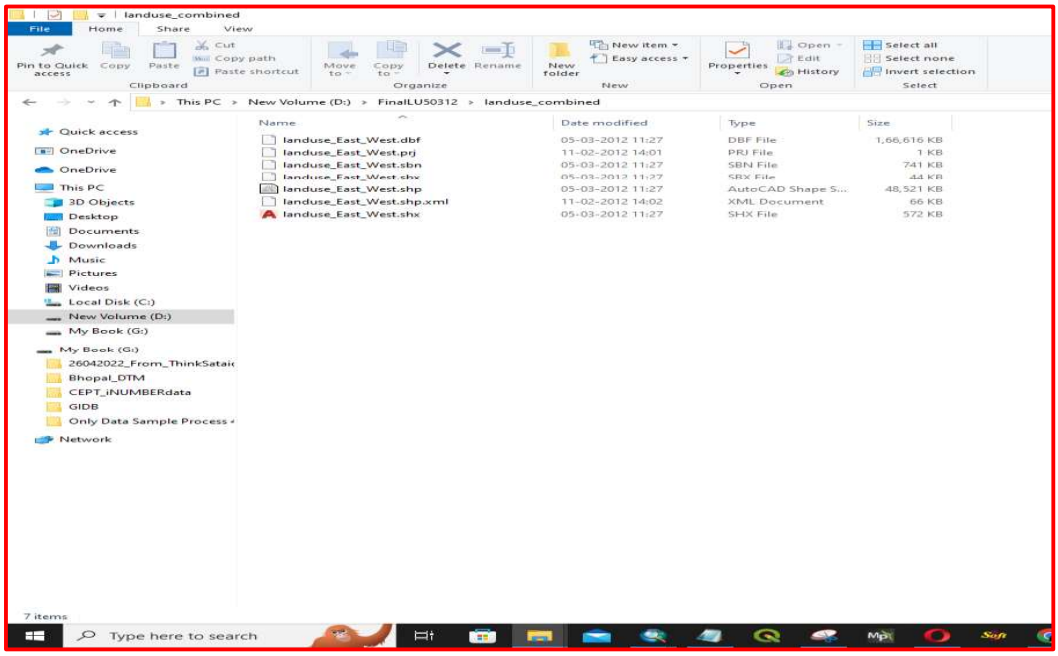

FIGURE 4.3 : Steps 1 to 4 -Analysis of Land Use

Step-5: Add file land use- "East_West.shp" showing Datasets, Layers and Results as shown in FIGURE 4.4.

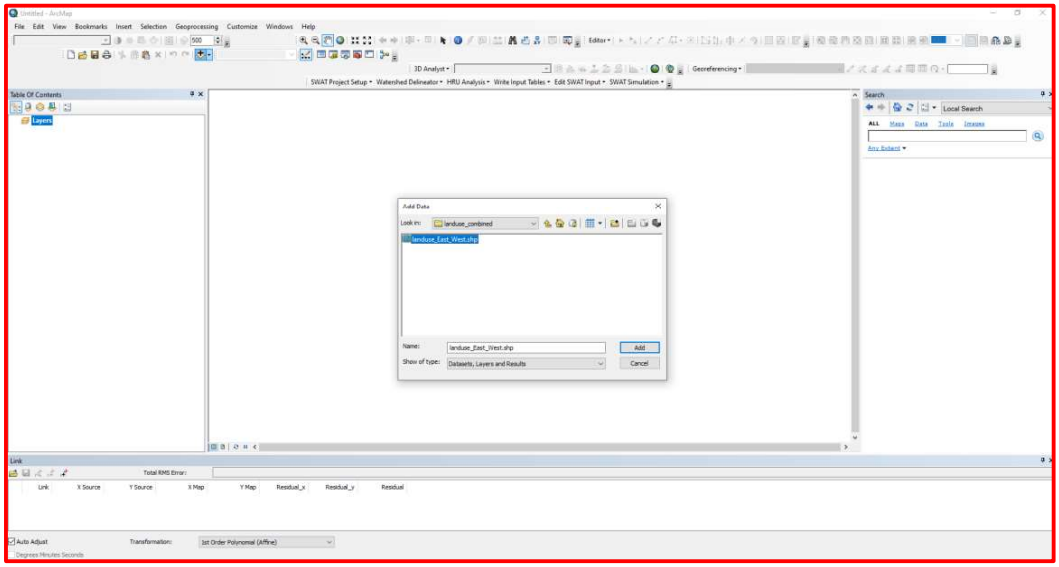

FIGURE 4.4 : Open File for Study Area

Able to see land use map of Ahmedabad as shown in FIGURE 4.5.

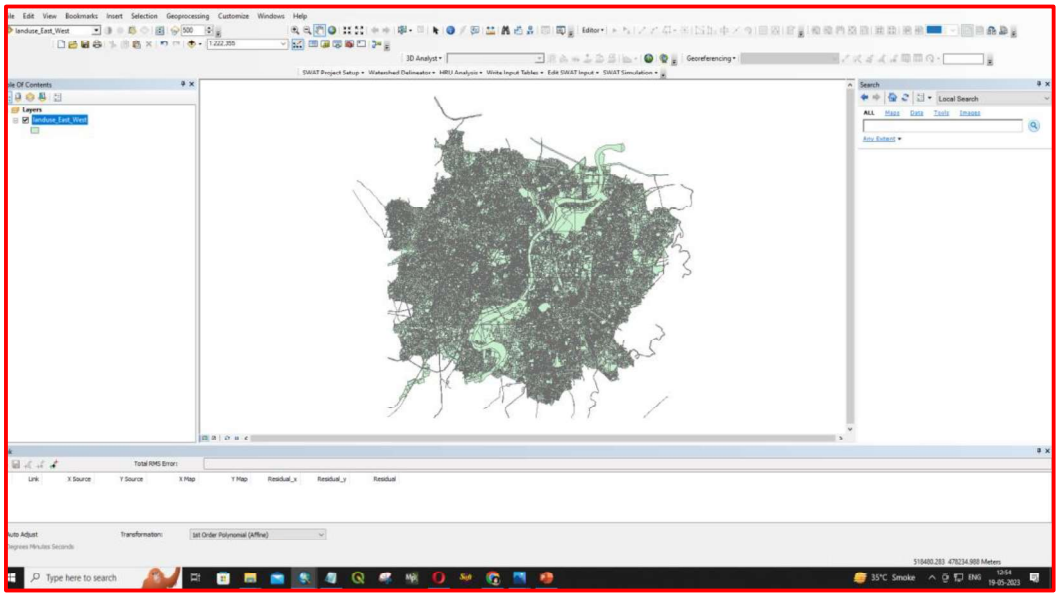

FIGURE 4.5: Open Land Use Map of Ahmedabad

Step-6: Open layer and open Attribute table as shown in screenshot FIGURE 4.6.

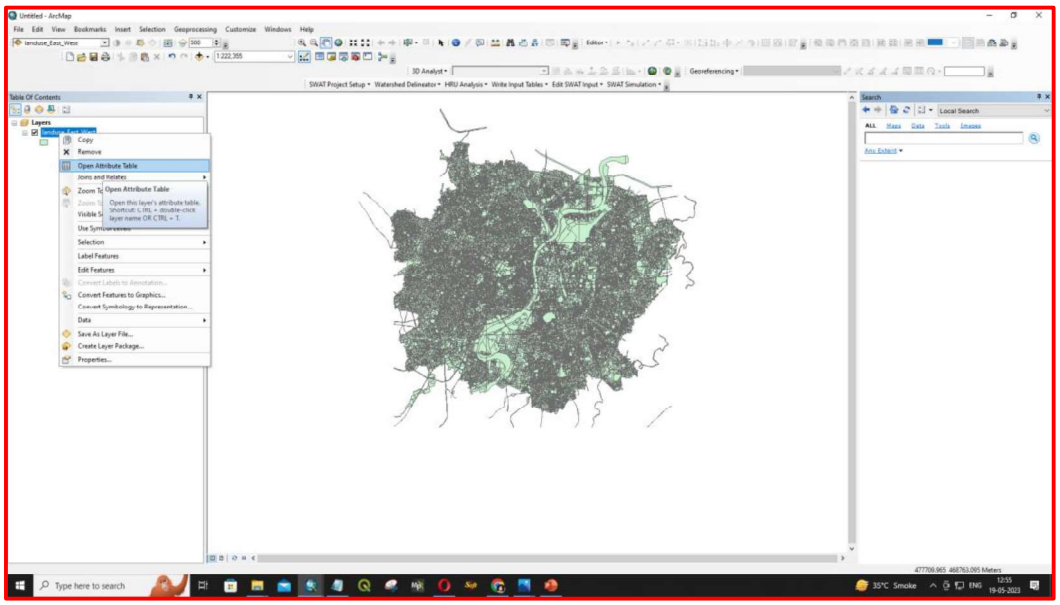

FIGURE 4.6: Step to Display Attribute Table

Able to see number of columns like Shape (Polygon), Area, Perimeter, CATEG (Category of land use) etc. information in columns as shown in FIGURE 4.7.

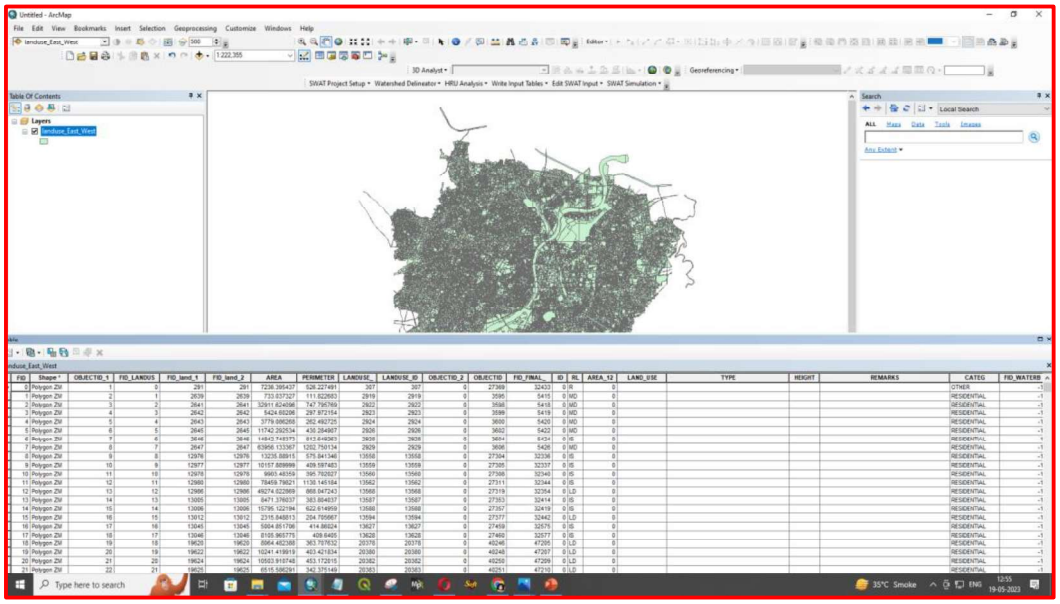

FIGURE 4.7: Various Information in Columns

Step-7: Select area column and click tab calculate geometry as shown in FIGURE 4.8.

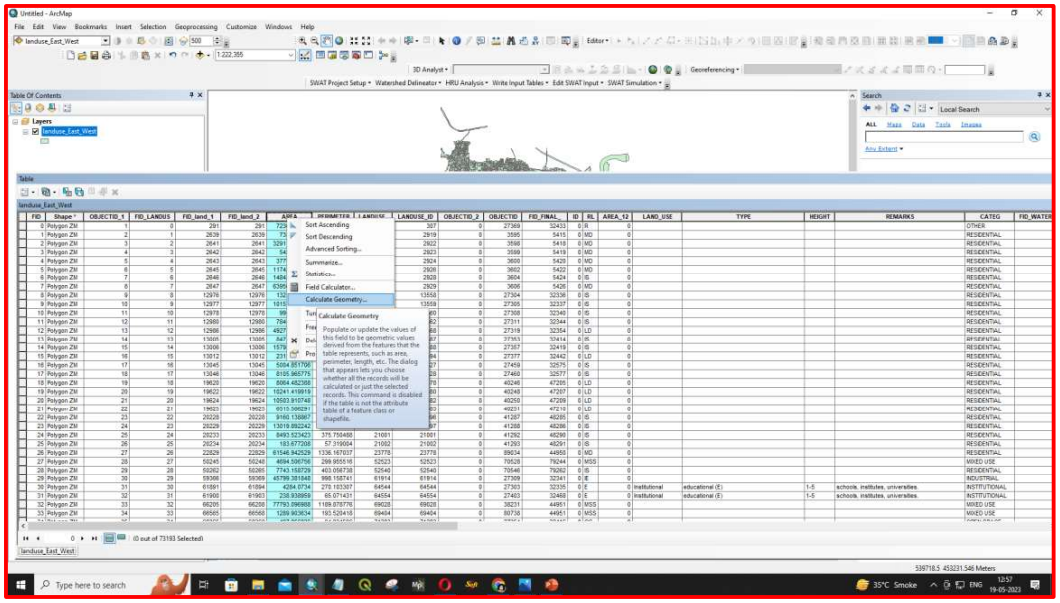

FIGURE 4.8: Calculate Geometry Tab

Step-8: Open WGS 1984 UTM Zone 43N in Data Frame Properties for Ahmedabad as shown in FIGURE 4.9

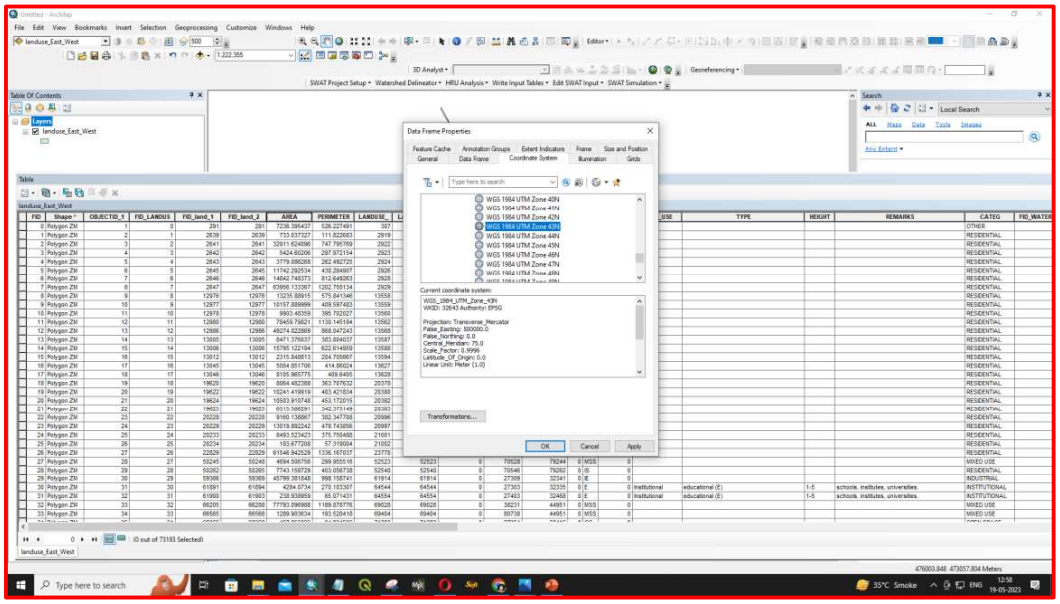

FIGURE 4.9: Selection of UTM Zone 43N

Step-9: Use coordinate system of the data source in calculate geometry tab. Select Square Kilometer [sq km] from Units. The land use area measured in Acres, Hectare[ha], Square Feet [sq ft], Square Mile [sq mi] etc. options in units are available to select as shown in FIGURE 4.10.

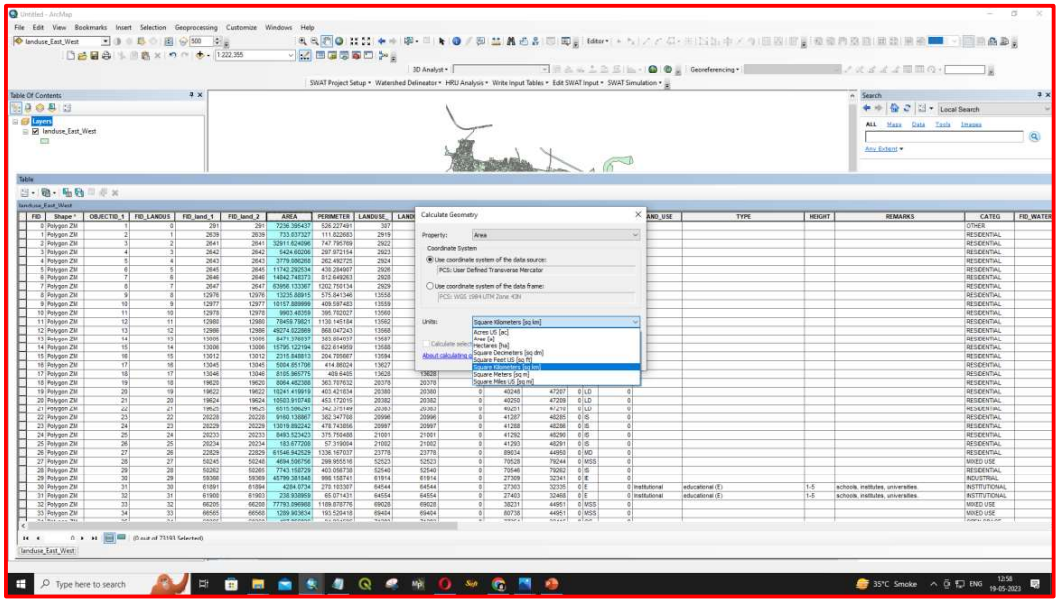

FIGURE 4.10: Selction of Unit for Area

Software starts to process area calculation in selected unit as shown in FIGURE 4.11.Extract shape file attribute data into Excel and then pivot and get final area summary. For ambiguity resolution BHUVAN and Google Earth Pro is used for confirming category of land use.

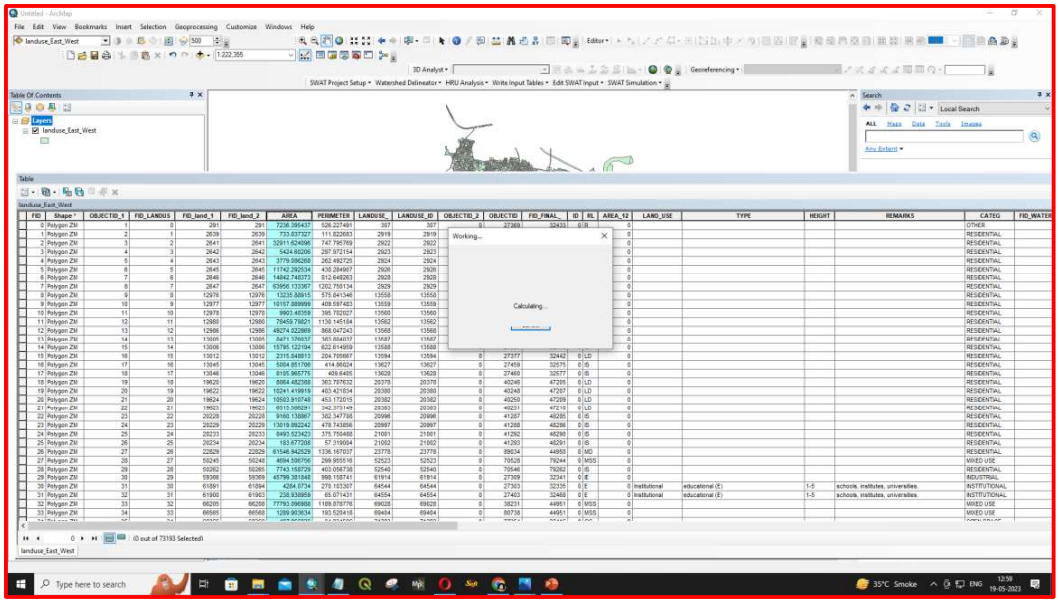

FIGURE 4.11: Process of Area Calculation in Software

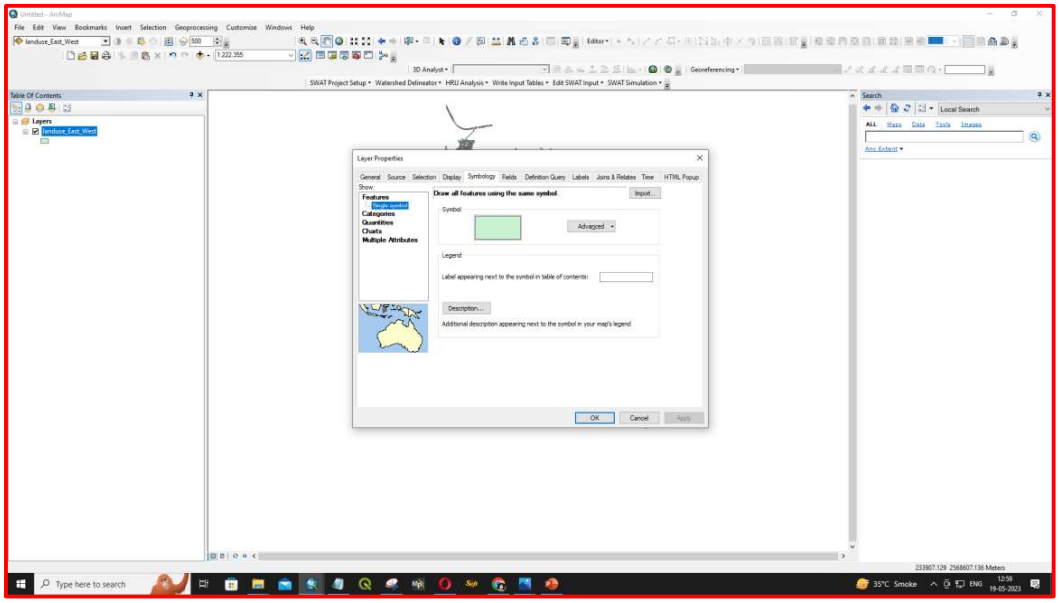

FIGURE 4.12: Selection of Single Symbol in Features

Step-10: Open layer properties and select symbol as shown in FIGURE 4.12. Select LAND_USE in Value field as shown in FIGURE 4.13.

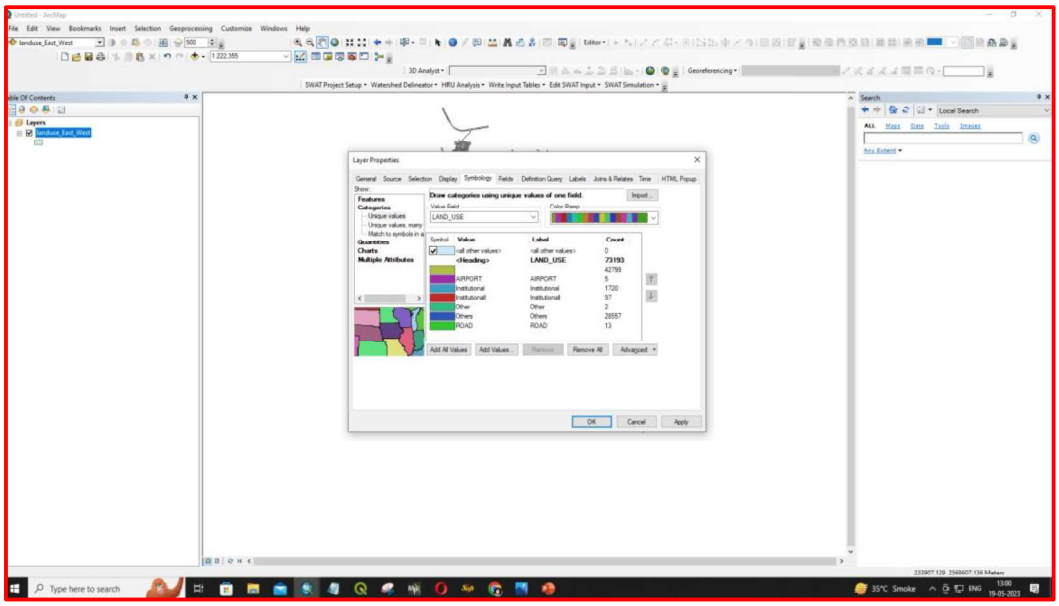

FIGURE 4.13: Draw Categories Using Unique Values

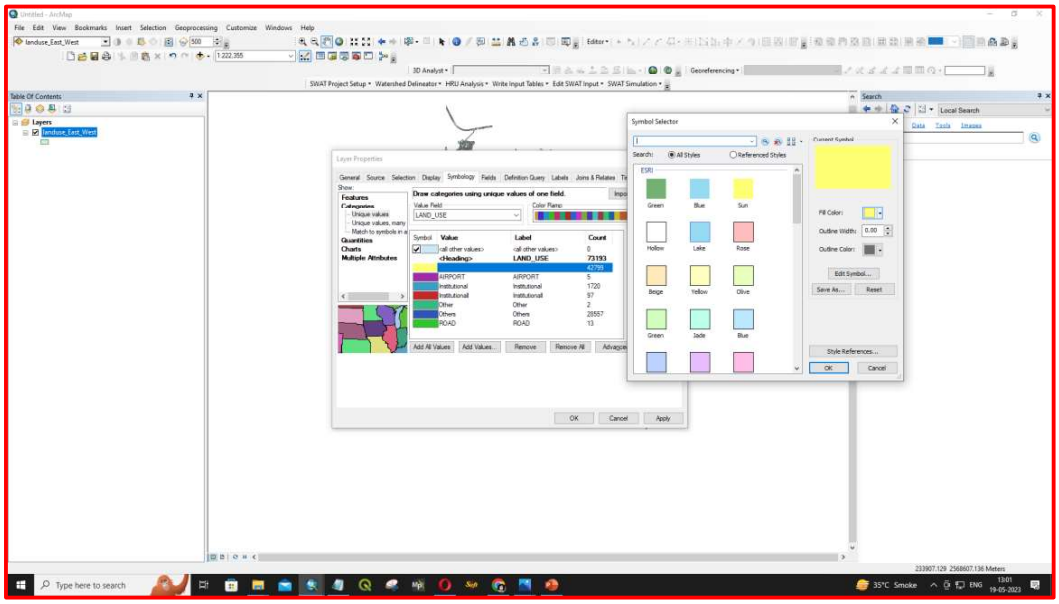

FIGURE 4.14: Selection of Yellow Colour for Residential Land Use

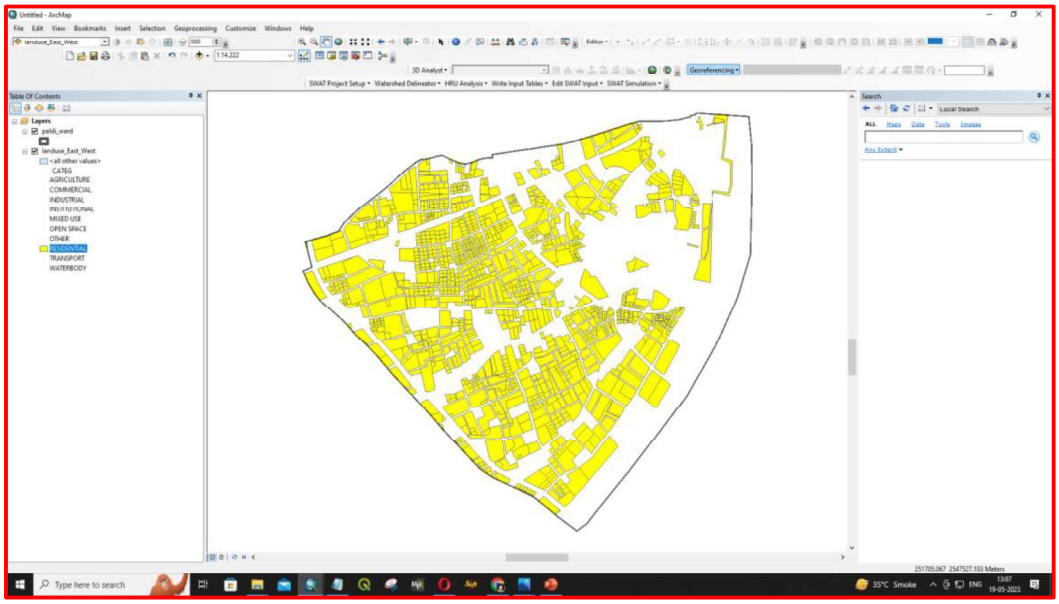

FIGURE 4.15: Display Residential Land Use Layer

Yellow colour selected for residential land use, which is displayed on PALDI ward as shown in FIGURE 4.14. Select ash grey colour to show transport land use as shown in FIGURE 4.16 for PALDI ward. Various types of land use are extracted for further analysis.

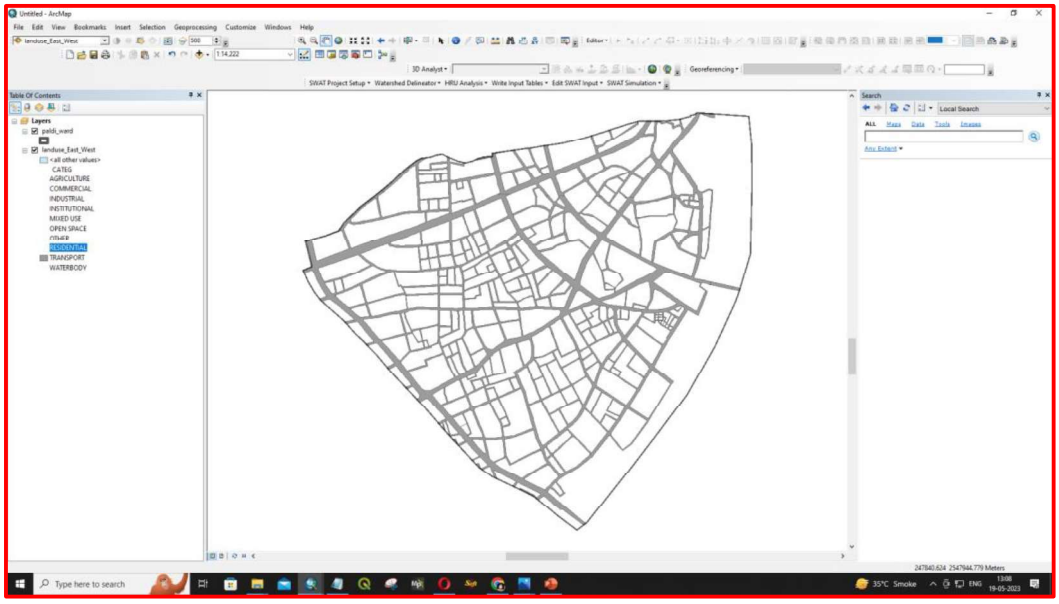

FIGURE 4.16: Display Transport Land Use Layer

Same procedure is followed to analyze land use map of 2017. The land use retrieved for all 9 wards of West zone, Ahmedabad. Agricultural, commercial, industrial, institutional, mixed use, waterbody, recreational and vacant land use is also computed.

4.9 Closure

Research methodology with flowchart and framework is discussed here to develop LUTI model for urban area. Based on literature review method of data collection and data analysis is included in this chapter. The survey procedure and steps of CCA, PTAL and Mode choice analysis is elaborated in the chapter. The FIGURE 4.17 shows how horizon year planning affected in cyclic mode. This justifies LUTI for horizon status.

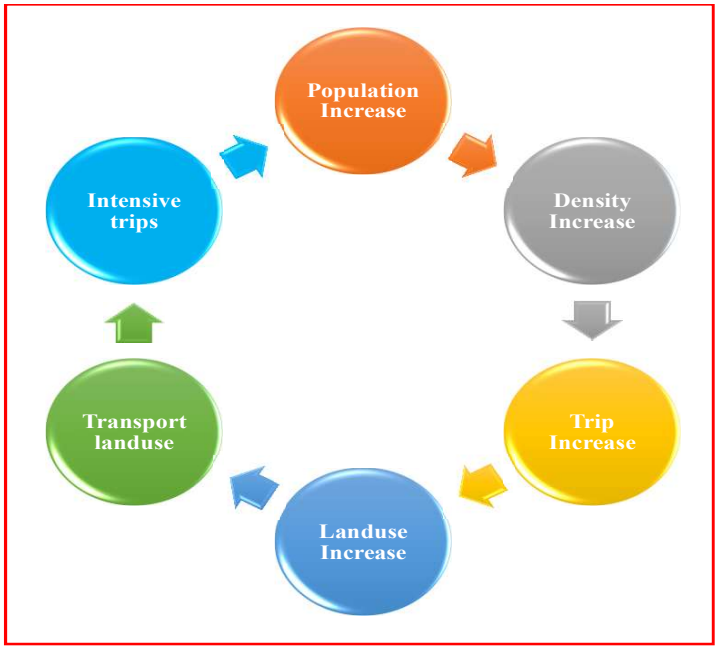

FIGURE 4.17: Development Cycle for Urban Area

CHAPTER - 5

Data Collection and Data Analysis

5.1 Data Collection

The data are of two types primary or preliminary data and secondary data. The data collected by conducting survey is primary data and data collected from various sources is secondary data. The source of secondary data should be reliable and acceptable. primary data is collected by framing survey form, questionnaire and google form. secondary data is collected by referring reports, website and visiting authority office. Data analysis is conducted as per methodology framed and literature reviewed.

5.1.1 Primary Data Collection

1. By conducting HIS following primary data has been collected by conducting interview of citizens at their home. (Appendix-A: HIS Survey Form).To get idea of intensive use of land use and density number of floors included in structured question form.
   - *Household information-Household Characteristics*

     Location, Number of persons in family, Number of working members, Vehicle ownership, Income of family, Age, Gender, Number of School/college going children
   - *Trip Information-Travel Characteristics*

     Origin and Destination of trip, Purpose of trip, Number of trips, Trip time, Trip cost, Trip length and Mode choice for trip.
2. By conducting public transport (PT) user's survey, by interview at SAPs following data has been collected. AMTS & BRTS bus stops are SAPs in study area. Bus transit is the public transport facility in study area. (Appendix-B_1 & B_2)
   - POI (Point of Interest) of PT users

- SAP near to origin and destination of user's activity center
- How PT user reach to SAP?
- Walk time of trip maker for public transport facility from POI to SAP
- Waiting time of trip maker for public transport vehicle
- Seat availability in PT vehicle
- Safety and comfort in PT vehicle

3. Land use map: Researcher need to digitize and generation of shape file for land use area computation for the year 2011 and 2017

5.1.2 Secondary Data Collection

The secondary data gathered from the following sources and formatted as per needs.

1. Data collected from RTO - Number of vehicle registration in Ahmedabad (*RTO,Ahmedabad(GJ-1) & ARTO,Ahmedabad(GJ-27)*, n.d.)
2. Data collected from AMC Report
   (*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021)
   Number of Household-owned & rented, Gender wise population, Working population, Anganwadi, School, College, University, Bank, Hotel, Restaurant, Guest house, Community Hall, Gymnasium, Playground, Garden, Swimming pool, Petrol Pump and CNG Station, Shop and Market, Off street parking lot of AMC etc. facilities in study area.
3. Real Estate price and rent trend (*Jantri Rates, Ahmedabad,2011*, n.d.), *https://garvi.gujarat.gov.in*
4. Income Group *(https://mohua.gov.in/,http://www.udd.gujarat.gov.in/)*
5. Number of bus stops, Name of bus stop, Bus frequency, Bus schedule, Bus route (*AMTS office ,BRTS office, https://www.amts.co.in/, http://www.ahmedabadbrts.org/)*
6. Map of Ahmedabad city, Zone & Wards in Ahmedabad ,Ward wise population as per census 2011, Ward area (*AMC office, Danilimda,Ahmedabad)*
7. About study area *(https://ahmedabadcity.gov.in/)*
8. Ward wise population as per census 2011*(https://www.census2011.co.in/)*
9. Land use map for 2011 *(SVNIT,Surat)*
10. Land use map for 2017 *(CEPT,Ahmedabad)*
11. Electoral list (*West zone office at Dr. Ramanbhai Patel Bhavan, Usmanpura Char Rasta, Ashram Road, Ahmedabad)*

5.2 Data Analysis

5.2.1 Based on HIS Survey

By conducting home interview survey for study area as per sample size total 2433 HH surveyed. The data collection carried out in 2 stages. In first stage approximate1500 data had been collected as per Hogg & Tennis method of sample size determination. In second stage approximate 900 data had been collected to make sample size more than 1% as per BPR Standards method of sample size determination. Some forms have data ambiguity and some information missing. Hence, finally 2400 data of HHs is finalised for further analysis. The data entry carried out in Excel sheet and same is retrieved in SPSS also. The results of data analysis based on household characteristics, trip information and mode choice in trip making are prepared in Tables and Figures in subsequent paragraphs.

The number of persons in family in HH are interviewed. They are categorised in Male & Female as 28% female and 72% male. From total trip makers in surveyed HH male & female trip makers are bifurcated as 26% female and 74% male.

Distribution of family members as contributor to trip making as per activities and status is carried out from HIS data. Number of employed persons in family are labelled as working persons and they are 36%. Housewife and retired persons in family are under category of non-working persons and they are 38%. There are 26% persons in family going for study to school or college. To get broader picture of income distribution, seven income groups based on income class interval accepted for study. The income group is divided into four classes and converted to EWS, LIG, MIG, HIG as per the urban development and housing department as shown in TABLE 5.1 below. It is expressed as yearly income in Rupees.

TABLE 5.1: Distribution of HHs as per Income Group

Income Group	Number & % of HH
EWS (Economically Weaker Section) Annual Income < 1 Lakh	155 (7%)
LIG (Low Income Group) Annual Income 1 Lakh to 2.5 Lakh	443(18%)
MIG (Middle Income Group) Annual Income 2.5 Lakh to 5 Lakh	820(34%)
HIG (High Income Group) Annual Income >5 Lakh	982(41%)

(Source: Urban Development and Urban Housing Department, Gujarat) under Mukhyamantri GRUH (Gujarat Rural Urban Housing) Yojana-2014 (Five - year plan).

The purpose-based trip data analysis revealed 57.53% work trip , 34.79% education trip and 7.68% trips for shopping and other purpose.

The number of vehicles in HHs plays an important role in trip making. Mode choice depends upon availability of vehicle with family. Number of trips depend upon number of vehicles in household among family members. From the data collection by HIS for 2400 HHs, total number of vehicles are bifurcated in 3 categories in percentage. FIGURE 5.1 shows percentage of HHs with number of vehicle ownership. There are 15.15% cycle, 64.49% two wheeler (2W) and 20.36% car as vehicle ownership. 2W is highest number of vehicles as personalized private vehicle ownership in study area.

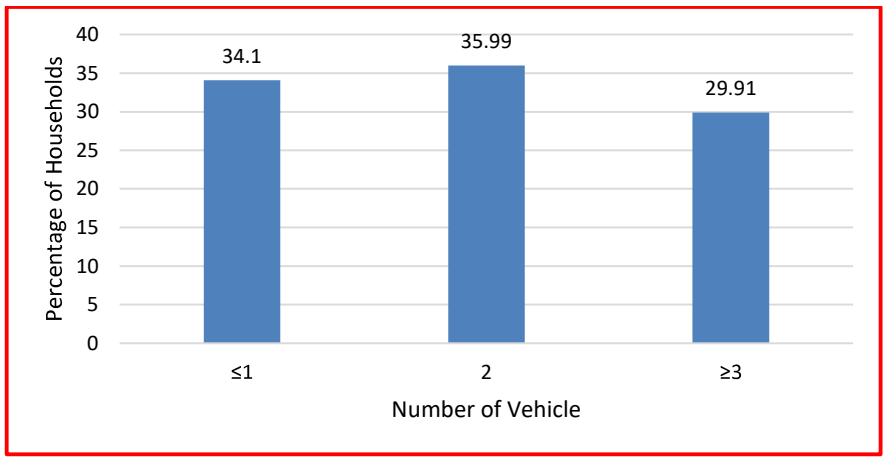

FIGURE 5.1: Vehicle Ownership

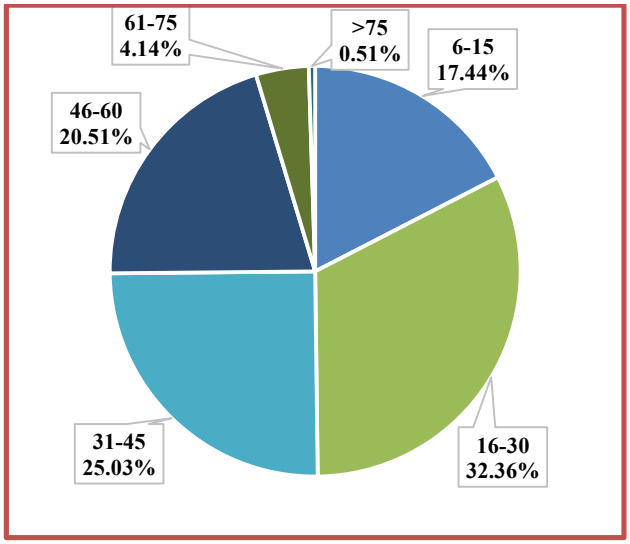

FIGURE 5.2: Agewise Tripmakers

FIGURE 5.2 shows age group wise distribution in percentage of trip makers. Maximum number of trip makers are in age group of 16 to 30 years. The age group 16 to 45 is most mobile persons and wage earners in family.

Trip makers choice for mode is as shown in FIGURE 5.3 below. Maximum mode choice 51.72% is for 2W. There are 18.88% NMT (9.24% bicycle and 9.64% by walk). Mode choice for trip making is 2.52% 3W-rickshaw, 11.82% 4W (11.56% private car, 0.26% OLA/UBER like hired cab), 15.06% bus (3.47% AMTS, 6.26% BRTS, 4.92% school college bus, 0.41% company staff bus). Planning in urban roads, provision for NMT 18.88% is important, which is observed neglected.

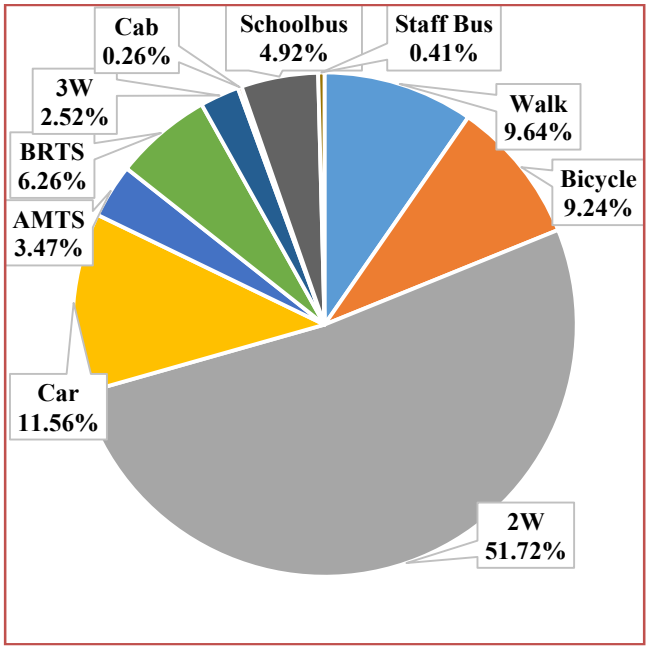

FIGURE 5.3: Mode Choice of Tripmakers

The trip cost is up to Rs. 20 for 81.93% of total trips surveyed. More than Rs.100 cost is with a few trips, only 0.92% of total trips. 10.81% of the trips have Rs.20.1 to 40, 3.65% trips have Rs.40.1 to 60 and 1.83% of trips have Rs.60.1 to 80. Trip cost Rs.80.1 to 100 is for 0.86% of the total trips.

The trip length or distance from origin to destination up to 4 km is of 53.06% of the total trips; Only 0.87% of total trips are more than 20 km trip length. 26.96% trips have trip length 4.1 to 8 km. 11.26% trips have trip length 8.1 to 12 km.5.46% have 12.1 to 16 km trip length. 2.39% have 16.1 to 20 km as trip length. Purpose wise trip cost distribution is as shown in FIGURE 5.4.

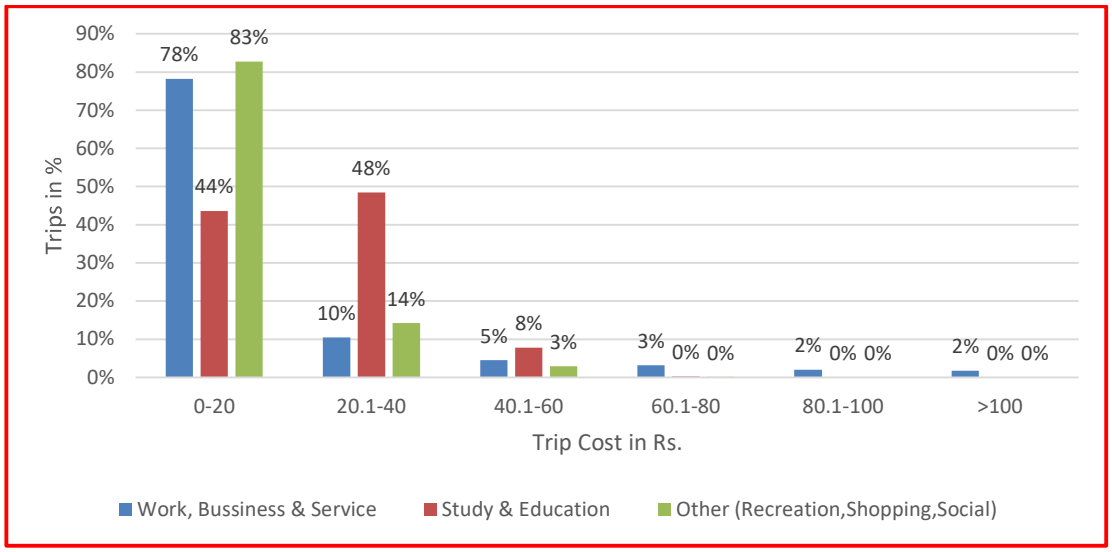

FIGURE 5.4: Purpose Wise Trip Cost Distribution

Mode wise trip length distribution is as shown in FIGURE 5.5 below. Trip length is displayed as code on X-axis. The codes indicating trip length in km as shown in Appendix-E. Code 1 indicates 0 to 4 km trip length. Likewise, 6 indicate more than 20 km length. Maximum 4 km trip length is observed by walk and bicycle. Rickshaw is preferred for maximum 12 km. Bus is selected for 1 to 20 and more km trip length. Hired cab is observed up to 16 km trip length.2W is preferred mode for 91.21% of trips made by 2W is for maximum 12 km length.4W is preferred for 1 to 16 km for 94% of trips made by 4W.

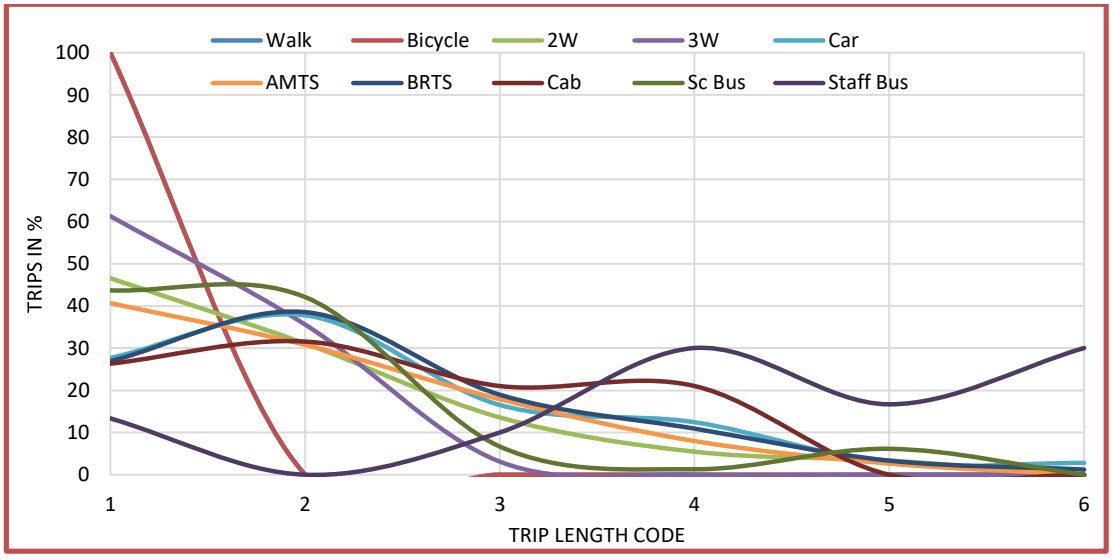

FIGURE 5.5: Mode Wise Trip Length Distribution

The major factor influencing the location of the middle income group population is the travel time to their places of interest and the state of the transportation facilities available for the travel.(Patnam, 2003). Major trips are taking time 0 to 20 minutes as 67.68% and 20 to 40 minutes are 26.51%. Trip travel time range 0 to 80 minutes is distributed in groups of 20 minutes and % trips are as shown in FIGURE 5.6 below.

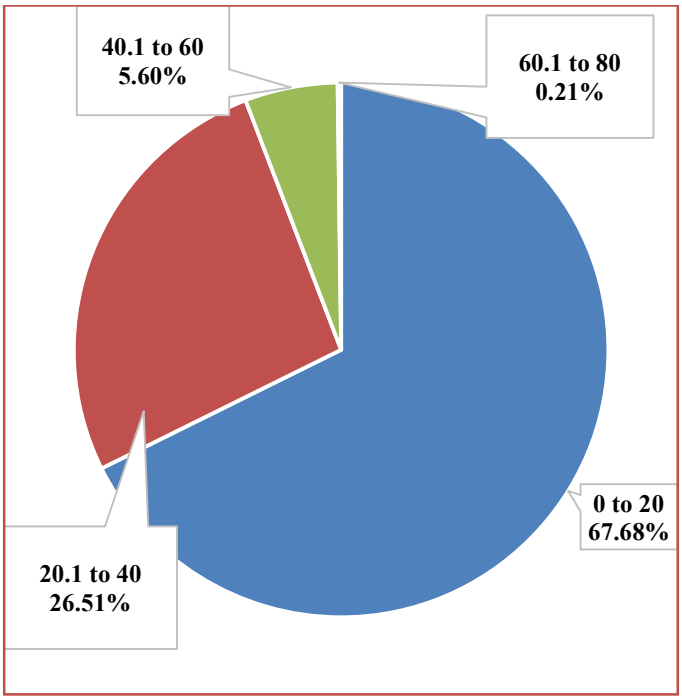

FIGURE 5.6: Trip Travel Time based Distribution

5.2.2 Based on Public Transport User's Survey

By personal interview at bus stops in wards of the west zone of Ahmedabad data has been collected. By interview of 2862 PT users of BRTS and 3599 users of AMTS at various SAPs of study area, Passengers waiting for buses at these stops are noted as per gender, age, and purpose of the trip. TABLE 5.2 shows the number of passengers interviewed at AMTS bus stops. TABLE 5.3 shows the number of passengers interviewed at BRTS bus stops. AMTS and BRTS SAPs with name is listed ward wise in TABLE 5.4 and TABLE 5.5 respectively. Route information for AMTS and BRTS at various SAPs is listed ward wise in TABLE 5.6 and TABLE 5.7 respectively.

TABLE 5.2: Number of Passengers Interviewed at AMTS Bus Stops

Sr. No.	Ward Name	Total Stops	Surveyed Stops	No. of Passengers Interviewed
1	Paldi	25	12	558
2	Vasna	11	7	326
3	Navrangpura	19	10	476
4	SP Stadium	2	2	96
5	Naranpura	8	8	390
6	Nava Vadaj	14	8	364
7	Sabarmati	13	8	400
8	Ranip	20	11	458
9	Chandkheda	19	11	531
Total		**131**	**77 (58.78%)**	**3599**

TABLE 5.3: Number of Passengers Interviewed at BRTS Bus Stops

Sr. No.	Ward Name	Total Stops	Surveyed Stops	No. of Passengers Interviewed
1	Paldi	3	2	100
2	Vasna	1	1	45
3	Navrangpura	12	10	976
4	SP Stadium	2	2	203
5	Naranpura	5	5	533
6	Nava Vadaj	1	1	207
7	Sabarmati	6	6	394
8	Ranip	1	1	70
9	Chandkheda	6	5	334
Total		**37**	**33 (89.19%)**	**2862**

TABLE 5.4: AMTS SAPs in Study Area West Zone, Ahmedabad

Sr.No.	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
1	Vikash Gruh	Jawahar Nagar	Shivranjani	R.T.O. Circle	Pragatinagar	Neel Complex	Laxmi Nagar-1	Ambedkar Foundation	Jaswinder Auto
2	Niranjan Society	Vasna Terminus	Umiya Vijay Society	Shubhash Bridge	Harish Chandra Park	Bhavsar Hostel	Laxmi Nagar-2	Vanraj Society	Shrupath Society
3	Sharda Nagar	Kesriyaji	Haridas Park		Housing Board	Vyash Wadi	Acher Depot	Umang Park	Sarathi bungalo
4	Dharnidhar Society	Gupta Nagar	L Colony		Pallav Society	Akhbar Nagar	Gandhi Bagh	Hanuman Park	Satyamev Hospital-1
5	Jalaram Mandir	Shiv Shakti	Shefaly		Naranpura Ratsta	Shrinath Apartment	Gandhi Vas	Radha Swami Satsang	Satyamev Hospital-2
6	Mahalakshmi Society	Pratap Kunj	Gujarat University		Amikunj	Chandrabhaga House	Toll Naka	Sarveshwar Mahadev	Chandkheda Gam
7	Mahalakshmi Rasta	Ayyappa Mandir	Dadasaheb Na Pagla		Devendra Park	Hari Om apartment	Abukala Road	Sarveshwar Mandir	Shiv Shakti Nagar
8	Jain Merchant	Sorai Nagar	Suchita Apartment		AEC Zonal office	R.H. Patel College	Chintamani	Shri Ram Chowk	Santok Baa Hospital
9	Paldi	Ekta Tower	Saurabh Society			Swaminarayan Mandir	Ambedkar Chowk	Sarkari Press Colony	Parshwanath Nagar
10	Paldi Turminus	Amar Flats	Apang Manav Mandal			Nava Vadaj	Municipal Nagar	Sarkari Litho Press	Parshwanath Township
11	Pritam Nagar	Pravin Nagar	Sahjanand College			Krushna Nagar	Rathi Apartment	Madan Pura Chowk	ONGC Avanibhavan
12	Arind Sales		Swastik Society			Poonam Party Plot	Quarter	Ranip Gam	ONGC Office

Sr.No.	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
13	Congress Bhawan		Passport Office			N. R. Patel Park	Power House	Sardar Patel Chowk	Gnagar Highway-1
14	V.S. Hospital		Commerce college			Police Chowki		Arvind Co-Op. Group	Gnagar Highway-2
15	Madalpuar		Commerce College Hostel					Gayatri AMTS Stop	Visat GSRTC
16	Town Hall		Nehru Nagar Rasta					Karan Complex	Vishwakarma Mandir
17	Fateh Nagar		Government Quarter					Balol Nagar	Maruti Tenament
18	Viswakunj		Satyakam Society					Natraj Shopping	GEC,Gnagar
19	Museum		Panjrapol					Gangotri	Ashok Vihar
20	Lavanya Soc.							Vrundavan Soc.	
21	Jivraj Mehta Hospital								
22	Bakeri Medical								
23	Bhatta								
24	Anand Nagar								
25	Malav Talav								

TABLE 5.5: BRTS SAPs in Study Area West Zone, Ahmedabad

Sr. No.	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
1	Chandranagar	Vasna bus stop	University	RTO	Pragatinagar	Akhbarnagar	Visat	Ranip Cross Road	Zundal Circle
2	Anjali		Himmatlal Park	Bhavsar Hostel	Shashtrinagar		Motera Cross Road		Sarthi Bungalows
3	Dharnidhar		Shivranjani		Jaimangal		Sabarmati Police Station		Chandkheda Gam
4			Jhansi ki Rani		Sola Cross Road		Sabarmati Muncipal Swimming Pool		Shivshaktinagar
5			Nehrunagar		Valinath Chowk		Rathi Apartment		Jantanagar
6			L Colony				Sabarmati Power House		ONGC
7			Panjarapol						
8			Gulbai Tekra						
9			LD Engineering College						
10			Commerce Six Road						

- Andhjan Mandal SAP is not considered in Navrangpura. It is part of Vastrapur. The SAP is on border of both wards.
- Memnagar SAP is not considered in Navrangpura. It is in Gurukul.
- Nava Vadaj is separated from Juna Vadaj. Some stops are on common border. BRTS SAP is only one.

TABLE 5.6: AMTS Bus Routes Available in Wards of West Zone

Ward	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
Sr. No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.
1	32	32	40	13/1	40	72	22	13/1	89/1
2	33	33	42	22	63	74	75	74	22
3	35	35	43	88	64	77	84	79	75
4	40	40	45	202	65	79	401	82	84
5	42	123	46	204	66	82	85-s	88	109
6	43	150	47	205	68	82	89/1	202	401
7	45	160	49	401	69	137	89-3s	204	30/3
8	47	200	50	85-S	70	202	90-s	205	85/s
9	49	202	56	89-3S	160	800		146-1	89/1
10	58	204	58		202	900		40/3	89-3s
11	68	205	68		300	130/4		74/1	90-s
12	123	300	136		400	137S			
13	136	401	142		500	146-1			
14	142	150S	144		64/2	40/3			
15	150	31/4	151		64/3	40-2			
16	200	31/4S	160		64-1	40-3			
17	204	31-5	200		65/1	70-2			
18	205	31S	300		65/2	71-1			
19	300	33/1S	400		65/3	74/1			
20	401	34-3	500		66/3				
21	900	34-4	800		66/3S				
22	14-1	36/1	138-1		66/3S				
23	150S	37-4	151/4		66-4				

Ward	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
Sr. No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.
24	151/4	38/1	151-3		67/1S				
25	151-3	40-1	40/3		70/1				
26	31/4	40-2	44-4						
27	31/4S		45/1						
28	31-5		49/1						
29	31S		49/2						
30	33/1S		49S						
31	33/2		51 SHILAJ						
32	34-3		51R						
33	34-4		52-2						
34	34-5		56-1						
35	36/1		65/1						
36	37-4		66/1						
37	38/1								
38	39-3								
39	40-1								
40	40-2								
41	44-4								
42	45/1								
43	49/1								
44	49/2								
45	49/S								
46	52/2								

TABLE 5.7: BRTS Routes Available in Wards of West Zone

Ward	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
Sr. No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.	Route No.
1	1	5	1	2	2	2	4	3	4
2	3		3	3	3	3	7	4	7
3	5		4	4	4	4		7	
4	101		8	7	9	10		10	
5	201		9	10	10	12		12	
6			10	12	12				
7			12						

For different purposes, people make trips in buses provided by the local authority as shown in TABLE 5.8. Other includes trips for swimming, temple, Satsang, just for fun, medical, license, banking, document collection, to pay school fees, to collect donations/charges/funds, to go for LIC policy work, going to bus stop for village visit etc.

TABLE 5.8: Purpose Wise Trip Distribution in PT Bus

Trip Purpose	Social	Work	Shopping	Education	Other
Trips in %	14.36	46.53	9.39	24.84	4.88

Passengers belong to LIG and MIG income groups prefer to use PT buses more. 34.94% & 34.08% of total bus users belong to LIG and MIG respectively. 5 lacs and more annual income families belongs to HIG category and prefer less to use the PT bus. Only 8.63% of total PT users have income more than 5 lacs. 22.35% trip makers are in EWS category. Comfort and seat availability in PT buses to the passengers are responded as below in TABLE 5.9

TABLE 5.9: Comfort & Seat Availability to Passengers in PT Bus

Comfort			Seat Availability		
Good	Poor	Average	Yes	No	Sometime
49.86%	5.14%	45.00%	41.79%	17.99%	40.22%

5.3 Land Use Data Analysis

Land use map of 2011 and 2017 analyzed for 10 different land use in study area. There are Residential, Commercial, Industrial, Institutional, Agricultural, Mixed, Vacant, Waterbody, Transport and Recreational land use. The land use maps used for extracting the information about land use land cover surface area within the study area and for quantification of the same over the study duration.

5.3.1 Land Use Year 2011

Land use file for Ahmedabad city based on survey conducted by AUDA is used for the project work. The file opened in ArcGIS for digitization. The generated shape files are used for area computation for various land use. AUDA has initiated to prepare GIS based city map from 2011 only. The colour codes for various land use is used as provided in Draft Comprehensive Development Plan report in AUDA booklet. The digitized map by researcher is as shown in below.

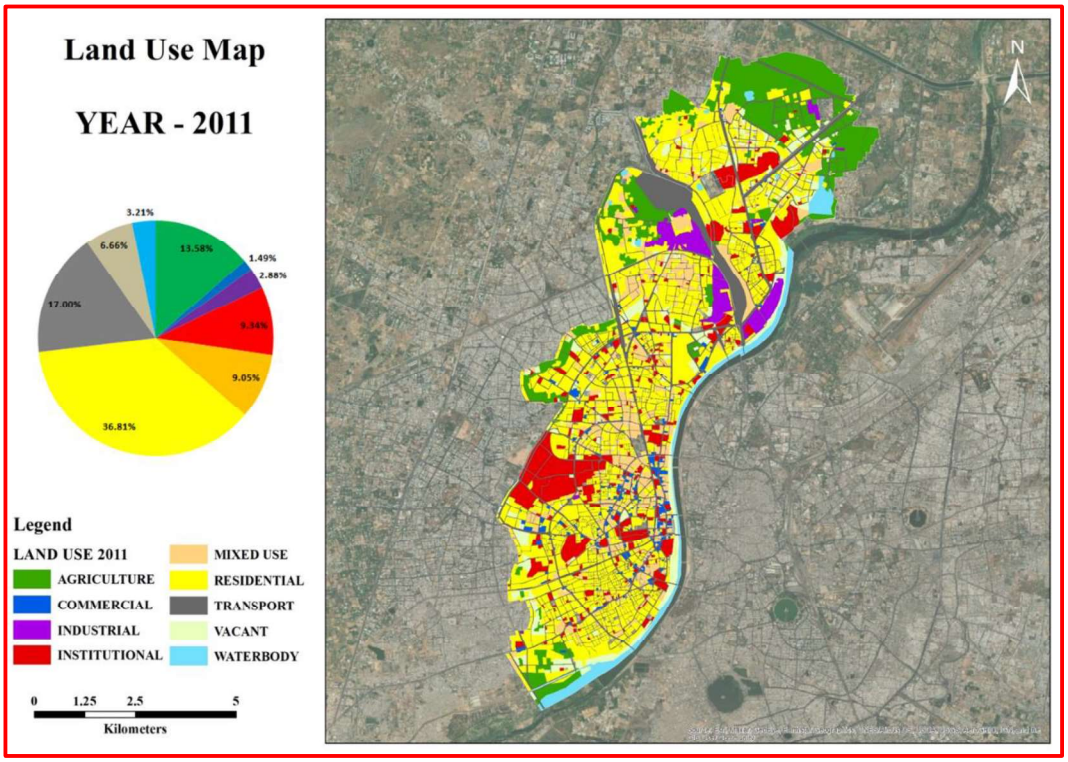

FIGURE 5.7: Digitized Land Use Map Year 2011

Land use in 2011; maximum area provided for residential land use and it is 36.81% of the total land in study area. Transport land use is 17% and Mixed land use is 9.05%. The vacant land available is 6.66%. Details of land use for Paldi ward is as shown in FIGURE 5.10. Details of land use for Vasna ward is as shown in FIGURE 5.11.Likewise for all as shown in figures below. Land use area in km^2 as computed from shape file extracted in MS Excel is as shown in TABLE 5.10.. Same is presented graphically in FIGURE 5.8 below.

TABLE 5.10: Land Use Area in km^2 for Study Area in Year 2011

Land Use	Ward Name								
	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
Agriculture	0.00	0.71	0.03	0.08	0.67	0.01	1.67	1.22	4.44
Commercial	0.15	0.03	0.53	0.09	0.08	0.03	0.05	0.00	0.01
Industrial	0.00	0.00	0.01	0.00	0.34	0.00	0.51	1.24	0.09
Institutional	0.43	0.13	3.04	0.52	0.00	0.11	0.77	0.09	0.64
Mixed Use	0.68	0.26	1.73	0.71	0.53	0.55	0.87	0.93	0.77
Residential	2.62	2.37	3.93	2.18	2.36	1.45	2.98	2.63	3.36
Transport	1.11	0.55	2.03	0.90	0.76	0.73	1.98	1.65	1.34
Vacant	0.39	0.71	0.62	0.38	0.19	0.23	0.86	0.18	0.76
Waterbody	0.25	0.62	0.06	0.23	0.00	0.00	0.79	0.07	0.06

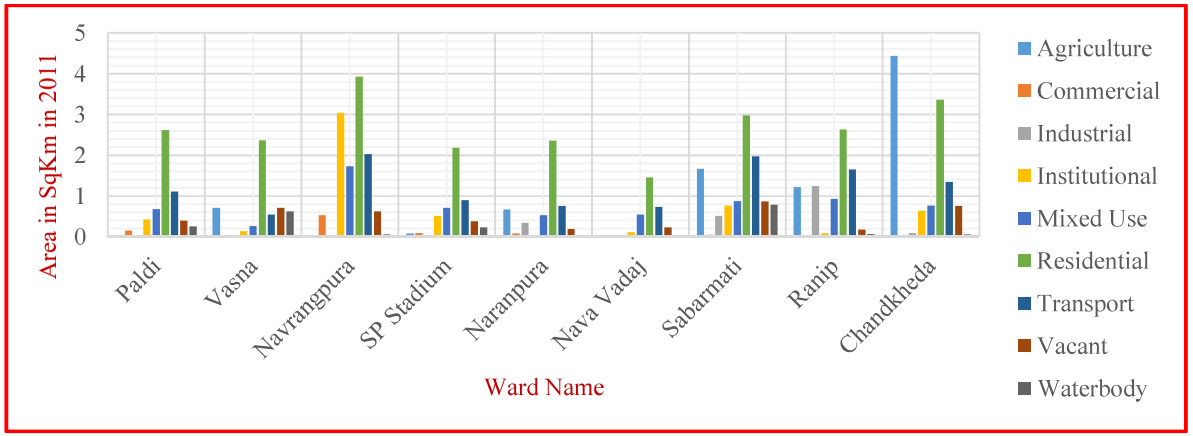

FIGURE 5.8: Land Use Area in km^2 for Study Area in Year 2011

Ward wise land use map is as shown in FIGURE 5.9 below for the year 2011. FIGURE 5.10 to FIGURE 5.18 show distribution in different wards.

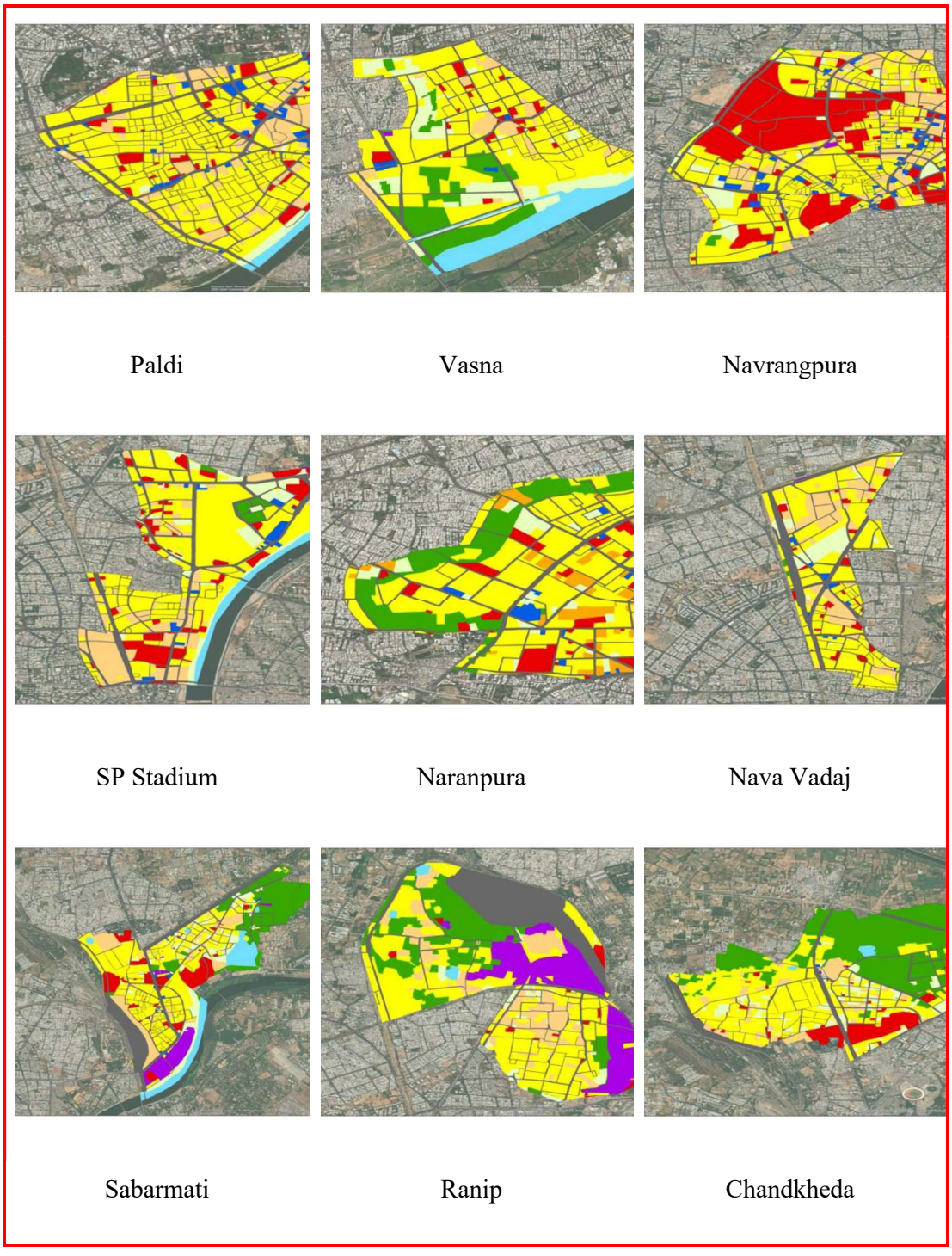

FIGURE 5.9: Land Use Map of 9 Wards of West Zone Year 2011

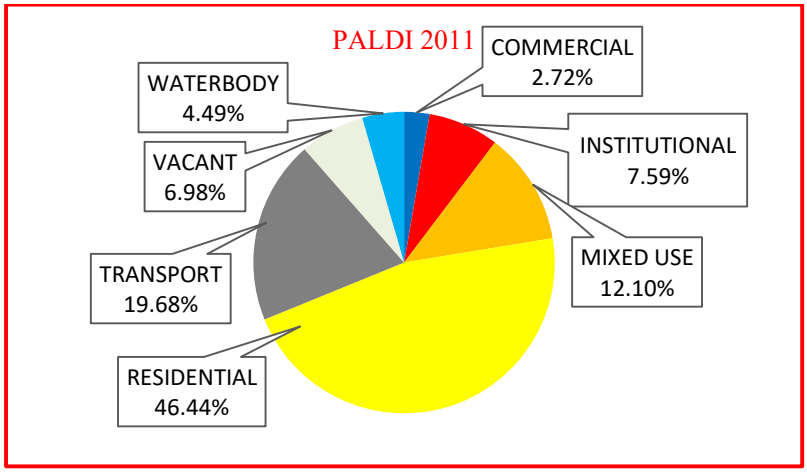

FIGURE 5.10: Land Use for Paldi Year 2011

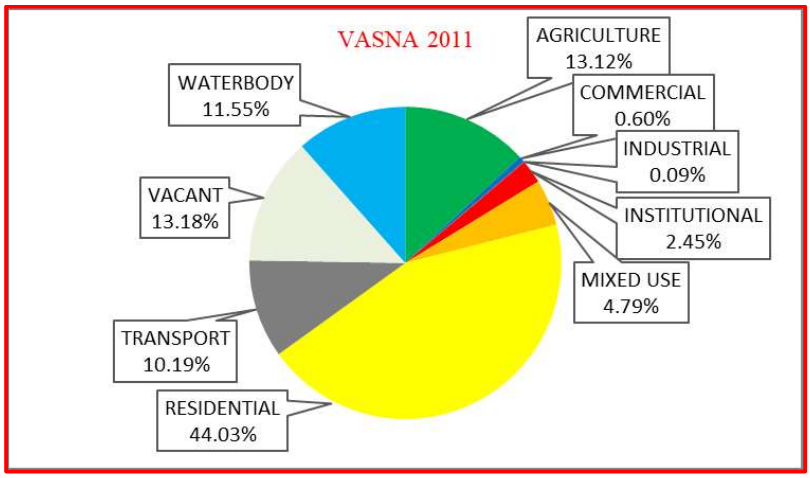

FIGURE 5.11: Land Use for Vasna Year 2011

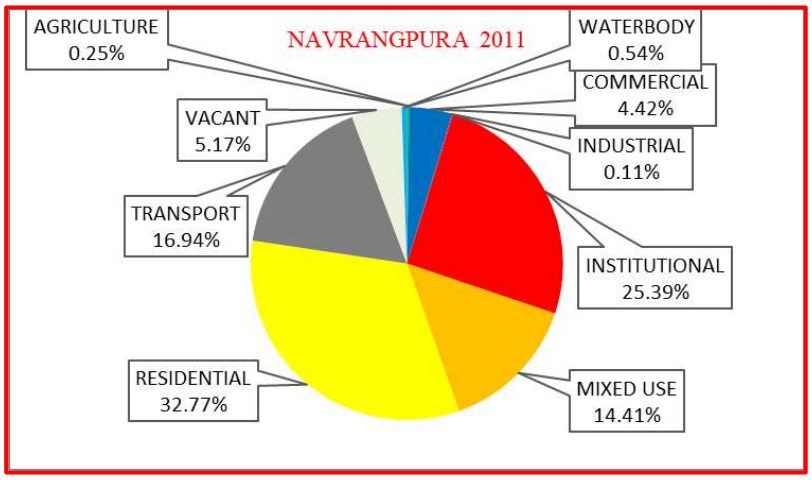

FIGURE 5.12: Land Use for Navrangpura Year 2011

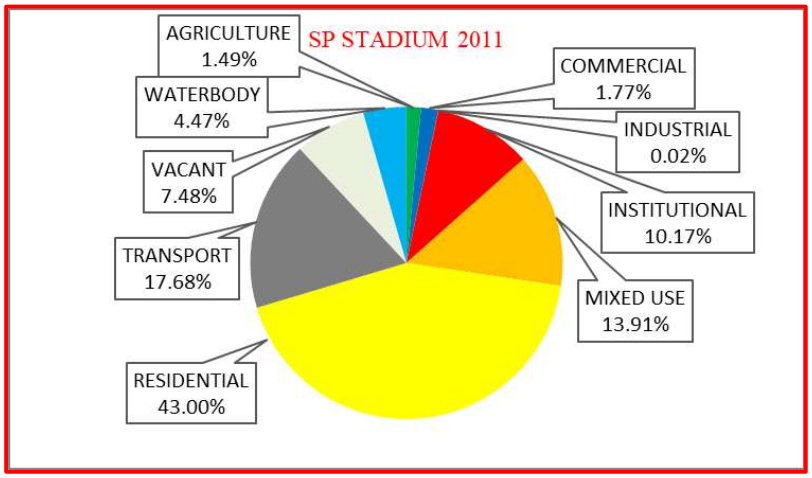

FIGURE 5.13: Land Use for SP Stadium Year 2011

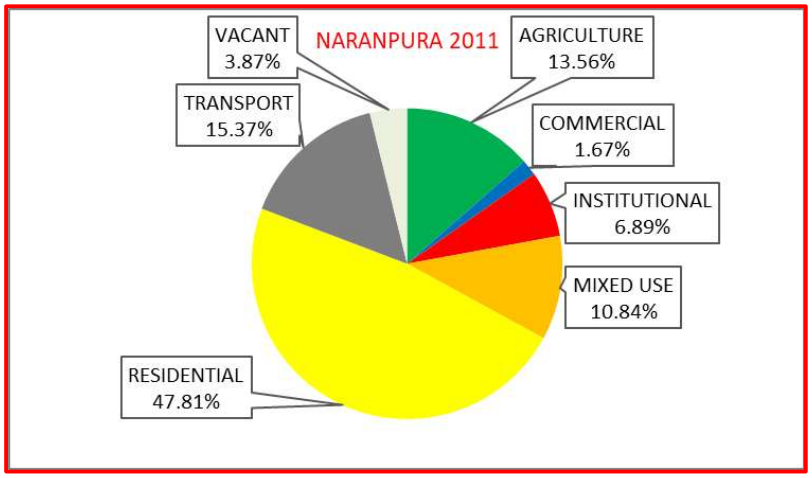

FIGURE 5.14: Land Use for Naranpura Year 2011

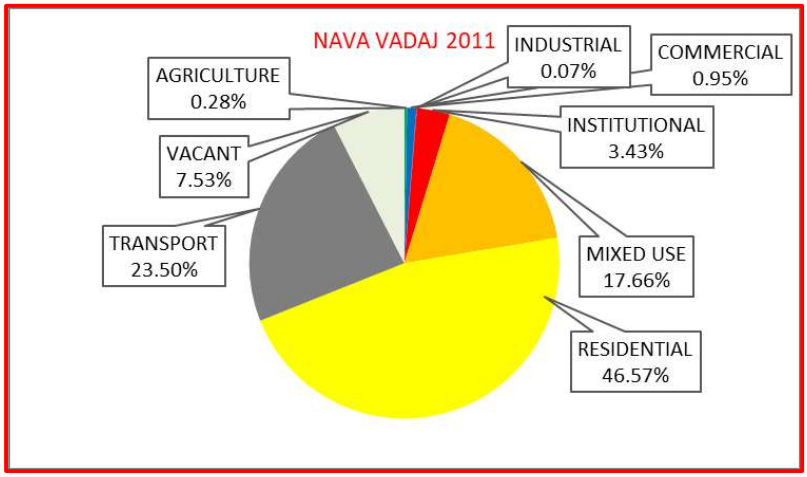

FIGURE 5.15: Land Use for Nava Vadaj Year 2011

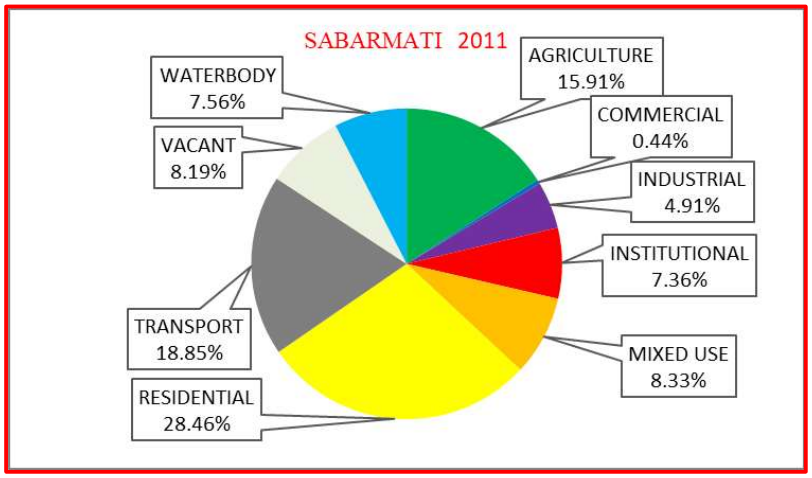

FIGURE 5.16: Land Use for Sabarmati Year 2011

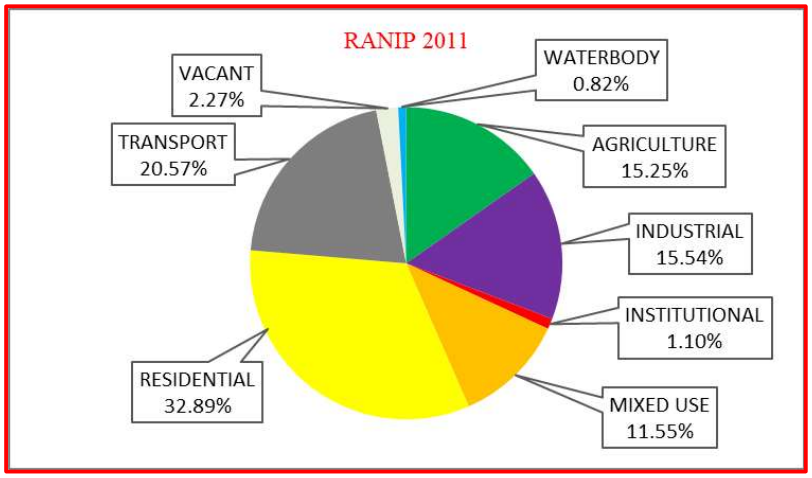

FIGURE 5.17: Land Use for Ranip Year 2011

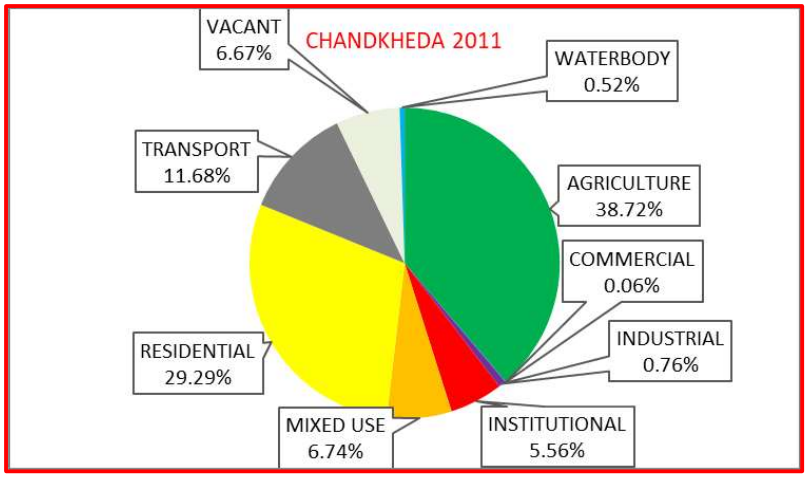

FIGURE 5.18: Land Use for Chandkheda Year 2011

5.3.2 Land Use Year 2017

As per availability of city map during study duration 2017 land use is studied after 2011. Various land use in study area in 2017 with pie chart and colour code as shown in FIGURE 5.19.

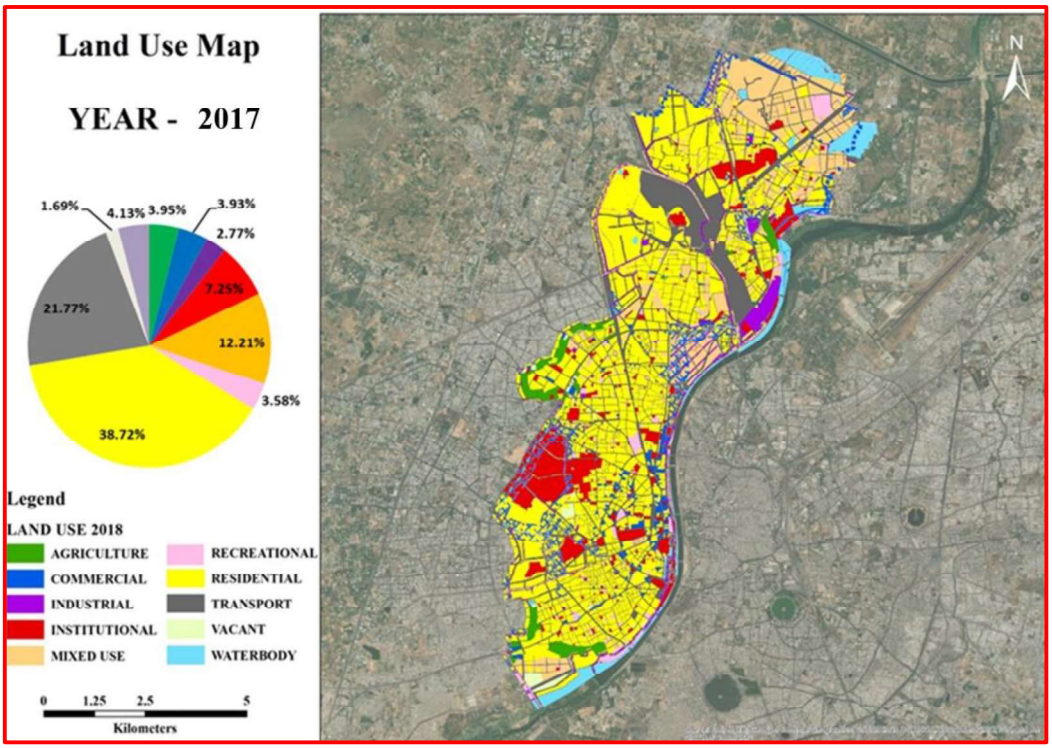

FIGURE 5.19: Digitized Land Use Map Year 2017

The area computation using GIS software for different land use is carried out as shown in TABLE 5.11. The area computation as per shape file is in km^2 .Same is graphically shown as in FIGURE 5.20. The land use observed in 2017 is 38.72% residential, 21.77% transport and 12.21% mixed land use. The agricultural land available in 2011 was13.58%, which is consumed and only 3.95% agricultural land left in study area as observed in 2017 land use map. The vacant plots available was 6.66% in 2011, which is consumed and left only 1.69% in 2017. Vacant area is used for development.3% of area is used for recreational facilities in study area which is observed in 2017 as change from 2011.Vacant land is used for public gardens provided by AMC. Riverfront along Sabarmati River is observed as new development. On one side of study area there is river. Widening of road for exclusive lane for BRTS and flyovers are observed change in transport land use in 2017 compared to 2011.

Maximum Commercial, Institutional, Residential and Recreational land use area in Navrangpura in year 2017 in comparison to all other wards in study area. Maximum Agricultural land area left in Chandkheda in year 2017. Mixed land use is maximum in Chandkheda in comparison to all other wards in study area. Maximum industrial, transport and waterbody land use in 2017 is in Sabarmati in comparison to all other wards in study area. Vacant land is less available in study area. It is observed that vacant land is more at Vasna in comparison to all other wards in study area.

Residential land use is maximum in all wards in 2017 as per land use data analysis except Sabarmati. Sabarmati has more transport land use followed by residential land use. Sabarmati has land allocation for upgradation of Sabarmati railway station, BRTS exclusive lane, Sabarmati railway station overbridge and for Metro rail transit.

Details of land use for Paldi ward in 2017 is as shown in FIGURE 5.22.Details of land use for Vasna ward in 2017 is as shown in FIGURE 5.23.Likewise for all as shown in FIGURE 5.24 for Navrangpura, FIGURE 5.25 for SP Stadium, FIGURE 5.26 for Naranpura, FIGURE 5.27 for Nava Vadaj, FIGURE 5.28 for Sabarmati, FIGURE 5.29 for Ranip and FIGURE 5.30 for Chandkheda.

TABLE 5.11: Land Use Area in km^2 for Study Area in Year 2017

Land Use	Ward Name								
	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
Agriculture	0.00	0.54	0.00	0.00	0.69	0.01	0.01	0.18	0.73
Commercial	0.20	0.09	1.01	0.45	0.10	0.07	0.02	0.43	0.35
Industrial	0.12	0.08	0.18	0.25	0.05	0.09	0.19	0.72	0.14
Institutional	0.36	0.06	2.73	0.22	0.28	0.05	0.16	0.49	0.67
Mixed Use	0.12	0.47	0.19	0.79	0.22	0.24	0.63	1.65	2.48
Residential	3.06	2.28	4.95	1.66	2.63	1.81	4.38	2.52	3.78
Transport	1.37	0.92	2.33	1.22	0.79	0.80	2.54	3.11	2.03
Vacant	0.04	0.23	0.13	0.14	0.06	0.00	0.00	0.03	0.10
Waterbody	0.16	0.54	0.12	0.00	0.00	0.01	0.04	1.10	0.74
Recreational	0.22	0.33	0.49	0.35	0.10	0.07	0.15	0.30	0.45

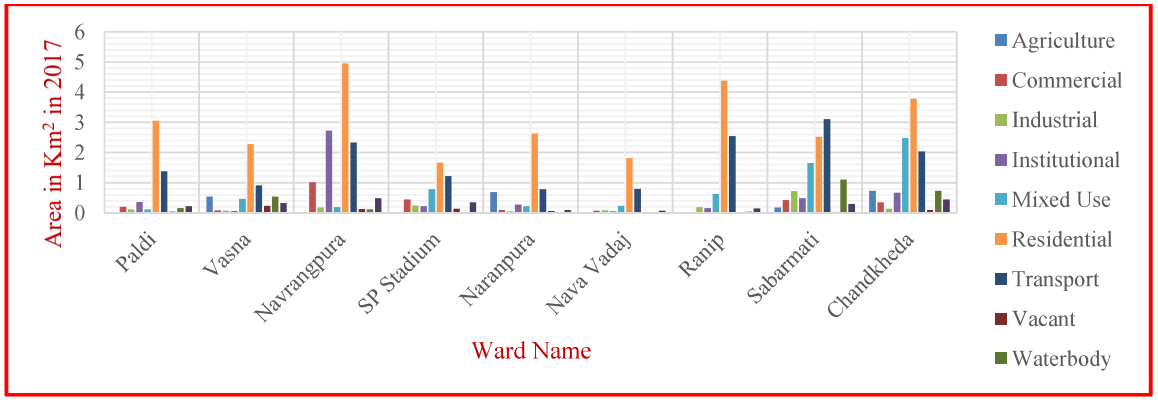

FIGURE 5.20: Land Use Area in km^2 for Study Area in Year 2017

Ward wise land use map is as shown in FIGURE 5.21 below for the year 2017.

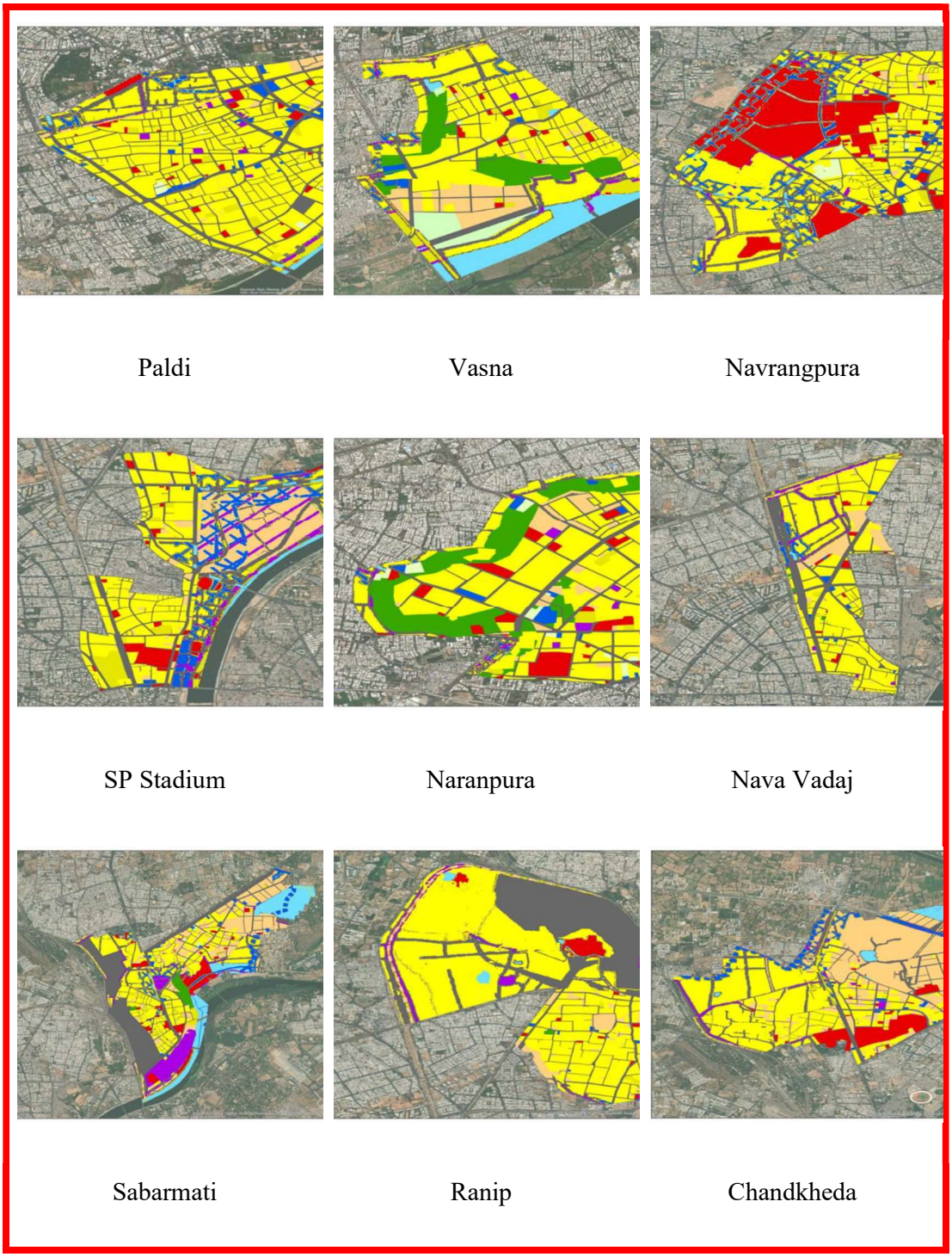

FIGURE 5.21: Land Use Map of 9 Wards of West Zone Year 2017

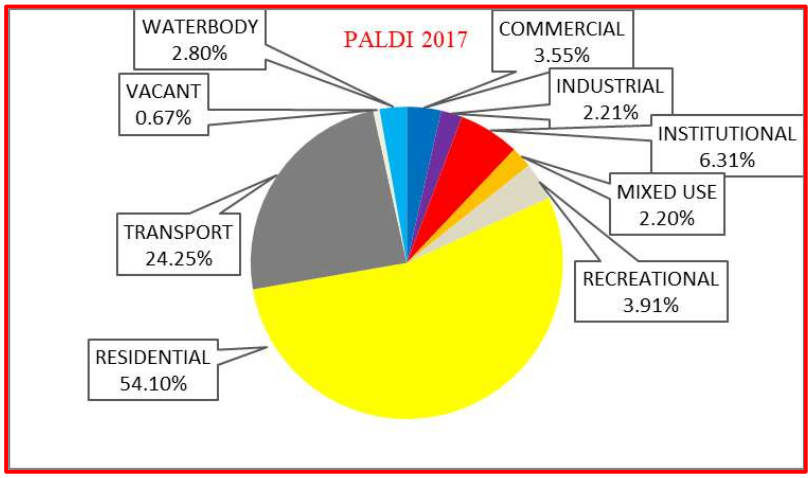

FIGURE 5.22: Land Use for Paldi Year 2017

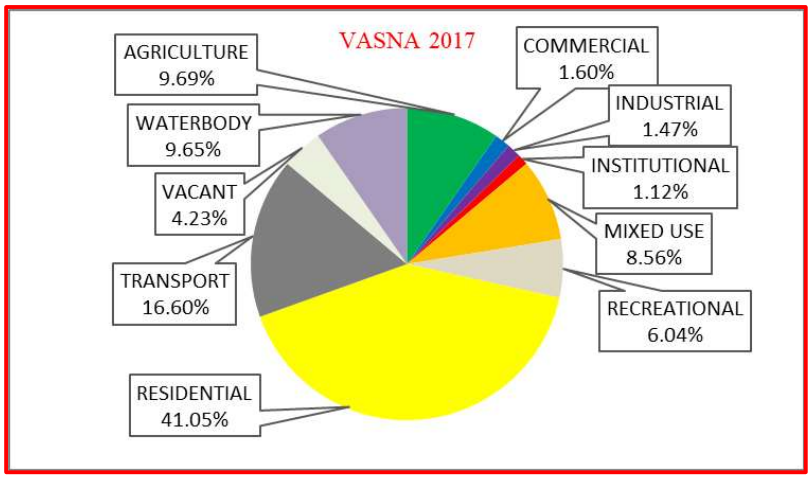

FIGURE 5.23: Land Use for Vasna Year 2017

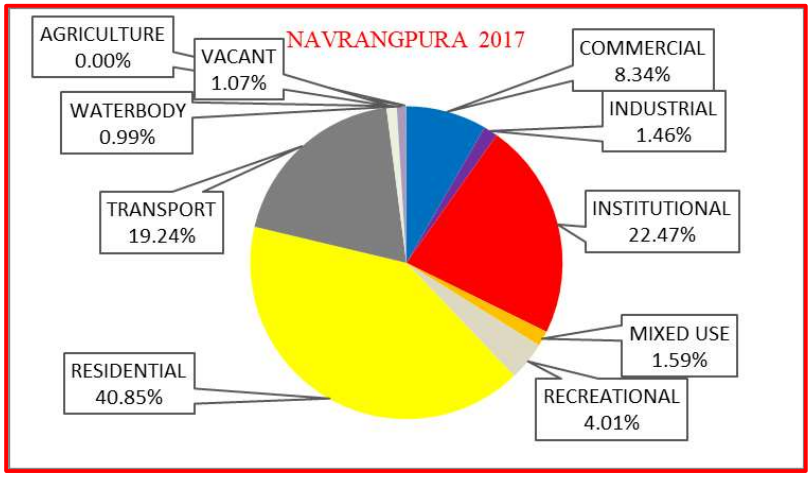

FIGURE 5.24: Land Use for Navrangpura Year 2017

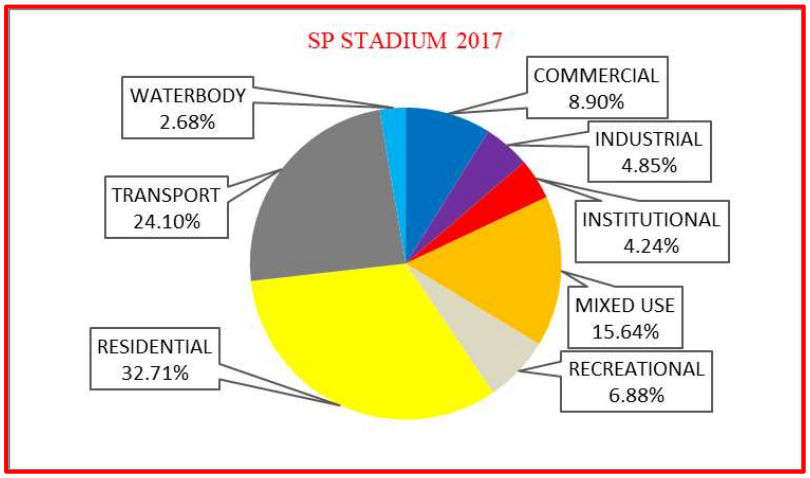

FIGURE 5.25: Land Use for SP Stadium Year 2017

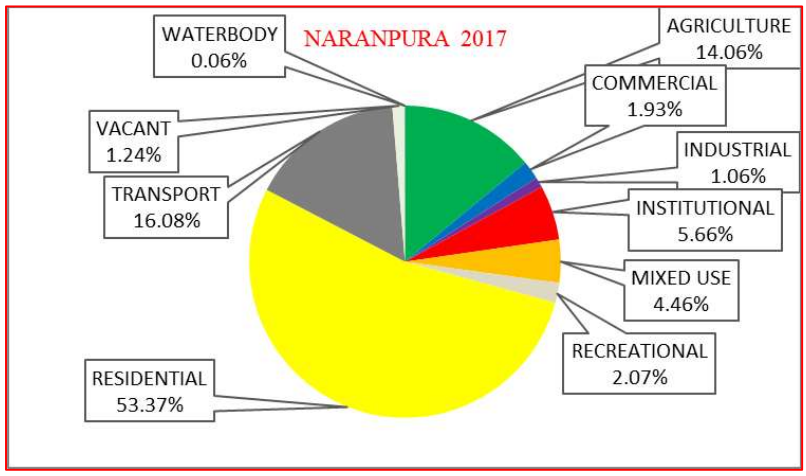

FIGURE 5.26: Land Use for Naranpura Year 2017

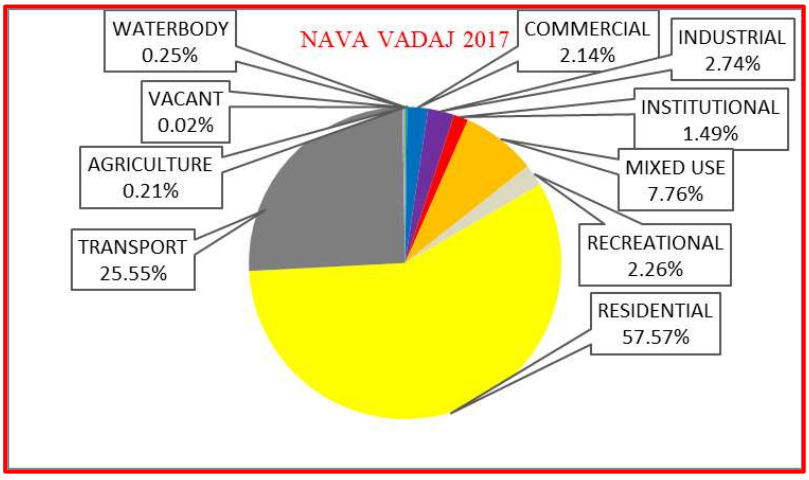

FIGURE 5.27: Land Use for Nava Vadaj Year 2017

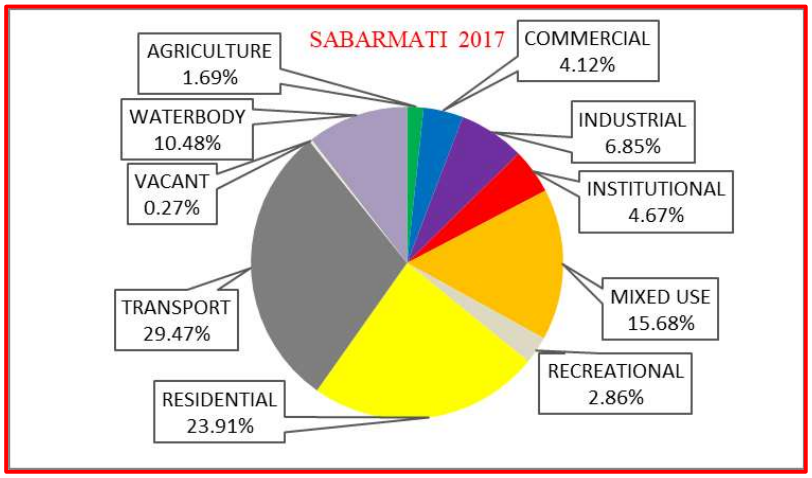

FIGURE 5.28: Land Use for Sabarmati Year 2017

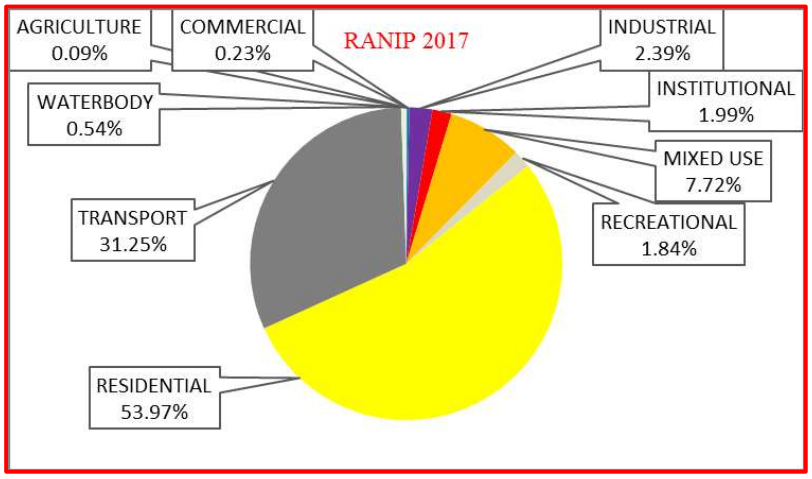

FIGURE 5.29: Land Use for Ranip Year 2017

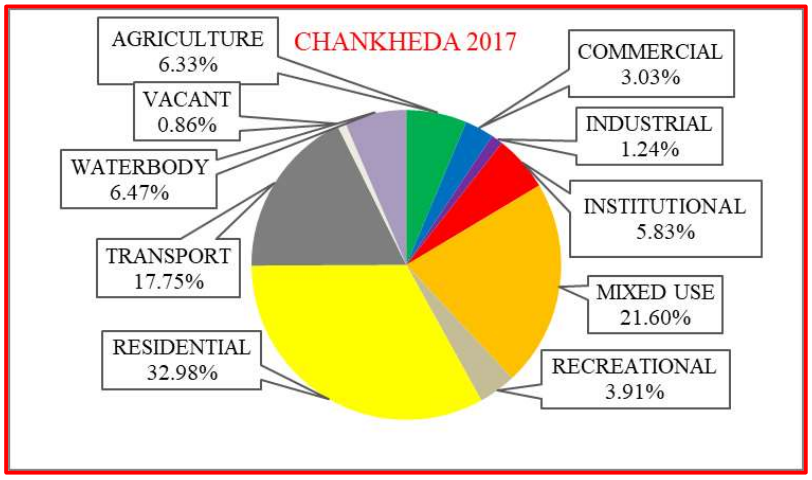

FIGURE 5.30: Land Use for Chandkheda Year 2017

5.3.3 Change in Land Use

For digitization of boundaries Google earth is also used as standard reference at some locations for verification of land use. The boundaries of each ward are taken same for 2011 and 2017. Area computed by shape file is verified with the area of each ward given by AMC on website. The change in land use in study area is analysed ward wise and as per types of land use. Various land use in 2011 is compared with land use in 2017.Change is indicated by % of land use in all the 9 wards of West zone, Ahmedabad.

FIGURE 5.31 Shows ward wise agriculture area in % of the total area in respective ward. It shows change observed in 2017 with respect to particular land use in 2011.Agriculture land use is decreasing. Change in vacant land is as shown in FIGURE 5.32. It is expressed in percentage of total ward area. There is no land available in Nava Vadaj, Navrangpura and Pladi for agricultural land use.

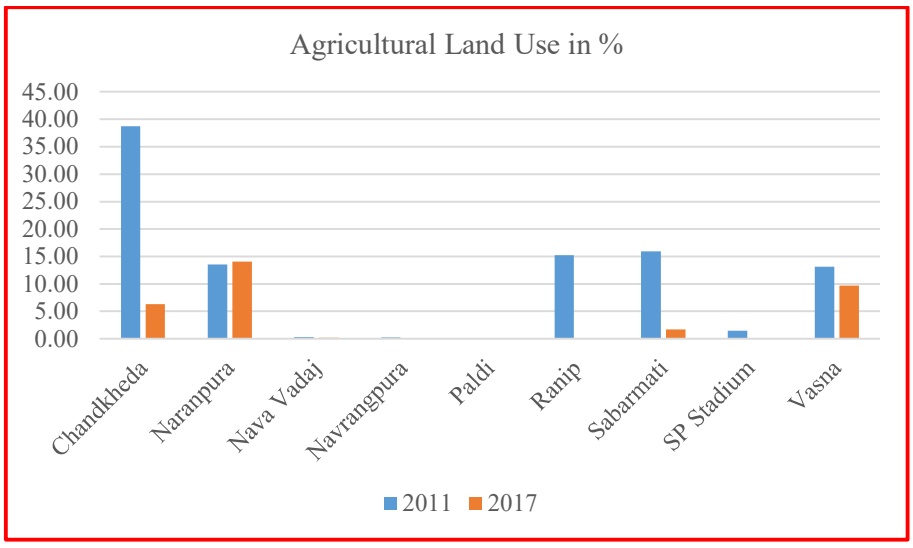

FIGURE 5.31: Change in Agriculture Land Use

There is change in vacant land in Chandkheda due to decrease in agricultural land use as shown in FIGURE 5.31. The policy decision taken by government agency to accommodate population and their demand for housing. Chandkheda is late under development compared to other wards in West zone. By Non-Agricultural process land is introduced for development.

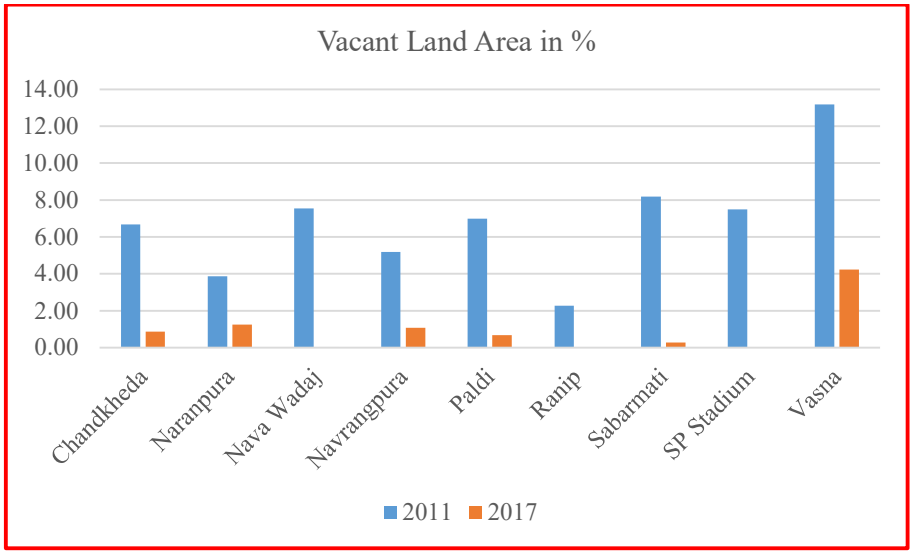

FIGURE 5.32: Change in Vacant Land Area

Change in residential land use is as shown in FIGURE 5.33.Change in transport land use is as shown in FIGURE 5.34. Land use parameters to develop LUTI model is area in km^2. Residential land use area is more important to accommodate increase in population. Population depends highly on transport facilities to perform their daily activities. Increase in population demands more transportation facilities. There is increase in transport land use due to increase in population.

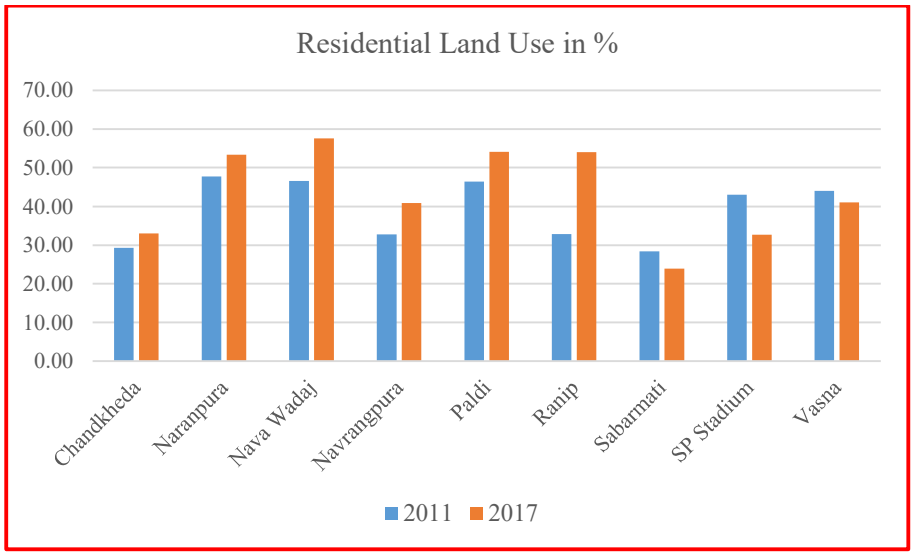

FIGURE 5.33: Change in Residential Land Use

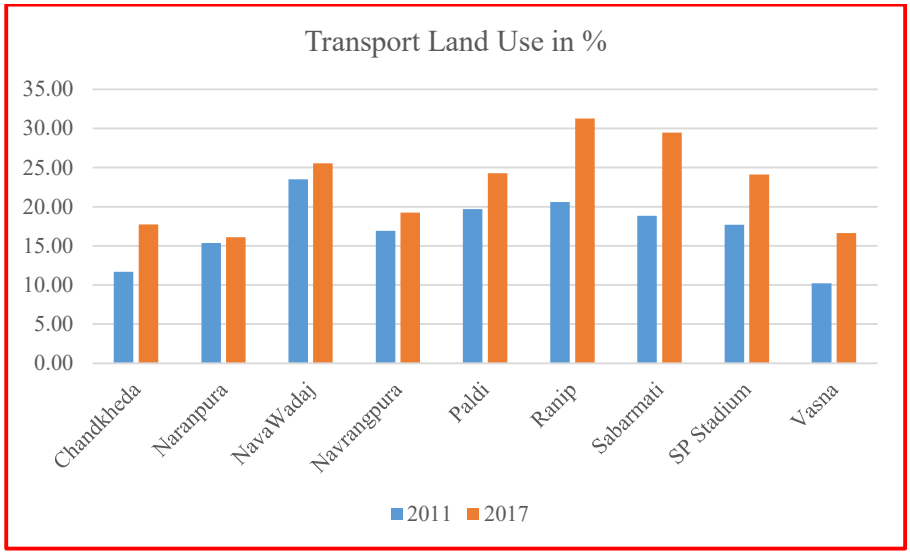

FIGURE 5.34: Change in Transport Land Use

Mixed land use in urban area is very common type of development. It is combination of commercial and residential land use in vertical growth type of development. There are shops & offices on ground floor and lower floors and dwelling units like flats in upper floors. Bank and hospital like facilities on lower floors and flats on upper floor in multi-story buildings. Change in mixed land use is as shown in FIGURE 5.35.

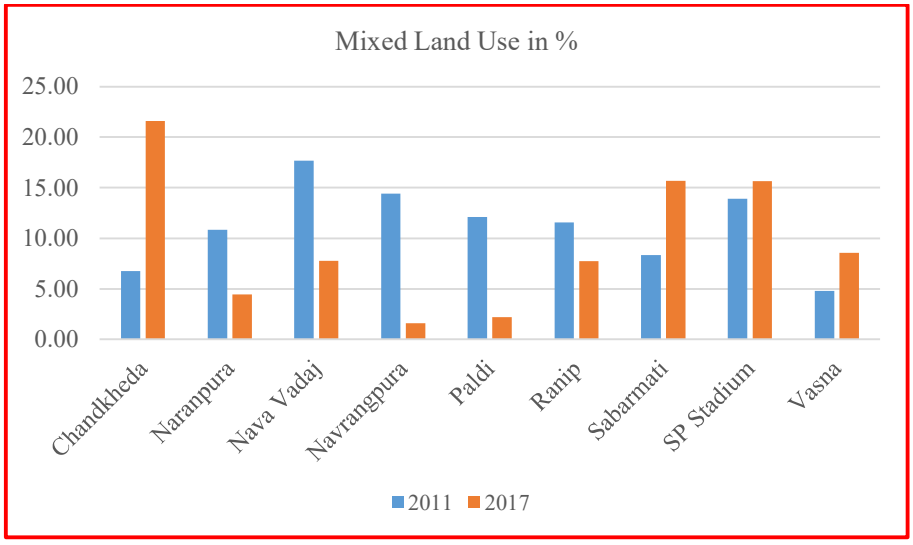

FIGURE 5.35: Change in Mixed Land Use

Commercial land use change is as shown in FIGURE 5.36. Markets, Shops and offices for job & business demands commercial land use. They are economic activity center for urban area.

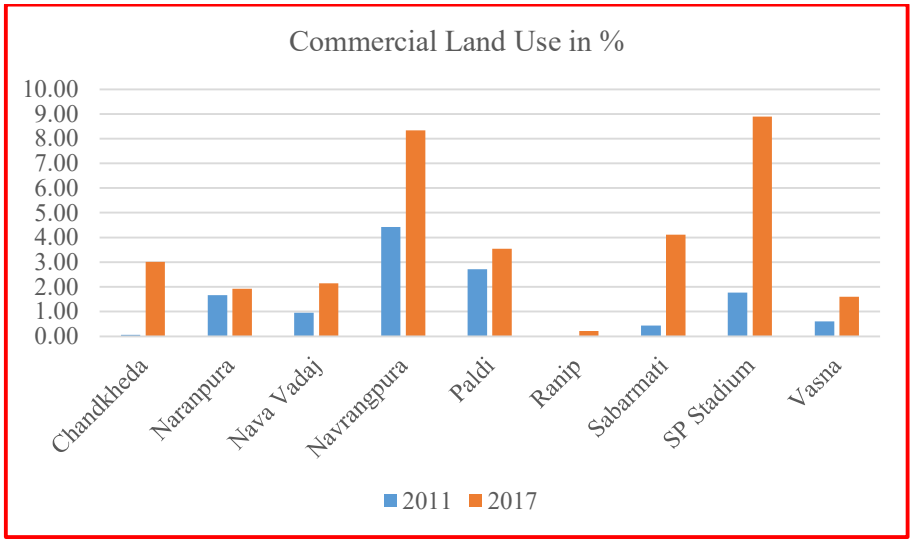

FIGURE 5.36: Change in Commercial Land Use

School, college and university are educational institutes. In study area at Navrangpura ward there are prominent colleges and university, which attracts students from nation and abroad. It demands for accommodation and there is demand of residential units, hostel, mess, hotels, restaurants etc. It causes transportation demand to perform study and other activity. There is demand for library, gymnasium, playground, parks, swimming pool like institutional and recreational land use. Change in institutional land use is as shown in FIGURE 5.37.

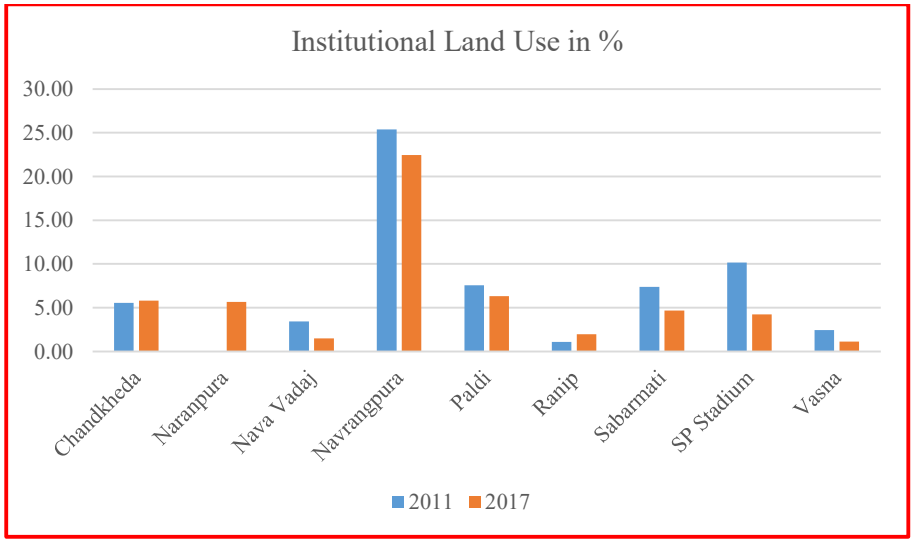

FIGURE 5.37: Change in Institutional Land Use

Industries are magnet to population in search of income by job or business. It creates chain of supplier and distributor. It demands for labour, helper, supervisor, engineer, accountant, maintenance staff, security staff etc. Industries are employment generator in urban area. Small to large scale production and manufacturing units cause migration of population from surroundings. Change in industrial land use is as shown in FIGURE 5.38.

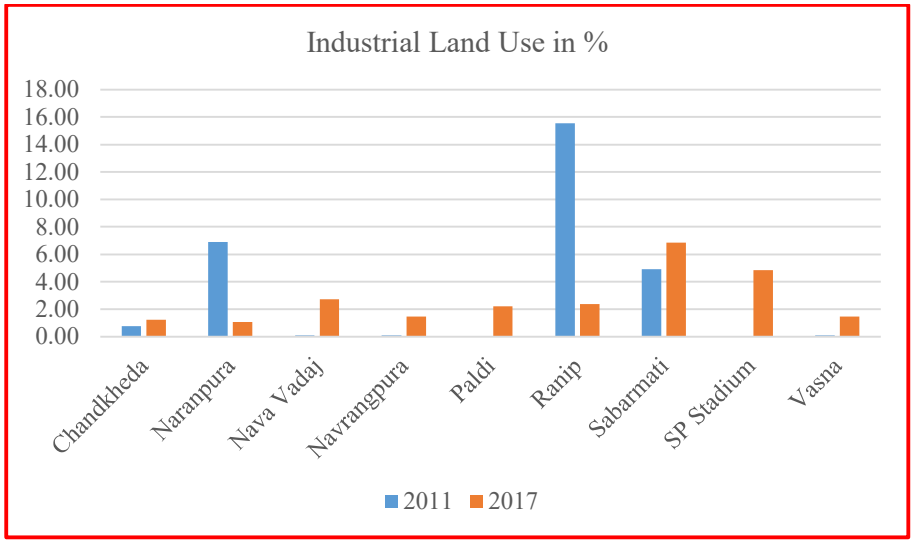

FIGURE 5.38: Change in Industrial Land Use

Pond, lake and river in study area is considered in waterbody area computation. Change in waterbody land use is as shown in FIGURE 5.39.There is no waterbody in Naranpura ward.There is increase in waterbody in Sabarmati ward area.

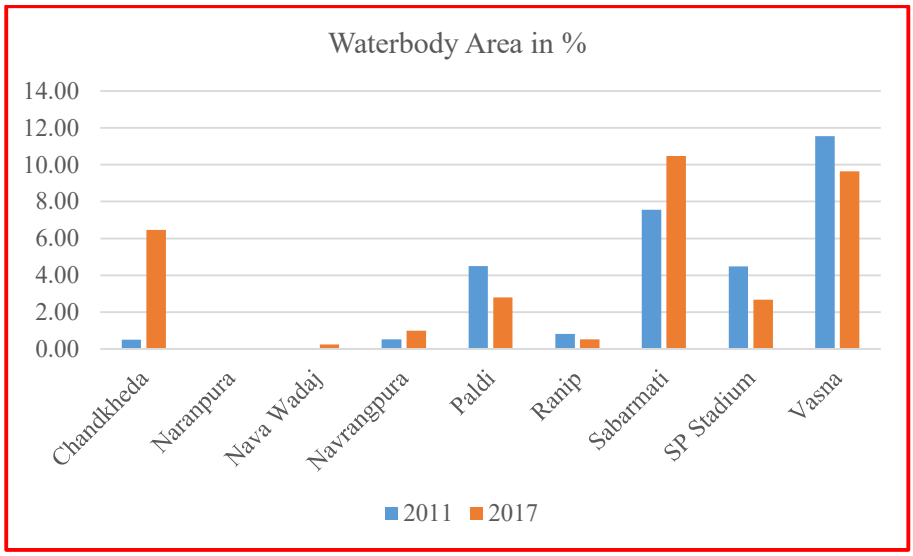

FIGURE 5.39: Change in Waterbody Area

Recreational land use in each ward of west zone in 2017 is provided. In land use map 2011, such land use was not considered. It is not observed in basic map provided by authority. Recreational land use considers parks, playground, swimming pool, sports complex, river front, multiplex theatre, gymnasium etc.

5.4 Trip Rate Estimation

Trip rate estimation is carried out based on data collection by HIS. Daily produced trips from HH are dependent variable. Selecting independent variable for the trip rate calculation are as below.

1- Total number of persons living in the household (HH)

2- Number of school/college going person (children) in the HH

3- Number of employed person in the HH

4- Vehicle ownership or number of vehicles with family in household

5-Income of family

Variables listed as above were first been analysed using Pearson correlation analysis. Results as shown in Appendix-C**.** For ungrouped variables best effective variable is Family size with high correlation with number of trips produced per HH which indicate high correlation with dependent variable. This correlation is significant at 95% confidence interval. Number of School/college going children in HH has second best correlation with dependent variable. Number of employed persons in household is at third number in correlation with dependent variable. Vehicle ownership is fourth and household income is fifth. It indicates that variable is comparatively less correlated with dependent variables. Family income in EWS, LIG, MIG, HIG is not considered in CCA and regression model development. Each variable is categorised further in 3 groups. Grouping of variables finalised, which are independent variables as shown in TABLE 5.12 below. Pearson test & ANOVA results for selected grouped variables are as shown in Appendix-C. Group is as per prevailing socio-economic scenario and literature review. By using CCA Trip rate is calculated for two cases as below. HIS data is entered in excel sheet and opened in SPSS for group wise category analysis.

Case-I: Number of persons in HH, School/college going person, Employed Person

Case-II: Number of persons in HH, School/college going person, Vehicle Ownership

TABLE 5.12: Grouping of variables

Variable Name	Grouping	Code	Categories
Family Size-Number of persons in HH	1-3	1	One, Two, three Person (1,2,3)
		2	Four, Five, Six Person (4,5,6)
		3	Seven or more Person (≥ 7)
School/college going Children/persons in HH	1-3	1	Zero (0)
		2	One (1)
		3	Two or more (≥ 2)
Employed Person	1-3	1	Zero Employed (0)
		2	One Employed (1)
		3	Two or more Employed (≥ 2)
Vehicle ownership	1-3	1	Zero or One Vehicle (≤ 1)
		2	Two Vehicles (2)
		3	Three or more Vehicles (≥ 3)

Trip rate matrix is developed by dividing number of trips produced from households of particular category to the number of households of that category. For three independent variables categories for Case-I number of households in each category are shown in TABLE 5.13. Cell value is number of households.

TABLE 5.13: Number of HHs for Case-I

Employed person in HH	School/college going children in HH	Family Size			Total HHs
		1,2,3	4,5,6	≥ 7	
0	0	25	1	0	26
	1	9	5	0	14
	≥ 2	1	2	0	3
1	0	205	43	2	250
	1	262	148	1	411
	≥ 2	10	340	3	353
≥ 2	0	103	168	16	287
	1	26	169	22	217
	≥ 2	0	98	37	135
	Total HHs	641	974	81	1696

There are empty cells occur for household size seven or more, employed person zero and some cells have very less observation. Number of trips produced in each category are shown in TABLE 5.14.Cell value is number of trips.

TABLE 5.14: Number of Trips for Case-I

Employed person in HH	School/college going children in HH	Family Size			Total Trips
		1,2,3	4,5,6	≥ 7	
0	0	31	2	0	33
	1	14	8	0	22
	≥ 2	2	4	0	6
1	0	289	64	2	355
	1	597	352	2	951
	≥ 2	30	1163	13	1206
≥ 2	0	244	486	58	788
	1	81	590	103	774
	≥ 2	0	419	208	627
Total Trips		1288	3088	386	4762

There are 974 Households with family size (4, 5, 6) which is more than other family sizes. Households with two or more employed person are more than other employed categories. Households with one school/college going children are more than other categories and household. Household with family size (4, 5, 6), Number of school /college going children two or more and number of employed person category produced majority of the trips. Household with Family size four, five and six produced 64% of total trips. Household with two employed persons produced 52% of total trips. Household with Zero, one and two or more school/college going children produced 24.7%, 36.7% and 38.6% trips respectively.

TABLE 5.15 shows conventional cross classification (CCA) trip rate matrix. It is a result of dividing number of trips (TABLE 5.14) by Number of households (TABLE 5.13) of respective categories. Cell value is trip rate. There are some cells with zero trip rates which is due to less observation or not available for those particular categories.

TABLE 5.15: Trip Rate for Case-I

Employed persons in HH	School/college going children in HH	Family Size 3		
		1,2,3	4,5,6	≥ 7
0	0	1.24	2.00	0.00
	1	1.56	1.60	0.00
	≥ 2	2.00	2.00	0.00
1	0	1.41	1.49	1.00
	1	2.28	2.38	2.00
	≥ 2	3.00	3.42	4.33
≥ 2	0	2.37	2.89	3.63
	1	3.12	3.49	4.68
	≥ 2	0.00	4.28	5.62

Result shows that trip rate is high for household with family size seven or more. Trips rate of families with two or more school/college going children are higher than families with zero or one children. Highest trip rate is for the categories family size (seven or more), number of school/college going children (two or more) and employed person (two or more).

Number of households in each category as per Case-II: Family size, School/college going children, Vehicle ownership are shown in below. Cell values is number of households.

TABLE 5.16: Number of HHs for Case-II

Vehicle Ownership	School/college going children	Family Size 3			Total HHs
		1,2,3	4,5,6	≥ 7	
≤1	0	198	55	2	255
	1	116	79	2	197
	≥ 2	3	121	2	126
2	0	100	63	7	170
	1	127	111	7	245
	≥ 2	7	177	11	195
≥3	0	35	94	8	137
	1	54	132	14	200
	≥ 2	1	142	27	170
	Total HHs	641	974	80	1695

There are 42% of total households has three or more vehicle ownership, 33% of households have two vehicles and 25% households have zero or one vehicle. There is no cell with zero value because observations are enough for the categories of Case II. Number of trips produced from households of each category are shown in TABLE 5.17 below. Cell value is produced trips in number.

TABLE 5.17: Number of Trips for Case-II

Vehicle Ownership	School/college going children	Family Size			Total Trips
		1,2,3	4,5,6	≥ 7	
≤1	0	300	124	8	432
	1	258	191	7	456
	≥ 2	6	414	10	430
2	0	188	162	27	377
	1	291	335	36	662
	≥ 2	22	634	54	710
≥3	0	76	266	24	366
	1	143	424	62	629
	≥ 2	4	538	157	699
	Total Trips	1288	3088	385	4761

From the TABLE 5.18, it is found that 37% of trips are produced from households which have two vehicle ownership, 36% of trips are produced from household which have three or more vehicle ownership and 27% of trips produced from households which have zero or one vehicle ownership. Maximum trips produced from households which has family size (4,5,6), number of school/college going children (two or more) and vehicle ownership (two).

TABLE 5.18 shows conventional cross classification (CCA) trip rate matrix. Cell value is trip rate. It is a result of dividing number of trips (TABLE 5.17) by Number of household (TABLE 5.16) of respective categories.

TABLE 5.18: Trip Rate for Case-II

Vehicle Ownership	School/college going children	Family Size		
		1,2,3	4,5,6	≥ 7
≤ 1	0	1.52	2.25	4.00
	1	2.22	2.42	3.50
	≥ 2	2.00	3.42	5.00
2	0	1.88	2.57	3.86
	1	2.29	3.02	5.14
	≥ 2	3.14	3.58	4.91
≥3	0	2.17	2.83	3.00
	1	2.65	3.21	4.43
	≥ 2	4.00	3.79	5.81

From TABLE 5.18 that trip rate is high in households which has family size seven or more. Average trip rate is more for households which have two vehicle ownership. Maximum trip rate 5.81 is for household with family size (seven or more), vehicle ownership (three or more) and number of school/college going children (two or more).

Income is not considered as independent variable to estimate trip rate. Trip rate is helpful to estimate produced trips for future if family size is known. As per increase in population by considering average family size, one is able to derive number of households required.

The summary of total produced trips along with number of surveyed households is as shown in TABLE 5.19 below. The number of persons in family in surveyed households is also shown ward wise. As per sample size number of households are surveyed ward wise in study area. The trips produced from home (origin is home) is considered for analysis. The trips for the purpose of work and study are considered in analysis.

Based upon HIS sample size data average family size is 4.09 persons, average produced trips are 2.51 numbers and average vehicle ownership is 2.37 vehicles.Total vehicles include cycle, 2W and 4W in HH with Family.

TABLE 5.19: Details of Surveyed Households

Name of Ward	Number of HHs Surveyed	Number of Persons in Surveyed HHs	Number of Produced Trips in Surveyed HHs	Number of Vehicles in Surveyed HHs
Paldi	346	1346	854	861
Vasna	299	1150	746	750
Navrangpura	150	620	372	361
SP Stadium	280	1158	687	727
Naranpura	347	1367	807	790
Nava Vadaj	192	818	532	468
Sabarmati	160	693	411	346
Ranip	335	1352	817	725
Chandkheda	324	1365	844	732
Total	2433	9869	6070	5760

5.5 Accessibility Index

As per method discussed in Chapter 4: Research Methodology Accessibility Index (AI) is calculated based upon interview conducted at SAPs in study area. The questionnaire is as in Appendix- B_1 and Appendix-B_2. The AI calculation for AMTS at SP Stadium ward is as shown in TABLE 5.22. Likewise for Paldi, Vasna, Navrangpura, Naranpura, Nava Vadaj, Sabarmati, Ranip and Chandkheda is calculated as shown in Appendix-D_1. AI calculation for BRTS at Chandkheda is as shown in TABLE 5.23. Likewise for Paldi, Vasna, Navrangpura, SP Stadium, Naranpura, Nava Vadaj, Sabarmati and Ranip is calculated as shown in Appendix-D_2.

Value of reliability of PT AMTS is taken as 2.5 and BRTS as 1. (Shah & Adhvaryu, 2016)BRTS is operating in exclusive lane hence, it has less chances of deviation from schedule. Whereas, AMTS is moving in heterogeneous traffic condition and facing problems of congestion and there are chances operational delay. Possibility of being late then schedule is frequent in case of AMTS bus.

TABLE 5.20: Boarding and Alighting data of BRTS SAPs

Sr.No.	SAP Name	Boarding	Alighting	Total
1.	Zundal Circle	5	0	5
2.	Sarthi Bungalows	5	0	5
3.	Chandkheda Gam	20	0	20
4.	Shivshaktinagar	3	0	3
5.	Jantanagar	9	1	10
6.	ONGC	5	1	5
7.	Visat	11	2	13
8.	Motera Cross Road	4	1	4
9.	Sabarmati Police Station	7	1	9
10.	Sabarmati Muncipal Swimming Pool	2	1	3
11.	Rathi Apartment	2	1	2
12.	Sabarmati Power House	3	2	4
13.	RTO	4	5	8
14.	Ranip Cross Road	6	6	12
15.	Bhavsar Hostel	4	3	7
16.	Akhbarnagar	9	2	10
17.	Pragatinagar	2	2	4
18.	Shashtrinagar	2	3	5
19.	Jaimangal	2	2	4
20.	Sola Cross Road	1	3	5
21.	Valinath Chowk	0	1	1
22.	Memnagar	1	8	9
23.	University	0	0	0
24.	Andhjan Mandal	1	9	10
25.	Himmatlal Park	1	2	2
26.	Shivranjani	3	15	18
27.	Jhansi ki Rani	2	1	3
28.	Nehrunagar	3	4	7
29.	L Colony	1	3	4
30.	Panjarapol	1	7	8
31.	Gulbai Tekra	0	3	3
32.	LD Engineering College	0	27	27
33.	Commerce Six Lane	0	0	0

Weight is given as per number of routes, frequency and boarding alighting survey conducted as SAPs. 0.5 and 1 value is given as weight.(Shah & Adhvaryu, 2016) The

boarding and alighting survey data for 33 BRTS Stops in study area is as shown in TABLE 5.20. The bus occupancy survey conducted during morning peak hours 8.00 am to 11.00 am is as shown in TABLE 5.21.Observations of bus occupancy carried out at SAPs for various route buses.This is used for determination of weight. 0.5 weight for 0 to 9 passengers, 0.75 for 10 to 19 and 1 for 20 to 29 is taken for BRTS SAPs. For AMTS Stops as per number of route buses coming at SAPs and their frequency is considered for weight. Weight 1 is given to maximum frequncy route and 0.5 is given for remaining.AMTS buses are comparatively crowded and there is in bus ticket issuing system.

TABLE 5.21: Bus Occupancy at BRTS SAPs

Sr.No.	SAP Name	Occupancy in Bus
1.	Zundal Circle	14
2.	Sarthi Bungalows	28
3.	Chandkheda Gam	85
4.	Shivshaktinagar	93
5.	Jantanagar	118
6.	ONGC	129
7.	Visat	156
8.	Motera Cross Road	164
9.	Sabarmati Police Station	182
10.	Sabarmati Muncipal Swimming Pool	186
11.	Rathi Apartment	188
12.	Sabarmati Power House	192
13.	RTO	188
14.	Ranip Cross Road	188
15.	Bhavsar Hostel	190
16.	Akhbarnagar	210
17.	Pragatinagar	210
18.	Shashtrinagar	207
19.	Jaimangal	208
20.	Sola Cross Road	202
21.	Valinath Chowk	200
22.	Memnagar	180
23.	University	180
24.	Andhjan Mandal	156
25.	Himmatlal Park	152
26.	Shivranjani	118
27.	Jhansi ki Rani	119
28.	Nehrunagar	116
29.	L Colony	108
30.	Panjarapol	90
31.	Gulbai Tekra	80
32.	LD Engineering College	0
33.	Commerce Six Lane	0

TABLE 5.22: AMTS Accessibility Index for SP Stadium

POI	SAP Name	Sr. No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
SP Stadium	R.T.O. Circle	1	13/1	3	0.5	5.02	10.00	2.5	12.50	17.52	1.71	0.86
		2	22	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		3	88	2	0.5	5.02	15.00	2.5	17.50	22.52	1.33	0.67
		4	202	1	0.5	5.02	30.00	2.5	32.50	37.52	0.80	0.40
		5	204	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		6	205	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		7	401	6	1	5.02	5.00	2.5	7.50	12.52	2.40	2.40
												5.81
	Shubhash Bridge Circle	1	13/1	3	0.5	5.00	10.00	2.5	12.50	17.50	1.71	0.86
		2	22	1.33	0.5	5.00	22.56	2.5	25.06	30.06	1.00	0.50
		3	88	2	0.5	5.00	15.00	2.5	17.50	22.50	1.33	0.67
		4	89-3S	1.5	0.5	5.00	20.00	2.5	22.50	27.50	1.09	0.55
		5	85-S	1.2	0.5	5.00	25.00	2.5	27.50	32.50	0.92	0.46
		6	202	1	0.5	5.00	30.00	2.5	32.50	37.50	0.80	0.40
		7	204	1.33	0.5	5.00	22.56	2.5	25.06	30.06	1.00	0.50
		8	401	6	1	5.00	5.00	2.5	7.50	12.50	2.40	2.40
												6.33
Total of all SAPs in SP Stadium												**12.14**

TABLE 5.23: BRTS Accessibility Index for Chandkheda

POI	SAP Name	ROUTE NO	f	W	WT	SWT	k	AWT	TAT	EDF	AI
Chandkheda	Zundal Circle	4	8	0.5	4.83	3.75	1	4.75	9.58	3.13	1.57
		7	5	0.5	4.83	6.00	1	7.00	11.83	2.54	1.27
	Sarthi Bungalows	4	8	0.5	4.24	3.75	1	4.75	8.99	3.34	1.67
		7	5	0.5	4.24	6.00	1	7.00	11.24	2.67	1.33
	Chandkheda Gam	4	8	1	5.07	3.75	1	4.75	9.82	3.05	3.05
		7	5	1	5.07	6.00	1	7.00	12.07	2.49	2.49
	Shivshaktinagar	4	8	0.5	5.15	3.75	1	4.75	9.90	3.03	1.51
		7	5	0.5	5.15	6.00	1	7.00	12.15	2.47	1.23
	Jantanagar	4	8	0.75	4.51	3.75	1	4.75	9.26	3.24	2.43
		7	5	0.75	4.51	6.00	1	7.00	11.51	2.61	1.96
	ONGC	4	8	0.5	3.34	3.75	1	4.75	8.09	3.71	1.85
		7	5	0.5	3.34	6.00	1	7.00	10.34	2.90	1.45
	Total of all SAPs in Chandkheda										**21.81**

AI calculated for SAPs of Paldi ward is as shown in TABLE 5.24 below. AI calculated for all wards in tabular format is as shown in Appendix- D_3

TABLE 5.24: AI for Paldi Ward

Sr.No.	SAP/Stop Name	AI
1	Vikash Gruh	2.30
2	Niranjan Society	1.09
3	Sharda Nagar	2.30
4	Dharnidhar Society	2.30
5	Jalaram Mandir	6.15
6	Mahalakshmi Society	6.83
7	Mahalakshmi Rasta	2.27
8	Jain Merchant	10.14
9	Paldi	7.07
10	Paldi Turminus	4.33
11	Pritam Nagar	6.33
12	Arvind Sales	6.17
13	Congress Bhawan	6.17
14	V.S. Hospital	3.02
15	Madalpuar	4.59
16	Town Hall	4.59
17	Fateh Nagar	9.64
18	Viswakunj	2.64
19	Museum	10.27
20	Lavanya Society	3.46
21	Jivraj Mehta Hospital	3.46
22	Bakeri Medical	4.12
23	Bhatta	8.72
24	Anand Nagar	10.46
25	Malav Talav	3.73
	Total AMTS AI	**132.15**
B1	Chandranagar	9.09
B2	Anjali	9.09
B3	Dharnidhar	6.06
	Total BRTS AI	**24.24**
	Combined AI for Paldi	**156.39**

TABLE 5.22 shows computation method to arrive at AI of AMTS accessibility for SP Stadium ward. TABLE 5.23 shows computation method to arrive at AI of BRTS

accessibility for Chandkheda ward. TABLE 5.24 shows computation method to arrive at AI of AMTS and BRTS combined accessibility for Paldi ward.

Accessibility Index (AI) for all wards in study area is as shown in TABLE 5.25 below Combined accessibility at AMTS & BRTS SAPs for each ward is calculated.

TABLE 5.25: Accessibility Index

Ward Name	AMTS AI	BRTS AI	Combined AI
Paldi	132.15	24.24	156.39
Vasna	48.64	2.56	51.20
Navrangpura	94.55	76.91	171.46
SP Stadium	12.14	15.93	28.07
Naranpura	32.07	36.17	68.24
Nava Vadaj	41.79	10.97	52.76
Sabarmati	49.10	18.97	68.07
Ranip	67.27	10.31	77.58
Chandkheda	51.44	21.81	73.25

5.5.1 Public Transport Accessibility Level

PTAL is a measure of connectivity by public transport, which has been used in various planning processes in London for many years. For any selected place, PTAL suggests how well the place is connected to public transport services.(Gent & Symonds, 2005).Map colour choice is of Author as shown in TABLE 5.26. PTAL 0/1 is for Zero AI.

TABLE 5.26: Ward wise PTAL with Description as per AI

Ward Name	Total AI (AMTS+BRTS)	PTAL	Map Colour	Description
Paldi	156.42	6a		Excellent
Vasna	51.20	3		Moderate
Navrangpura	171.46	6b		Excellent
SP Stadium	28.07	2		Poor
Naranpura	68.24	4		Good
Nava Vadaj	52.76	3		Moderate
Sabarmati	68.07	4		Good
Ranip	77.58	5		Very Good
Chandkheda	73.25	5		Very Good

Accessibility is widely used to evaluate the level of service of urban transportation systems. However, with diverse land-use types, accessibility level varies and not all residents benefit equally from public transit.

Accessibility of wards prepared on colour map is as shown in FIGURE 5.40 below. Only SP Stadium has poor accessibility. There are a smaller number of SAPs. Paldi and Navrangpura has excellent accessibility. Frequency, routes and PT users are also more.

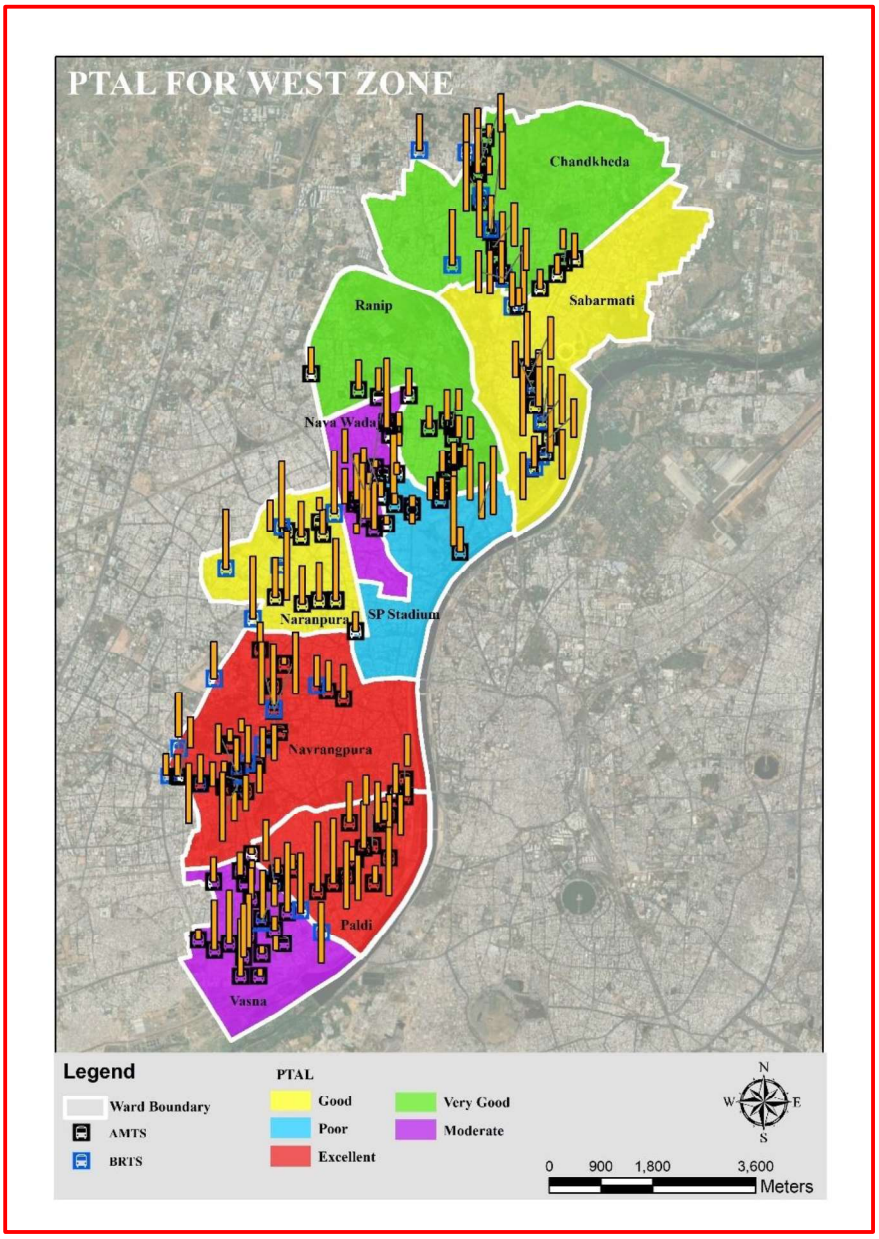

FIGURE 5.40: Accessibility of Wards

5.6 Real Estate Scenario

Land value and built-up price is affecting residential location choice. Agricultural land plots are converted to non agriculture plot for development. Builders purchase agriculture land and local authority sanction NA permission. With increase in population there is demand for land or built up for dwelling units. Authority declares new TPS with systematic land development plan. The area where there is good amenities and public transport facilities, people prefer it more. Near to transport corridor FSI is more and dwelling units also more in demand. The affordability for real estate property depends upon so many factors. Income and job security is more affecting factor. There is demand for rented house in urban area. Initially migrated population lives on rent. With time and increase in economy and stability of migrants, demand for land plot or own house generated. There is demand of industrial plots, shops and offices in urban area to start business. Location of rented and owned, shops and offices affect price of property. Residential land plot price rate scenario in study area is as shown in FIGURE 5.41.

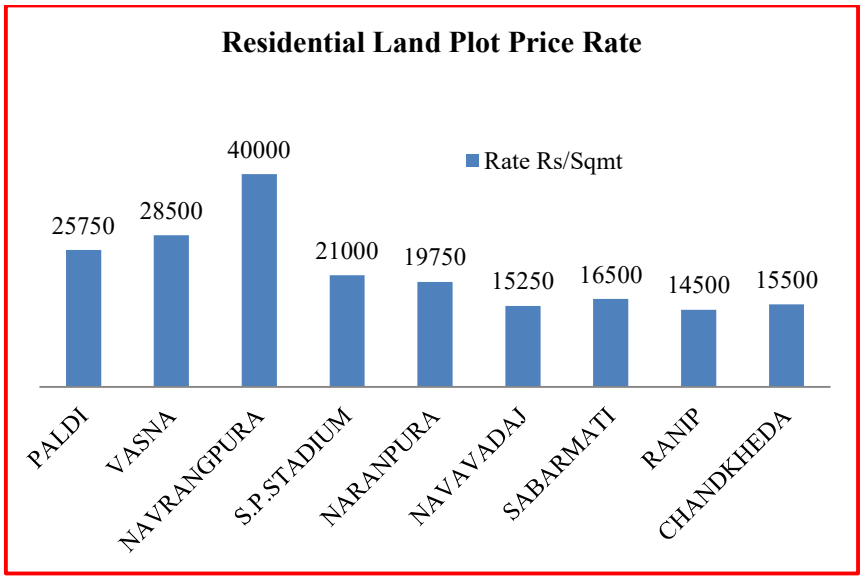

FIGURE 5.41: Residential Land Plot Price in Study Area

(*Jantri Rates, Ahmedabad,2011*, n.d.)

Availability of agricultural and vacant land in urban area, will allow increase in land use area. But, if it is not available, then it causes change in land use type and built up area. Authority increases FSI, to accommodate increased population. Old buildings are replaced

by new buildings as per new FSI for more area. Residential plots rate in Rs.per m^2 is highest in Navrangpura and lowest in Ranip. Paldi and Vasna have also high rate. Ranip and Chandkheda are new in comparison to other wards in study area. There is agricultural land available for future development. Navrangpura is an education hub for Ahmedabad and attracting students from Gujarat and other states. There is very good public transport system connectivity. Land and built up area for flats/Apartment in residential land use is as shown in FIGURE 5.42 below for the study area.

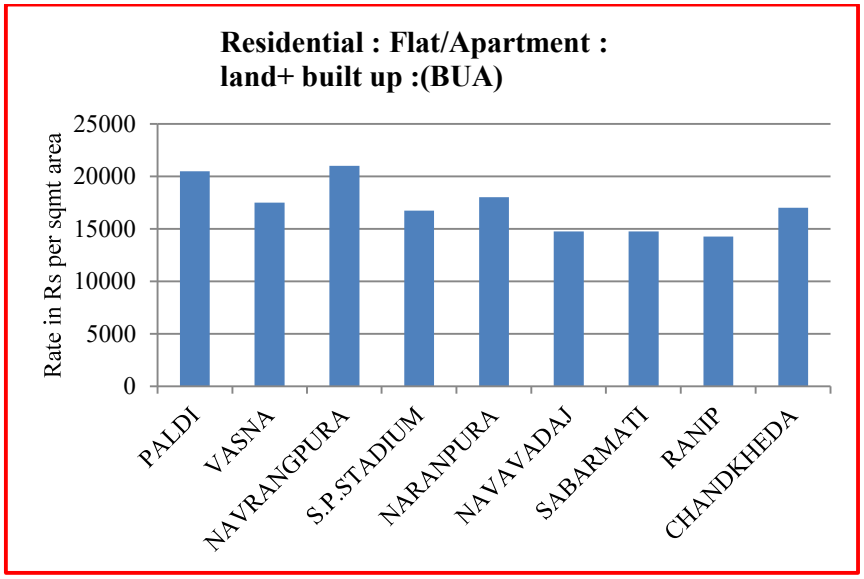

FIGURE 5.42: BUA rate for Flats/Apartment in Study Area

Land plus built-up rate in Rs. per m^2 is 14000 to 21000 as per Annual Statement of Rates, Gujarat State Government 2011. Rate is highest in Navrangpura and Paldi and lowest in Ranip. Industrial plots available at lower rate in Chandkheda, Ranip, Sabarmati and Vadaj. But it is observed that industries are shifting away from residential area. Small scale industries only there. Paying guest (PG) for students is more in Navrangpura, SP Stadium and Naranpura. Vasna, Nava Vadaj and Ranip have availability of small size flats at affordable rate.

Land and built-up area for offices and shops in commercial land use in study area is as shown in FIGURE 5.43 and FIGURE 5.44 along with rate for purchase. Rent is high, if purchase rate is high. Location of shops and offices also affected by number of factors such as type of business, connectivity to clients in vicinity, availability of parking space, living standards of life etc. Rate of Commercial property such as offices and shops are high in

Naranpura, Navrangpura and Paldi. The low rates observed in Ranip, Nava Vadaj and Chandkheda. Moderate rate in SP Stadium, Vasna and Sabarmati.

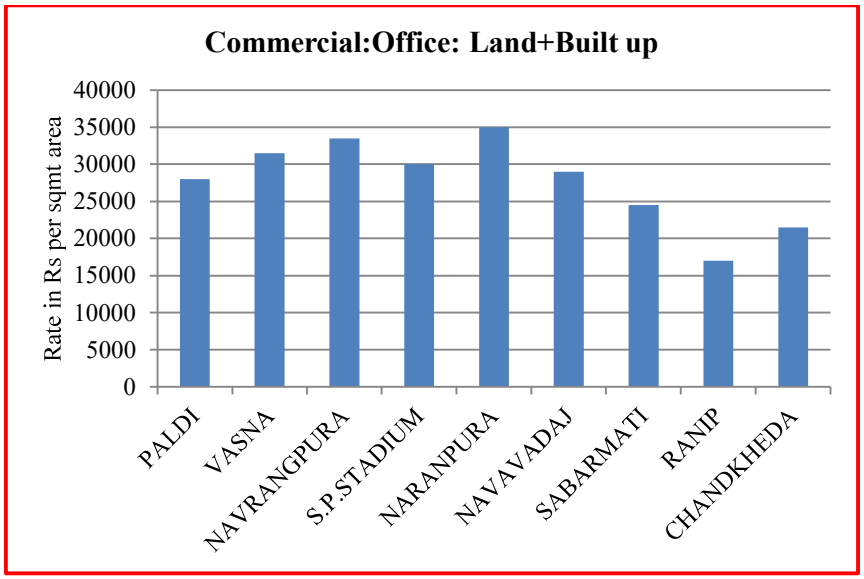

FIGURE 5.43: Rate for Office in Study Area

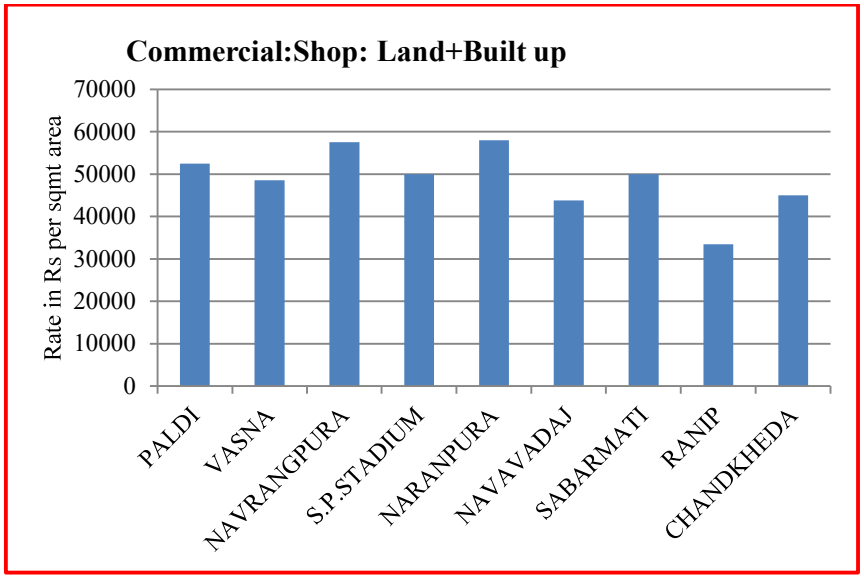

FIGURE 5.44: Rate for Shop in Study Area

Synchronized trend of real estate property of each ward in study area is displayed as shown in FIGURE 5.45.All the data related to real estate is referred from latest jantri collected from AMC office. (SOURCE: JANTRI 2011: Annual Statement of Rates, Gujarat

State Government, AMC website, https://garvi.gujarat.gov.in). Ward wise data extraction is summerised and charts prepared.

FIGURE 5.45: Real Estate Scenario

Flat/apartment rate are higher in Navrangpura, Paldi and Naranpura compared to others. Small size houses in economical range are available in Ranip,Sabarmati and Nava Vadaj .Vasna has new area as new Vasna (South Vasna) near National Highway. In Navrangpura luxurious flats with more parking and less density are available. Old bunglows with large plot size and abutting to road are converted to mixed land use with vertical growth. FSI also increased by AMC to accommodate migrating population. Day by day population density is increasing. FSI along BRTS corridor is increased by authority.

Rent in Rs. per month for flats and Apartments is in the range of Rs.14500 to Rs. 31000 and more observed in study area. (*Real Estate Scenario, Ahmedabad, 2018: Https://Www.Makaan.Com/*, n.d.) Navrangpura, Naranpura and Paldi have high rent. Vasna, Ranip and Chandkheda have low rent. SP Stadium, Nava Vadaj and Sabarmati have medium rent.

Vacant and agricultural land is more with Vasna in 2011 and yet some in 2017. Naranpura, Sabarmati, Ranip and Chandkheda has also more agricultural land in 2011 which is almost utilized till 2017 for development. Under development and grown successively have more diversity than already established area like Navrangpura, Vadaj, SP Stadium, Naranpura and Paldi. Vadaj is divided in Nava Vadaj and Juna Vadaj.

Rate per sqft for Villa is in range of Rs.2500 to Rs.15000 in January 2017 and highest in Navrangpura. Builder floor in range of Rs. 3500 to Rs.8000 per sqft in January 2017.Buy price of apartment in west zone in January 2017 is in range of 3200 to 7300 Rs.per sqft.

5.7 Population and Density Change

Population in 2011 and 2017, area in km^2 for study area is as shown in TABLE 5.27 below. By taking ratio of population with area, density is computed in number of persons per km^2 area in West zone of Ahmedabad. Average population density for west zone, Ahmedabad is 14,384 in 2011 and 20,568 in 2017.

TABLE 5.27: Population and Density in Study Area

Name of Ward	Area (km^2) 2011 & 2017	Population 2011	Density 2011	Population 2017	Density 2017
Paldi	5.58	83109	14894	117301	21022
Vasna	5.57	123116	22103	115936	20814
Navrangpura	11.98	55647	4645	121091	10108
SP Stadium	5.24	75051	14323	132625	25310
Naranpura	4.91	88032	17929	133456	27180
Nava Vadaj	3.17	77814	24547	130388	41132
Sabarmati	9.78	68566	7011	121060	12378
Ranip	7.55	120152	15914	124790	16528
Chandkheda	11.9	96266	8090	126607	10639

Source:(*Urban Profile 2017, Ward Patrak, Patrak-B*, 2021)

The highest population density is observed in Nava Vadaj in 2011(24,547) and 2017(41,132). The lowest population density is at Navrangpura in 2011 (4645) and 2017 (10,108) in West zone of Ahmedabad. Juna Vadaj is adjacent area of Nava Vadaj and Ambawadi is adjacent with Navrangpura. But they are in different zone. The facilities and parallel development are somewhat inseparable. At Navrangpura, Sabarmati and Chandkheda population density is less than average population density of West zone in Ahmedabad.

Change in population density is as shown in FIGURE 5.46.Vasna has new vasna area in vicinity for development. Density at Vasna decreased by 5.83% in 2017 in comparison to 2011. Village culture is yet observed there. Metro route, National Highway, APMC Market

is there and some land acquisition for that observed during study period. Navrangpura density is more than double (117.61%) in 2017 in comparison to 2011. PTAL for Navrangpura is excellent as observed in Table 5.26. Density change is high in Navrangpura as observed in Figure 5.46, Indicating land use interaction with transportation. Increase in density of Ranip is least, only 3.86% increase in 2017 from 2011.

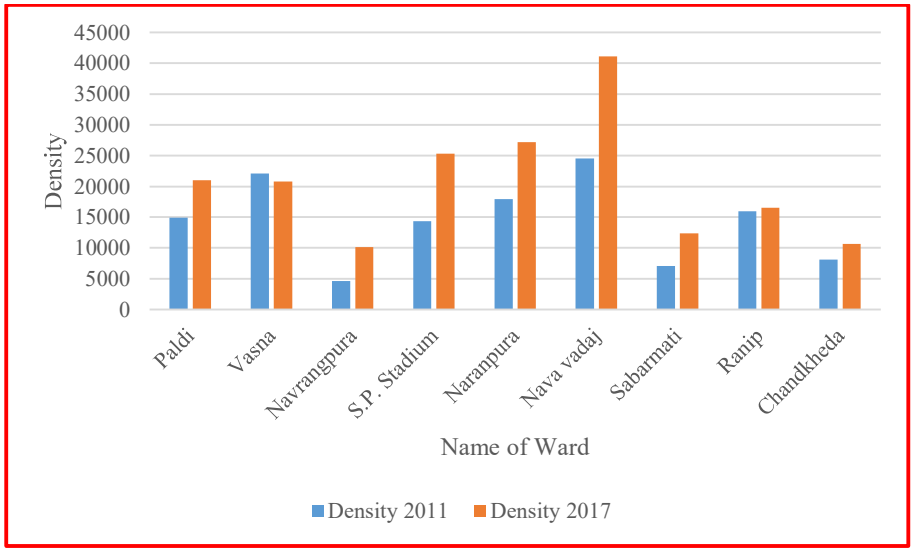

FIGURE 5.46: Change in Population Density

5.8 Closure

This chapter includes primary data collected by survey and secondary data from various sources. Data analysis of HIS and public transport user's survey along with sample size, graphs, pie charts and tables are included here. Details are summerised in tables and presented by figures in this chapter. Land use data for year 2011 and 2017 is analysed as per area and type of land use along with change in land use. Grouping of variables and trip rate estimation is included in data analysis.AI and PTAL is calculated and shown in colour map. Real estate scenario in study area is discussed. Population and density data collection and change by analysis is included in this chapter. The next chapter will discuss about model development, calibration and validation of model.

CHAPTER - 6

Trip Production and Land Use Model

Objective of the study is to develop LUTI model which shows interaction between land use and transport. Land-use–transportation (LUT) models belong to the mathematical family of models. The proposed system of interaction models based on regression techniques for land use and transport parameters. The regular produced trips from residential land use is transport parameter. A regression model provides a function that describes the relationship between one or more independent variables and a response, dependent, or target variable. Regression analysis is a reliable method of identifying which variables have impact on a topic of interest. The process of performing a regression allows one to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other.

6.1 Trip Production Model development

Analyzing the data collected from Home Interview Survey, the general trip Production model is developed using the multiple linear regression analysis. As discussed in chapter 4 independent and dependent variables are selected for model development. The dependent variable is trip produced per HH. Independent variables are Family Size (FS), Number of employed persons in HH (EMP), Number of persons going to school/college (SC) and number of vehicles owned by HH. i.e. Vehicle Ownership (VO). Grouping of variables are as per Pearson correlation and ANOVA test performed as shown in Appendix-C. 66.67% is training data to develop model and 33.33% is test data to validate model by looking to relationship among observed data and estimated data. Data sheet format is as shown in TABLE 6.1.

TABLE 6.1: HIS Data Sheet Sample

HH No.	Produced trips	Family Size (FS)	Number of Employed Person in HH (EMP)	Number of Children going to School/College (SC)	Vehicle Ownership (VO)
225	3	4	1	2	1
232	3	4	1	2	2
242	3	4	1	2	3
293	4	4	1	2	2
360	2	4	1	1	1
398	3	7	1	1	2
476	2	5	2	0	2
483	2	3	1	1	2
506	6	3	1	1	2
566	3	3	1	1	1
610	3	4	2	1	2
665	2	4	1	1	3
778	3	6	2	2	3

The identified variable set elements were tried to develop trip production models.

6.1.1 Trip Production Model 1

Using all the independent variables the regression model generated with regression technique is as shown in equation 6.1 with statistical parameters.

Produced Trips = 0.11 (Family Size) + 0.85 (Number of employed persons in family) + 0.81 (Number of school college going persons in family) + 0.08 (Number of vehicles in household) as shown in TABLE 6.2.

$$\mathbf{T_{HH} = 0.11\ FS + 0.85\ EMP + 0.81\ SC + 0.08\ VO} \quad \text{.....(6.1)}$$

$R^2 = 0.92$ Significance F = 0.00 RMSE = 0.85

TABLE 6.2: Trip Production Regression Model 1

SUMMARY OUTPUT							
Regression Statistics		Corelation Matrix					
Multiple R	0.96		*FS*	*EMP*	*SC*	*VO*	*Trips*
R Square	0.92	*FS*	1				
Adjusted R Square	0.92	*EMP*	0.42	1			
Standard Error	0.85	*SC*	0.46	-0.15	1		
Observations	1598	*VO*	0.34	0.23	0.24	1	
		Trips	0.51	0.39	0.51	0.29	1

ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	13805.01	3451.25	4738.47	0.00	
Residual	1594	1160.99	0.73			
Total	1598	14966				
	Coeffi.	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
FS	0.11	0.02	6.44	0.00	0.08	0.15
EMP	0.85	0.03	25.69	0.00	0.78	0.91
SC	0.81	0.03	27.74	0.00	0.75	0.87
VO	0.08	0.02	4.41	0.00	0.04	0.11

The outlier is observed in 3 data. Model is validated on 803 data. Model is developed on 1598 data. The validated model showing R^2 value 0.90 and indicating relationship between observed and predicted trips as shown in FIGURE 6.1. Developed model is validated.

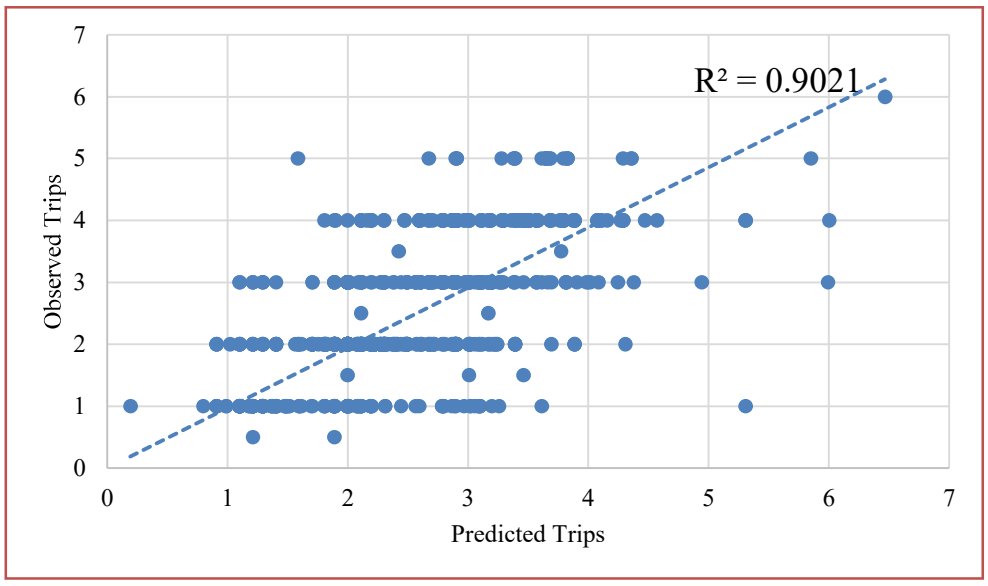

FIGURE 6.1: Validation of Trip Production Regression Model 1

6.1.2 Trip Production Model 2

Produced Trips = 0.16 (Family Size) + 0.84 (Number of employed persons in family) + 0.82 (Number of school college going persons in family)

T_{HH} = 0.16 FS + 0.84 EMP + 0.82 SC ……. ……. (6.2)

R^2 = 0.92 Significance F = 0.00 RMSE = 0.78

TABLE 6.3: Trip Production Regression Model 2

SUMMARY OUTPUT						
Regression Statistics		Corelation Matrix				
Multiple R	0.96		*FS*	*Emp*	*SC*	*Trips*
R Square	0.92	FS	1			
Adjusted R Square	0.92	EMP	0.43	1		
Standard Error	0.84	SC	0.45	-0.17	1	
Observations	1598	Trips	0.52	0.38	0.50	1

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	13661.56	4553.85	6436.67	0.00
Residual	1595	1128.44	0.71		
Total	1598	14790			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
FS	0.16	0.02	9.48	0.00	0.13	0.19
EMP	0.84	0.03	25.73	0.00	0.78	0.91
SC	0.82	0.03	27.90	0.00	0.77	0.88

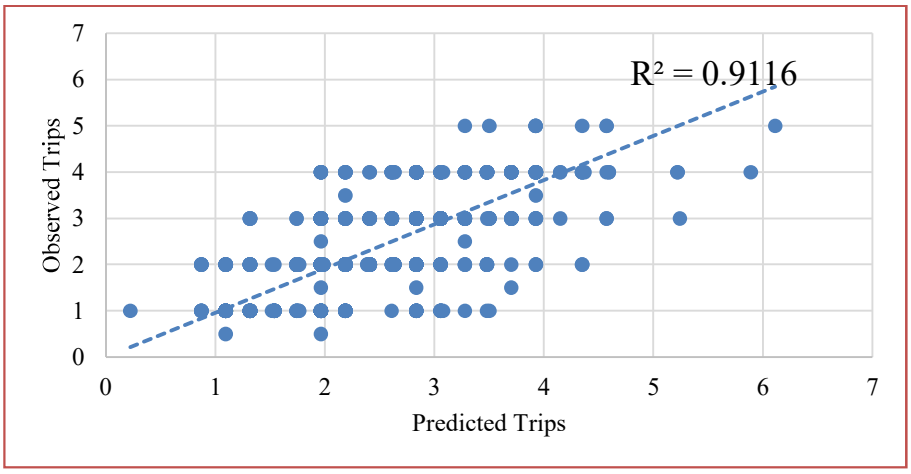

FIGURE 6.2: Validation of Trip Production Regression Model 2

6.1.3 Trip Production Model 3

Produced Trips = 0.44 (Family Size) + 0.48 (Number of school college going persons in family) + 0.17 (Number of vehicles in household)

$$T_{HH} = 0.44\ FS + 0.48\ SC + 0.17\ VO \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.3)$$

$R^2 = 0.90$ Significance F = 0.00 RMSE = 0.83

TABLE 6.4: Trip Production Regression Model 3

SUMMARY OUTPUT						
Regression Statistics		Corelation Matrix				
Multiple R	0.95		*FS*	*SC*	*VO*	*Trips*
R Square	0.90	FS	1			
Adjusted R Square	0.90	SC	0.45	1		
Standard Error	0.98	VO	0.34	0.23	1	
Observations	1600	Trips	0.52	0.50	0.29	1
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	13321.24	4440.41	4593.54	0.00	
Residual	1597	1543.76	0.97			
Total	1600	14865				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.00	#N/A	#N/A	#N/A	#N/A	#N/A
FS	0.44	0.01	29.85	0.00	0.42	0.47
SC	0.48	0.03	15.64	0.00	0.42	0.55
VO	0.17	0.02	8.30	0.00	0.13	0.21

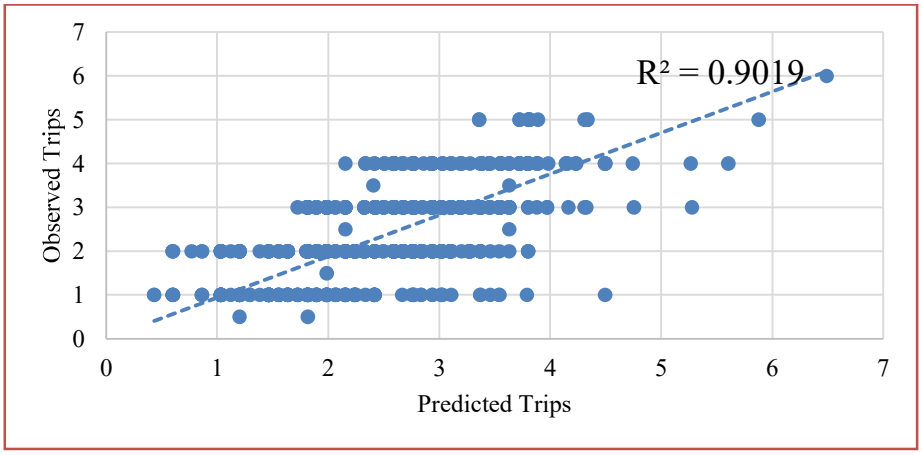

FIGURE 6.3: Validation of Trip Production Regression Model 3

Regression analysis between observed trips and predicted trips, and estimating RMSE, each analysis seems to be good enough. Anyone can be presented.

6.1.4 Univariate Regression Models

All the regression model are acceptable. Developed models are calibrated and validated. Univariate regression model showing relationship between produced trips (T_{FS}) and most effective independent variable family size (FS) as shown is as

T_{FS} = 0.64 x (FS) …… (6.4)

$R^{2`}$=0.86 Standard Error=1.11 RMSE=1.08

Second most effective variable school/college (SC) going children/persons in family. Regression among produced trips and SC going persons as:

T_{SC} = 1.77 x (SC) …… (6.5)

$R^{2`}$=0.68 Standard Error=1.69 RMSE=1.69

Third best corelated variable is number of employed persons in family. Regression among produced trips and employed persons as:

T_{EMP} = 1.60 x (EMP) …… …… (6.6)

$R^{2`}$=0.78 Standard Error=1.41 RMSE=1.76

Forth effective variable is vehicle ownership with family. Regression among produced trips and number of vehicles in family as:

T_{VO} = 0.97 x (VO) …… …… (6.7)

$R^{2`}$=0.75 Standard Error=1.50 RMSE=1.50

The plots developed for predicted trips and observed trips are as shown in FIGURE 6.4,FIGURE 6.5,FIGURE 6.6 and FIGURE 6.7. X axis is number of HHs surveyed as per sample size. Outlier is removed from 2423 HH data. Observations are 2401.

Total trips observed in HIS is 13035 by considering home based trips from residential land use. Home based trips have either origin or destination is home. There are 6518 produced trips originating from HH. The surveyed HH have 2479 SC going persons,

3484 employed persons and 5682 number of vehicles in family. Total persons in family are 6500.Univariate models are not so effective for prediction, as only one parameter is not always sufficient to produce trips. It is useful for Instantaneous prediction of trips at a glance. There is variation in results obtained by surveyed and predicted trips as per univariate model.

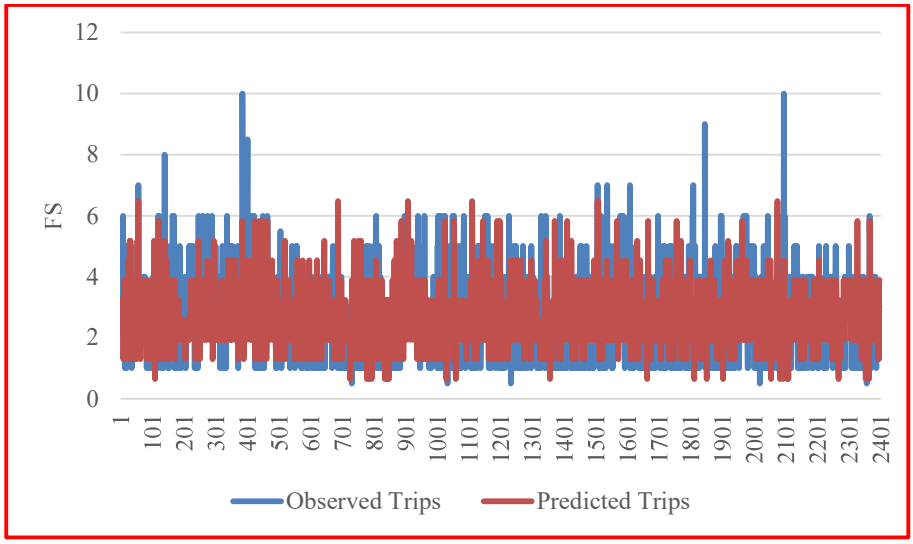

FIGURE 6.4: Observed and Predicted Trips (FS)

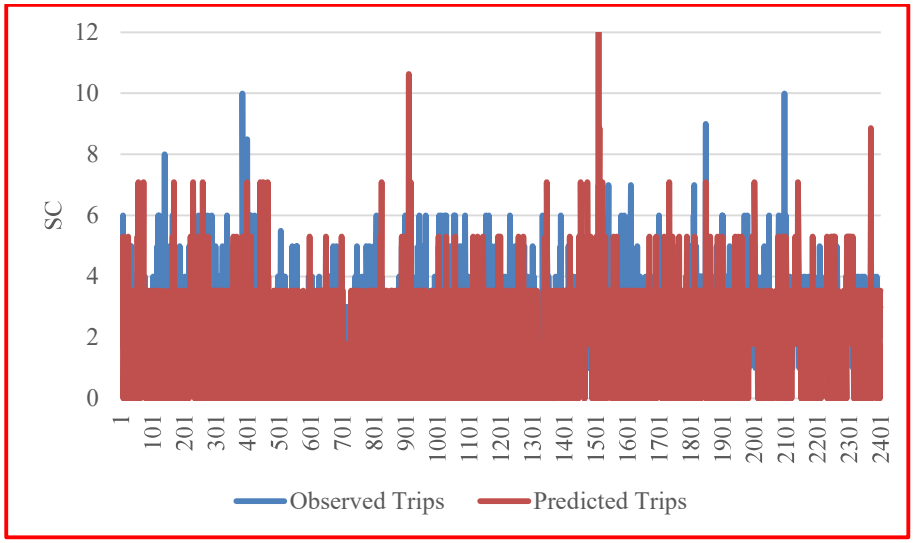

FIGURE 6.5: Observed and Predicted Trips (SC)

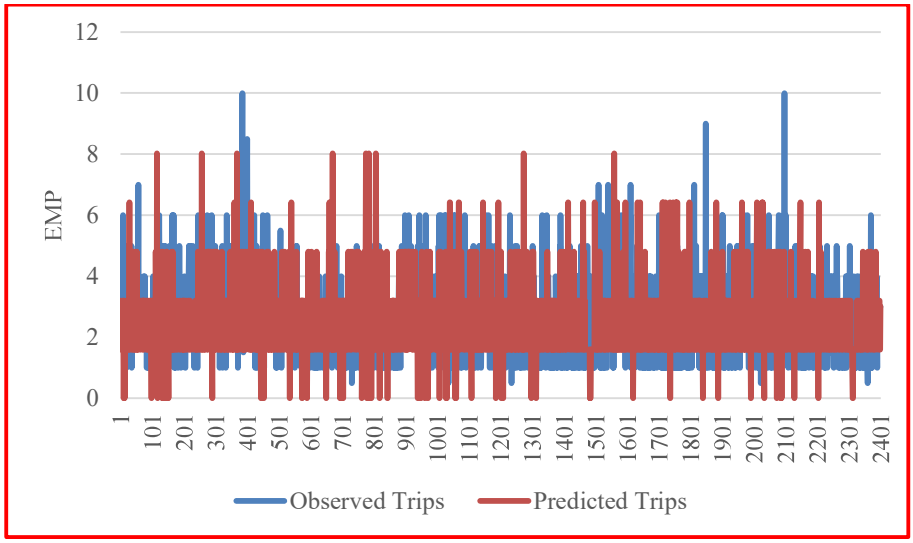

FIGURE 6.6: Observed and Predicted Trips (EMP)

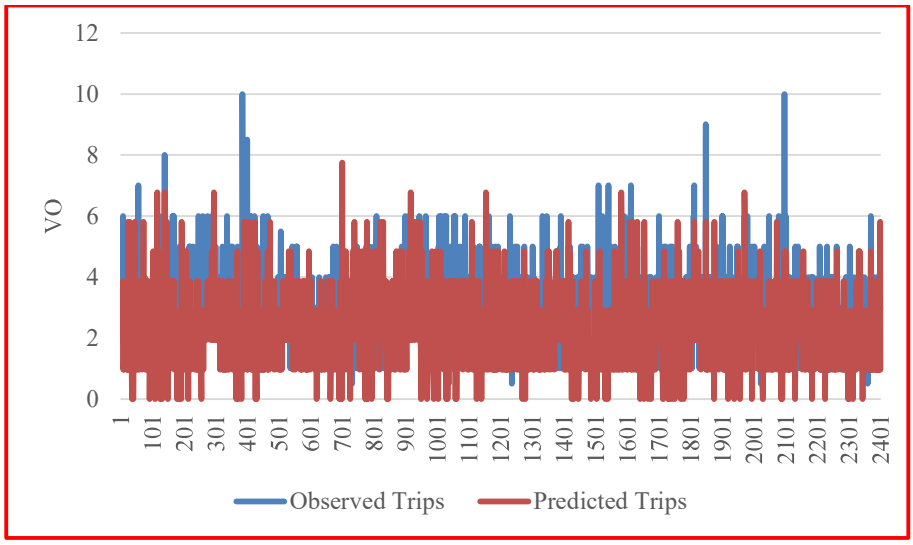

FIGURE 6.7: Observed and Predicted Trips (VO)

6.1.5 Ward wise Regression Models

Trip generation models for 9 wards of West zone of Ahmedabad is developed as multivariate regression models. Three most effective variables are taken to develop multivariate regression model for each ward. Family Size (FS), School/College going children/persons (SC) and number of employed persons in family (EMP). Wards have different land use and real estate scenario. Wards have different PT system. Wards have

different economy as per % of population belong to income group. Ward wise change in population and density is different. Hence, it is taken into consideration to develop ward wise models. Developed models are as shown in TABLE 6.5 and TABLE 6.6 as below. This is variety of models in study area and useful for future prediction. The trips considered are home based produced for the purpose of work and study.

a: Intercept or additive constant: it is taken as zero.

x_1: Number of Persons in Family (FS)

x_2: Number of Employed Persons in Family (EMP)

x_3: School /College going persons in Household (SC)

cell values of column 2,3 and 4 is multiplying constant of the variable.

TABLE 6.5: Multiplying Constants & R^2 for Ward Models

Sr.No.	Ward Name	b_1 for (x_1)	b_2 for (x_2)	b_3 for (x_3)	R Square
1.	PALDI	0.32	1.62	1.33	0.94
2.	VASNA	0.64	1.26	1.59	0.89
3.	NAVARANGPURA	0.40	1.72	1.67	0.93
4.	SP STADIUM	0.15	1.84	1.22	0.97
5.	NARANPURA	0.30	1.66	1.68	0.94
6.	NAVA VADAJ	0.15	1.98	1.81	0.94
7.	SABARMATI	0.18	2.19	1.88	0.92
8.	RANIP	0.27	1.75	1.99	0.94
9.	CHANDKHEDA	0.51	1.31	1.45	0.95

All the developed models have good R^2 value as shown in TABLE 6.5. All the multiplying constants are positive. The root mean square error (RMSE) for a regression model is similar to the standard deviation (SD) for the ideal measurement model. The SD estimates the deviation from the sample mean x. The RMSE estimates the deviation of the actual y-values from the regression line. RMSE for all the wards is less and acceptable as shown in TABLE 6.6. RMSE is in number of trips. The developed models are acceptable and have application for future prediction.

TABLE 6.6: Ward Wise Models

Ward Name	Regression Equation	RMSE
PALDI	0.32 (FS) + 1.62 (EMP) + 1.33 (SC)	1.33
VASNA	0.64 (FS) + 1.26 (EMP) + 1.59 (SC)	2.06
NAVARANGPURA	0.40 (FS) + 1.72 (EMP) + 1.67 (SC)	1.75
SP STADIUM	0.15 (FS) + 1.84 (EMP) + 1.22 (SC)	0.98
NARANPURA	0.30 (FS) + 1.66 (EMP) + 1.68 (SC)	1.30
NAVA VADAJ	0.15 (FS) + 1.98 (EMP) + 1.81 (SC)	1.56
SABARMATI	0.18 (FS) + 2.19 (EMP) + 1.88 (SC)	2.09
RANIP	0.27 (FS) + 1.75 (EMP) + 1.99 (SC)	1.52
CHANDKHEDA	0.51 (FS) + 1.31 (EMP) + 1.45 (SC)	1.34

6.2 Mode Choice Model Development

Based upon literature review multinomial logit model (MNL) is developed for mode choice analysis. Utility is the dependent variable used for model development. The independent variables are trip time (TT) in minutes, trip cost (TC) in Rs, trip length (TL) in km and income group in Rs per month for model development. Considerations for utility model development are summerised as below.

6.2.1 Trip Time Categories

- Trip time is considered as total trip time including total walking time and total traveling time. Upper limit for trip time is taken as 80 minutes for model development and trip time is distributed in 4 groups as shown in TABLE 6.7 below. Based upon data collected minimum and maximum value is used for range and range is divided equally in four groups.

TABLE 6.7: Trip Time Categories

Code	1	2	3	4
Trip time range (Minutes)	0 to 20	20.1 to 40	40.1 to 60	60.1 to 80

6.2.2 Trip Length Categories

- Maximum trip length observed is 23 km and more than 20 km length as upper limit. For walking maximum 2 km length is observed. For bicycle trips maximum 4 km length is

observed from data collection. Trip length is categorised into 6 groups as shown in TABLE 6.8 below.

TABLE 6.8: Trip Length Categories

Code	1	2	3	4	5	6
Trip Length range (km)	0 to 4	4.1 to 8	8.1 to 12	12.1 to 16	16.1 to 20	> 20

6.2.3 Trip Cost Categories

- Maximum trip cost Rs.130 is observed as upper limit for a few trips. Data is classified into 6 groups for model development as shown in TABLE 6.9 below.

TABLE 6.9: Trip Cost Categories

Code	1	2	3	4	5	6
Trip cost range (Rs.)	0 to 20	20.1 to 40	40.1 to 60	60.1 to 80	80.1 to 100	> 100

6.2.4 Monthly Income based Categories

Income of family per month is categorised in 7 range by considering maximum and minimum income in data collected.

TABLE 6.10: Monthly Income Categories

Code	Income Group (Rupees/Month)
1	Upto 20,000
2	20,001 to 40,000
3	40,001 to 60,000
4	60,001 to 80,000
5	80,001 to 1,00,000
6	1,00,000 to 1,50,000
7	More than 1,50,000

6.3 Utility Functions for Various Mode of Travel

- Utility functions were developed using TransCAD software for following categories of modes of travel. Only single mode of travel is considered as traveling mode. Trips with more than one mode are not considered for model development. Statistical parameter McFadden R^2 Asymptotic rho squared (ρ2) is mentioned for developed equations. Traveling modes considered for model development along with code used is as shown in TABLE 6.11**Error! Not a valid bookmark self-reference.** below.

TABLE 6.11: Mode of Travel Categories

Sr. No.	Vehicle Category	Code for Model
1	Walk	1
2	Bicycle	2
3	Two-wheeler	3
4	Car + Cab	4
5	Public transport (AMTS+BRTS)	5
6	Three-wheeler	6
7	School/college + Staff Bus (Private Bus)	7

6.3.1 Utility Functions for Walk Trips

$$U_{Walk} = -0.1994\ (I) + 0.9417\ (TT) - 1.0770\ (TL) \ldots\ldots \rho 2 = 0.02 \ldots\ldots\ldots\ldots\ldots\ldots (6.8)$$

Utility of walking mode is decreasing as income and trip length increases. Daily long-distance trips by walk for study or job is less preferred.

6.3.2 Utility Function for Bicycle Trips

$$U_{Bicycle} = -0.5352\ (I) + 0.8474(TT) - 1.6367\ (TL) \ldots\ldots \rho 2 = 0.03 \ldots\ldots\ldots\ldots\ldots (6.9)$$

As income and trip length increases bicycle trips are decreases. People use cycle for fitness but it is not preferred during peak hour in congestion due to risk of accident and pollution. Short trips are preferred on cycle. It is less preferred for work trips.

6.3.3 Utility Function for Two-wheeler Trips

$$U_{2W} = 0.3070\ (I) + 0.7053\ (TT) + 0.8375\ (TL) - 1.1644\ (TC) \ldots \rho 2 = 0.18 \ldots\ldots (6.10)$$

Operation and maintenance cost along with instalments of new vehicle make total cost of travel. Increase in trip cost results in decrease in use of 2W.

6.3.4 Utility Function for Three-wheeler Trips

$$U_{3W} = -1.1673\ (I) - 0.1443\ (TT) - 1.1916\ (TL) + 1.6152\ (TC) \quad \ldots\ \rho 2 = 0.05 \ldots\ldots (6.11)$$

Intermediate public transport in urban area is trip made by hired vehicle like auto rickshaw. The person who has not own private vehicle availability and not comfortable to travel in public transport is preferring 3W. The person who has not driving license or not driving skill also prefer 3W. The travel cost by 3W is more in comparison to own 2W and public transport bus. There are chances of mode shift from 3W to 2W on increase of income. More travel time may decrease use of 3W. Longer distance travel also less preferred in 3W. As trip length increases, utility of 3W will decrease.

6.3.5 Utility Function for Car + Cab Trips

$$U_{Car+Cab} = 1.3162\ (I) - 2.8847 (TT) - 1.4954\ (TL) + 2.4796\ (TC) \ldots\ \rho 2 = 0.15 \ldots (6.12)$$

As income increases car and cab users are increases. Increase in income give purchase power for car and affordability to cab as mode of travel. As distance increases, use of car is decreases. For long distance travel car/cab sharing is preferred.

6.3.6 Utility Function for AMTS + BRTS Trips

$$U_{AMTS+BRTS} = -0.8494\ (I) + 1.3906\ (TT) + 0.3470\ (TL) - 1.7702\ (TC) \ldots\ \rho 2 = 0.04 \ldots . (6.13)$$

Increase in income and travel cost i.e., higher bus fare is resulting into decrease in utility of public transport vehicle as mode of travel.

6.3.7 Utility Function for (School + College +Staff) Bus Trips

$$U_{(S+C+St)\ Bus} = -1.5149\ (I) + 0.5072\ (TT) + 0.2946\ (TL) - 0.2192\ (TC)\ \rho 2 = 0.04 \ldots (6.14)$$

As income and trip cost increases utility of private bus is decreasing. Employee of company prefer to travel by bus due to far location of company and transport facility provided by company. If it is not free and at higher deduction for travel from salary, then people will prefer another mode. Increase in trip length and trip time results into the increase in utility of private bus. School college buses are provided by educational institutes on

payment base. If it is more, family member prefers to pick up and drop in personal vehicle or on sharing bases in group. Hence, utility of institute bus will reduce. If school are far away then due to travel time and travel length people prefer institute bus. Increase in family income affects use of institute bus.

Utility of mode as per income is as shown by graph in FIGURE 6.8 below. Utility of mode as per TT, TL and TC is as shown in FIGURE 6.9, FIGURE 6.10 and FIGURE 6.11 respectively as below.

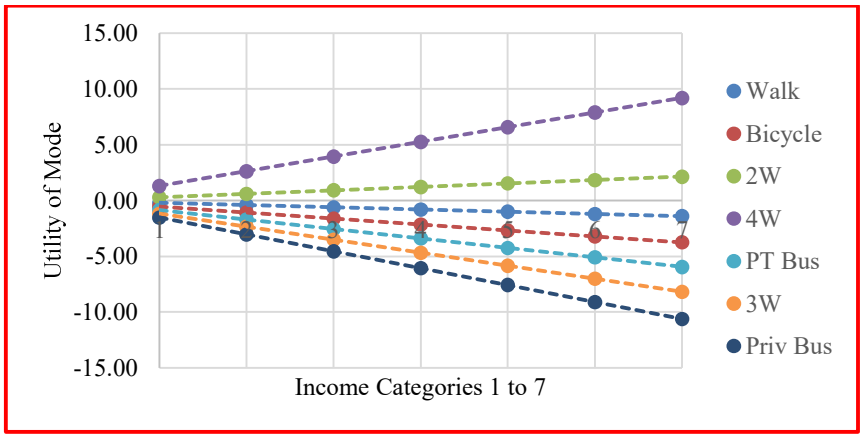

FIGURE 6.8: Utility of Mode as per Income of Trip Maker

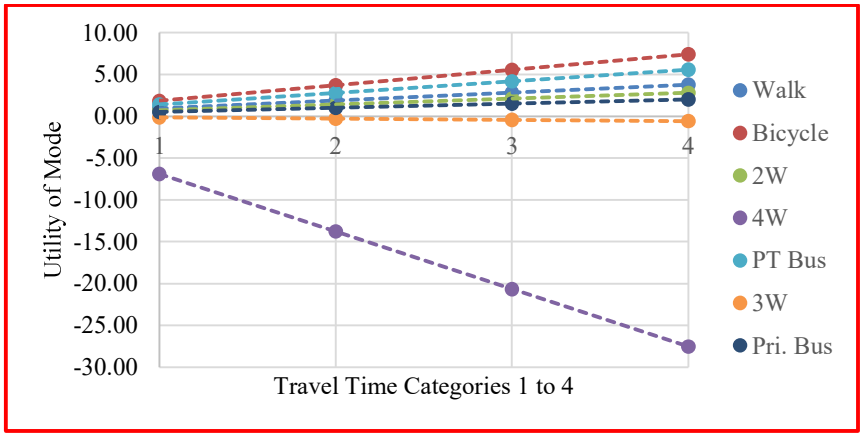

FIGURE 6.9: Utility of Mode as per Travel Time

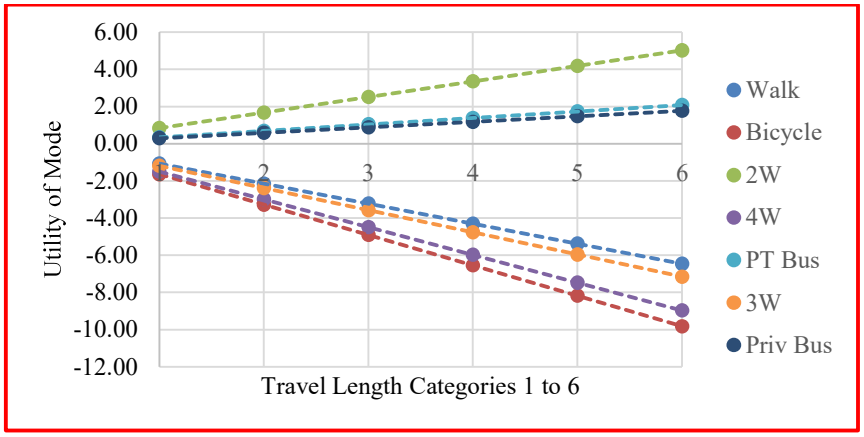

FIGURE 6.10: Utility of Mode as per Travel Length

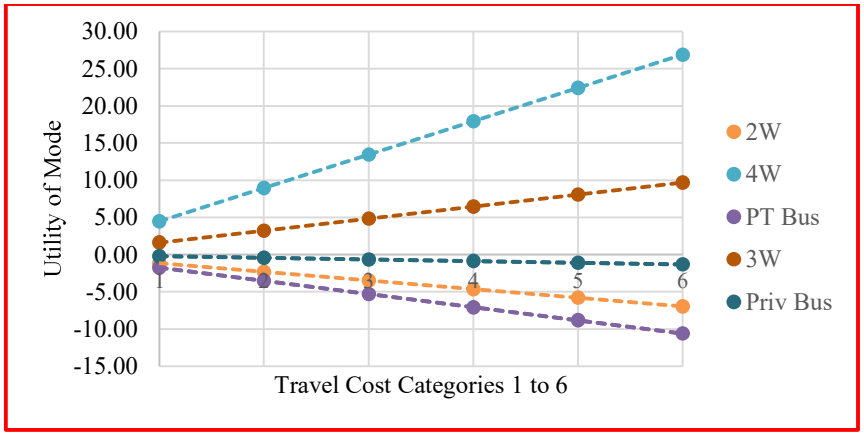

FIGURE 6.11: Utility of Mode as per Travel Cost

6.3.8 Calibration of Model by Probability Analysis

The logit formulation is sharing model as gravity model that divides the persons between various modes depending on each mode's relative desirability for any given trip. Modes are said to be relatively more desirable if they are faster, cheaper or have other more favourable features than competitive modes.

Following equation is used to find out the probability, $P_r(i)$using mode i :

$$\boldsymbol{P_r(i) = \frac{\mathbf{Exp(U_i)}}{\sum_{j=1}^{J} \mathbf{exp}\,(U_j)}} \quad \text{.....(6.15)}$$

Where; Probability of any mode of transport $p = 0 < p < 1$

Total probability is 1.

For finding out the probability of choosing different modes the category of different parameters 1-1-1-1 was considered for example. Probability analysis is done for income, trip time, trip length and trip cost for the category group of 0 to 20000 Rs. per month income, 0 to 4 km trip length, 0 to 20 minutes trip time and 0 to 20 Rs. trip cost. FIGURE 6.12 and TABLE 6.12 shows utility and probability of different modes for category 1-1-1-1. The linked excel sheet as shown in Appendix-E (shown for group 2-2-2-2) can generate for 1008 and more different combinations for modal split.

TABLE 6.12: Probability Analysis for Category Group 1-1-1-1

Vehicle Category	Utility	$\text{Exp}(U_i)$	$\sum_{j=1}^{J} \exp(U_j)$	$P_r(i) = \frac{\text{Exp}(U_i)}{\sum_{j=1}^{J} \exp(U_j)}$	Probability (%)
Walk	- 0.3347	0.715551	4.717649	0.15168	15.17
Bicycle	-0.3246	0.722828		0.15322	15.32
2W	0.68548	1.984726		0.4207	42.07
4W: Car, Cab	-2.5844	0.075444		0.01599	1.60
PT: AMTS and BRTS	-0.8819	0.414009		0.08776	8.78
3W	-0.8881	0.411428		0.08721	8.72
Private Bus	-0.9323	0.393664		0.08344	8.34
Total	---	---	---	1.00	100.00

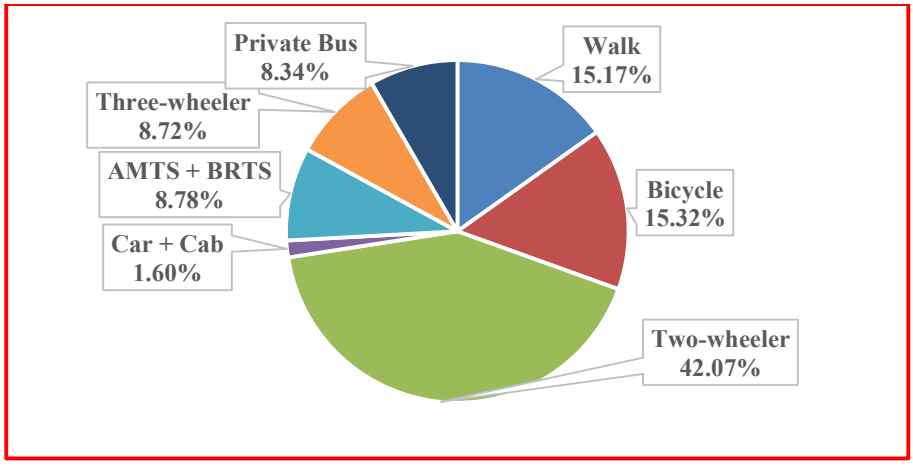

FIGURE 6.12: Mode Choice for Category Group 1-1-1-1

Probability of mode choice as per income group 1 to 7 is as shown in FIGURE 6.13 below. Probability of mode choice as per TT, TL and TC is shown in FIGURE 6.14, FIGURE 6.15 and FIGURE 6.16 respectively as below.

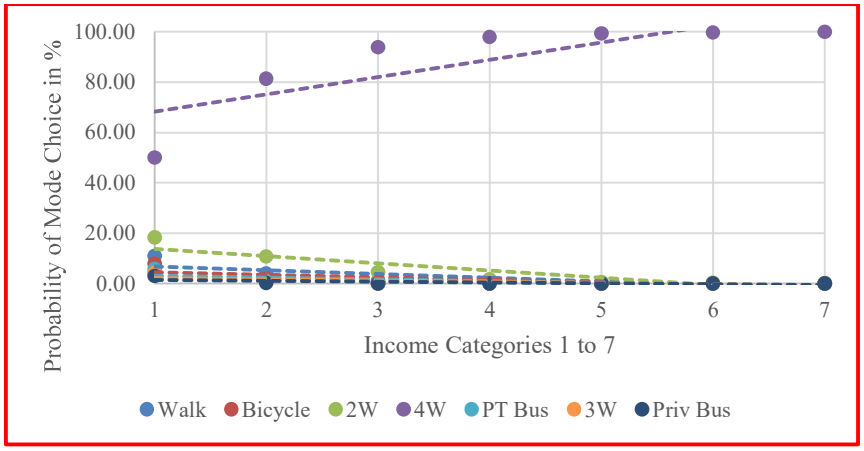

FIGURE 6.13: Probability of Mode Choice as per Income

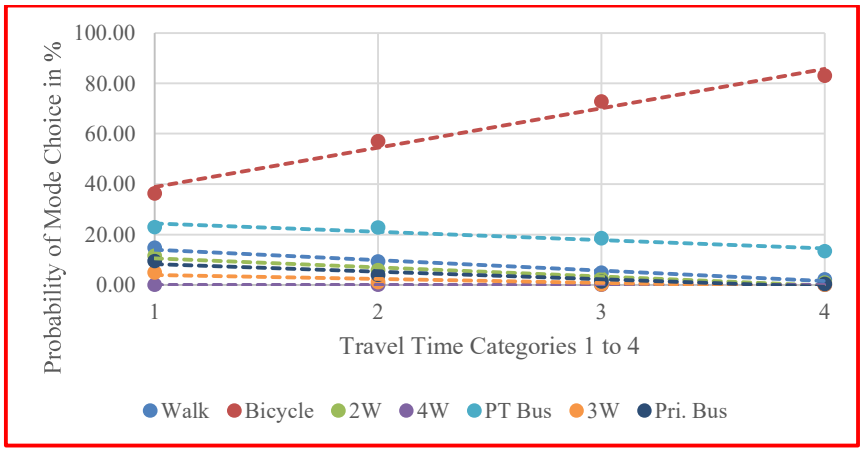

FIGURE 6.14: Probability of Mode Choice as per Travel Time

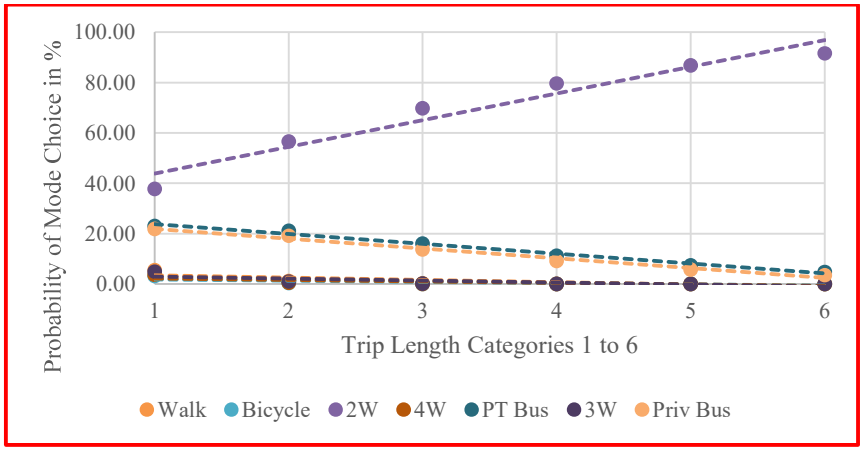

FIGURE 6.15: Probability of Mode Choice as per Travel Length

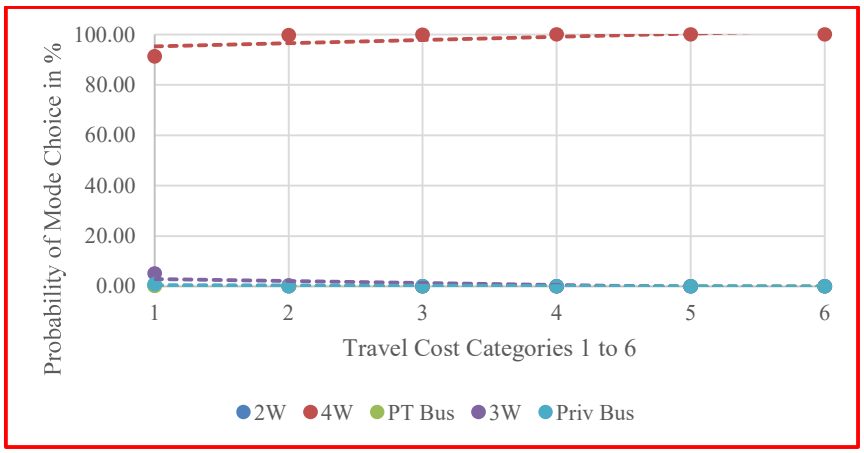

FIGURE 6.16: Probability of Mode Choice as per Travel Cost

6.4 Population Density and Produced Zonal Trips

Population in 2017 as per statement B and area as per AMC record is taken to develop Regression Model based on 70% data. The relation developed between produced zonal trips (T_Z) and zonal density (Z_D) is as shown in equation.

$T_Z = 3.26 \times Z_D$ .....(6.16)

R^2=0.85 Significance F=0.00 RMSE=3.64

Developed model is validated on 30% data. To develop model, trips for study area is obtained by expansion of surveyed trips. Ward wise population is multiplied with trips per

person. There is average 0.61 trip per person as per surveyed household data. Total expanded produced trips in study area are 6,85,185.

TABLE 6.13: Produced Trips in Study Area as per Density Model

Name of Ward	Density 2017	Predicted Trips
Paldi	21022	68531
Vasna	20814	67855
Navrangpura	10108	32951
S.P. Stadium	25310	82511
Naranpura	27180	88608
Nava vadaj	41132	134090
Sabarmati	12378	40353
Ranip	16528	53883
Chandkheda	10639	34684
Total Predicted Trips		6,03,466

6.5 Univariate LUTI Models

Produced zonal trips is dependent variable and taken as (T_Z) in equation. Independent variables residential land use (LUR) and transport land use (LUT) in zone. Additive constant 'a' is taken as 0 looking to trends of land use trips in logical sense. Multiplying constants are denoted by 'b'. Produced trips increasing with increase in area provided for development and population density. Residential land use area and transport land use area is taken as land use parameter and trips as transport parameter. Based upon HIS survey obtained trips for sample size is expanded for the study area.

6.5.1 Model for Produced Trips and Residential Land Use Area

Produced Trips = 21192 (Residential Land Use Area in km^2)

T_Z = 21192 x LUR……..(6.17)

R^2 = 0.85 Significance F = 0.0003 RMSE = 4.37%

Multiple R= 0.92 p-value= 0.0002 < 0.05 Adjusted R^2 = 0.72

Multiple R is considered as Pearson Correlation test in case of univariate regression model. Here it is more than 0.50 and acceptable. It shows good correlation among variables.

Ward wise produced trips and residential land use area 70% of total is used to develop regression model as shown in FIGURE 6.18. Area is in km^2.

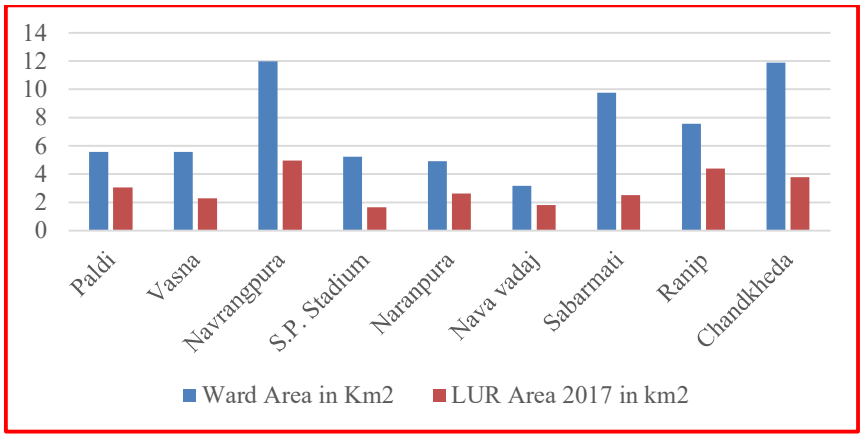

FIGURE 6.17: Ward Wise LUR

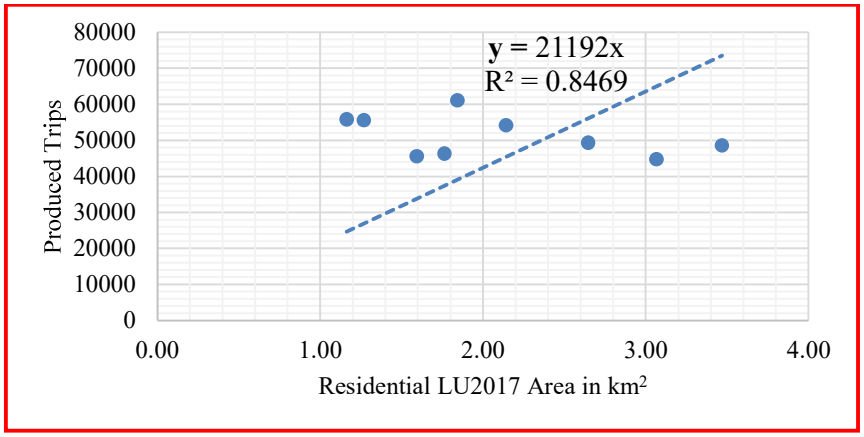

FIGURE 6.18: Model Development based upon Residential Land Use Area

Remaining 30% data is used to validate the developed model as shown in FIGURE 6.19. The estimated/predicted trips are compared with observed/surveyed trips. Low RMSE and high values of the correlation coefficient are desirable measure of goodness of fit. Coefficient of determination (R^2) value is used for validating estimated trip rate against observed trip rate for data which is not used in model development.

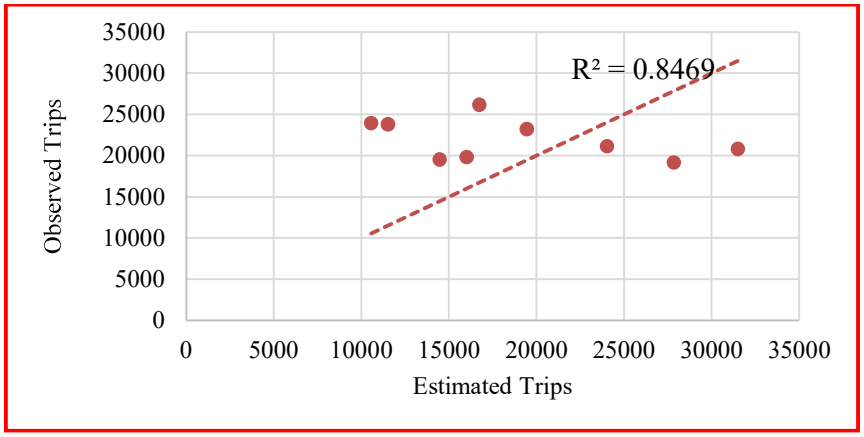

FIGURE 6.19: Validation of Model based upon Residential Land Use Area

6.5.2 Model for Produced Trips and Transport Land Use Area

Produced Trips = 34317 (Transport Land Use Area in km^2)

Tz = 34317 x LUT……(6.18)

$R^2 = 0.75$ Significance F = 0.0017 RMSE = 5.55%

Multiple R= 0.86 p-value=0.0011<0.05 Adjusted $R^2 = 0.63$

The developed model is as shown in FIGURE 6.20 and validation of model is as shown in FIGURE 6.21. Expanded trips as per survey data is as shown in TABLE 6.14.

TABLE 6.14: Ward Wise Trips

Name of Ward	Number of Surveyed HH	Produced Trips from Surveyed HH	Average trips per HH	Total No. of HH	Expanded Trips
Paldi	346	854	2.47	31325	77373
Vasna	299	746	2.5	26054	65135
Navrangpura	150	372	2.48	27971	69368
S.P. Stadium	280	687	2.45	32574	79806
Naranpura	347	807	2.33	37437	87228
Nava vadaj	192	532	2.77	28666	79405
Sabarmati	160	411	2.57	25741	66154
Ranip	335	817	2.44	26181	63882
Chandkheda	324	844	2.6	27098	70455

Total produced trips as per survey as per number of households in study area is observed 6,58,806. To develop model for the area of West zone, Ahmedabad, it is required to expand the trips. Area in km^2 for transport land use is as shown in TABLE 6.15.

TABLE 6.15: Ward Wise Residential and Transport Land Use Area

Ward Name	Paldi	Vasna	Navrangpura	SP Stadium	Naranpura	Nava Vadaj	Sabarmati	Ranip	Chandkheda
RLU area	3.06	2.28	4.95	1.66	2.63	1.81	4.38	2.52	3.78
TLU Area	1.37	0.92	2.33	1.22	0.79	0.80	3.11	2.54	2.03

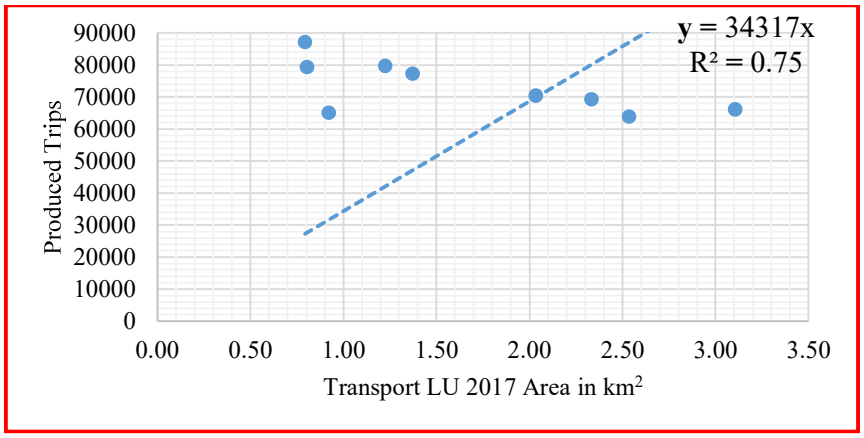

FIGURE 6.20: Model Development based upon Transport Land Use Area

The scattered points are representing transport land use area for nine wards of study area which are almost parallel to X axis. Different socio-economic conditions are represented. From the validation result, it is shown that R^2 value between observed and predicted/estimated trip rate is 0.75 and higher than 0.4 which shows good correlation.

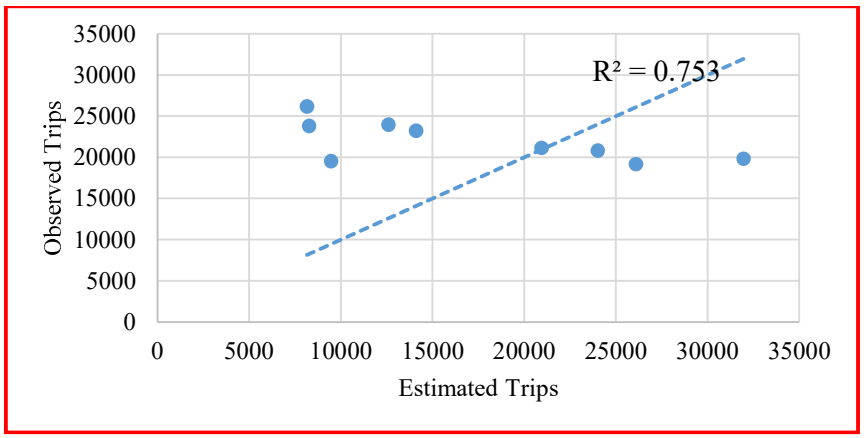

FIGURE 6.21: Validation of Model based upon Transport Land Use Area

6.6 Multivariate LUTI Models

6.6.1 Model-1 for Transport Parameter and Land Use Parameter

The models developed are based on data collected by survey. The sample data is used for equation 6.17 and 6.18. Residential land use-HH characteristics: Number of HHs and FS is independent variable. Transport parameter trips are dependent variable. T_S is trips from selected HHs as per sample size. Household characteristics surveyed is as shown in TABLE 6.16 below.

TABLE 6.16: Household Characteristics of Surveyed Households

Name of Ward	Produced Trips in Surveyed HH (T_S)	Number of Surveyed HH (HH)	Number of Persons in Surveyed HH (P)	Number of Vehicles in Surveyed HH (VO)
Paldi	854	346	1346	861
Vasna	746	299	1150	750
Navrangpura	372	150	620	361
S.P. Stadium	687	280	1158	727
Naranpura	807	347	1367	790
Nava Vadaj	532	192	818	468
Sabarmati	411	160	693	346
Ranip	817	335	1352	725
Chandkheda	844	324	1365	732

$T_S = 0.65 \times HH + 0.45 \times FS$……(6.19)

Produced Trips = 0.65 (Number of Households) + 0.45 (Family Size)

$R^2 = 1$ Significance F = 0.0005 RMSE = 7

Number of households is more affecting parameter in comparison to family size.

Correlation among variables is as shown in TABLE 6.17 below.

TABLE 6.17: Correlation among Trips, HH and FS

	Trips	Number of HHs	Family Size
Trips	1		
Number of HHs	0.99	1	
Family Size	0.99	0.99	1

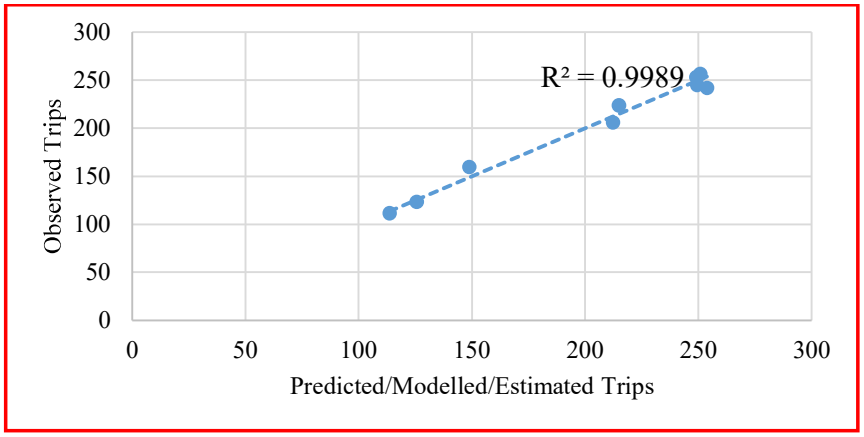

FIGURE 6.22: Validation of Model based upon HH & FS

From the sample data 70% data is used to develop model and remaining 30% data is used to validate model. Difference between predicted trips and observed trips is 3 only.

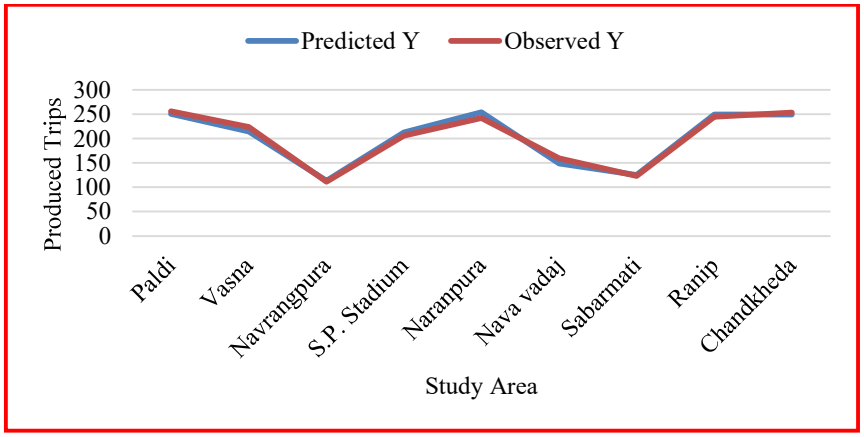

FIGURE 6.23: Predicted and Observed Trips based upon HH & FS

6.6.2 Model-2 for Transport Parameter and Land Use Parameter

Produced Trips = 5.87 + 0.02 (Number of Households) + 0.20 (Vehicle Ownership) + 0.49 (Family Size)

T_S = 5.87+0.02 x HH + 0.20 x VO + 0.49 x FS……(6.20)

R^2 = 0.99 Significance F = 0.000 RMSE = 6.80

TABLE 6.18: Correlation among Trips with HH, VO and FS

	Trips	Number of HH	Vehicle ownership	Family Size
Trips	1			
Number of HH	0.99	1		
Vehicle ownership	0.96	0.97	1	
Family Size	0.99	0.99	0.96	1

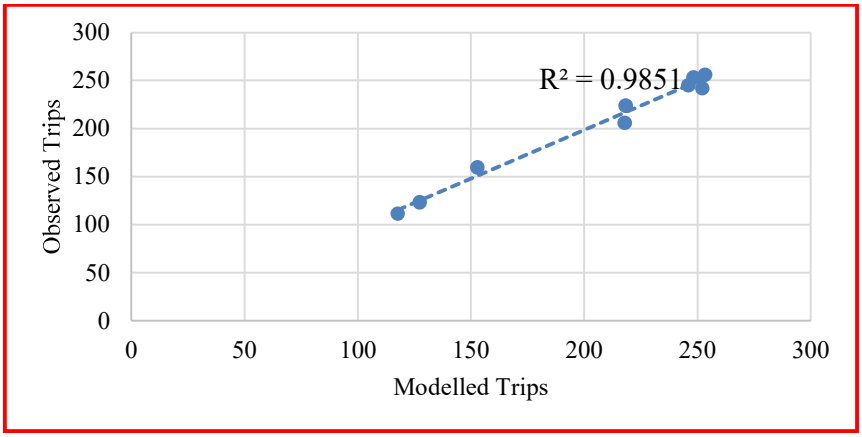

FIGURE 6.24: Validation of Model based upon HH, VO and FS

Difference between predicted trips and observed trips is 13 only. Model is validated on 30% of the surveyed sample data. Number of households is less affecting parameter in comparison to vehicle ownership and family size.

6.6.3 Model-3 for Transport Parameter and Land Use Parameter

To develop equation 6.21 and 6.22, the vehicle ownership is expanded for the study area based upon VO for sample size. Vehicle ownership in each surveyed household is summerised ward wise as shown in TABLE 6.16 above. The ward wise population is taken to develop model with LUR area.

Produced Trips = 0.35 (Population) + 0.38 (Vehicle Ownership) + 186 (Residential Land Use Area in km^2)

T_S = 0.35 x P + 0.38 x VO + 186 x LUR……..(6.21)

R^2 = 1 Significance F = 0.000 RMSE = 0.42%

Multiple R=1 Adjusted R^2=0.83

6.6.4 Model-4 for Transport Parameter and Land Use Parameter

Produced Trips = 0.34 (Population) + 0.40 (Vehicle Ownership) + 341 (Transport Land Use Area in km^2)

T_S = 0.34 x P + 0.40 x VO + 341 x LUT……..(6.22)

R^2 = 1 Significance F = 0.000 RMSE = 0.42%

Multiple R=1 Adjusted R^2=0.83

6.7 Land Use Models

The models showing relationship among population and number of households with residential and transport land use area.

6.7.1 Residential Land Use and Number of Households

The land use intensity increases as the time passes. The following two relations for LUR 2011 and LUR 2017 with number of HHs is shown. LU area is taken here in m^2, to develop good visible relation with number of households and population.

I. Residential land use area in 2011 in m^2= 127.72 (Number of HHs in 2011)

LUR_{2011}= 127.72 x Number of HH_{2011}……(6.23)

Multiple R = 0.93 R^2 = 0.86 Significance F = 0.0002

II. Residential land use area in 2017 in m^2= 99.95 (Number of HHs in 2017)

LUR_{2017}= 99.95 x Number of HH_{2017}……..(6.24)

Multiple R = 0.92 R^2 = 0.85 Significance F = 0.0003

It is observed that multiplier of number of HHs is decreasing with time. Supply of land for residential use is decreasing and number of HHs increasing. Either size of HHs is decreasing or number of floors per building is increasing. Density is increasing.

6.7.2 Residential Land Use and Population

I. Residential land use area in 2011 in m^2 = 28.19 (Population in 2011)

LUR_{2011}= 28.19 x P_{2011}……..(6.25)

Multiple R = 0.93 R^2 = 0.86 Significance F = 0.0002

II. Residential land use area in 2017 in m^2 = 23.92 (Population in 2017)

LUR_{2017}= 23.92 x P_{2017}……..(6.26)

Multiple R = 0.94 R^2 = 0.87 Significance F = 0.0001

It is observed that population is increasing with time. Supply of land for residential area is not increasing as required with time. Multiplier of population is decreasing. Model predict more land use for residential area with time as shown in 2011 equation. This indicates that population density is increasing. Number of persons per unit area in residential land use is increasing.

6.7.3 Transport Land Use and Number of Households

I. Transport land use area in 2011 in m^2 = 57.02 (Number of HHs in 2011)

LUT_{2011}= 57.02 x Number of HH_{2011}……(6.27)

Multiple R = 0.85 R^2 = 0.72 Significance F = 0.0026

II. Transport land use area in 2017 in m^2 = 54.60 (Number of HHs in 2017)

LUT_{2017}= 54.60 x Number of HH_{2017}……(6.28)

Multiple R = 0.86 R^2 = 0.75 Significance F = 0.0018

It is observed that transport land use area in m^2 of land in 2017 is increasing with time but not as predicted in 2011.It is decreasing with time in comparison to increase in number of HHs. Number of HHs are increasing but multiplier is decreasing. There is not sufficient space to widen road as per demand. The flyover is introduced for traffic management. Increase in HHs cause increase in number of trips. To accommodate additional trips public transport is increasing. New routes, extended routes and frequency is increasing. Faster PT buses in exclusive lane such as BRTS is provided. Proposal for rail transit is under consideration.

6.7.4 Transport Land Use and Population

I. Transportation land use area in 2011 in m^2= 12.69 (Population in 2011)

LUT_{2011}= 12.69 x P_{2011}……...(6.29)

Multiple R = 0.86 R^2 = 0.74 Significance F = 0.0022

II. Transportation land use area in 2017 in m^2 = 13.33 (Population in 2017)

LUT_{2017}= 13.33 x P_{2017}……...(6.30)

Multiple R = 0.90 R^2 = 0.80 Significance F = 0.0007

There is increase in population in 2017. The model developed based on population in 2011 is used to predict transport land use area in m^2 in 2017.Transport land use obtained from land use map shows area but area is not multiplied due to flyover on road. Road at ground level and flyover at upper-level handle more traffic. As per population, if transport land use is not introduced then it causes congestion on roads and crowd in public transport buses.

There is good relationship among density and residential land use area provided in study area. Trip production based on population and number of households have more standard error. The data for year 2011 and 2017 is as tabulated in TABLE 6.19. The LUR & LUT are in km^2, derived using Equation 6.23 to equation 6.30.

TABLE 6.19: Land Use Area as per Population and Number of HH

Year	Density	Population	FS	HH	LUR	LUT
2011	14384	787753	4.5	174251	23.90	11.04
2017	20568	1123254	4.27		31.66	14.24
2017				263047	33.60	15.00
Area Observed in Land Use Plan in 2017					27.08	15.13

As per population-based model residential land use required is 31.66 km^2 and transport land use required is 14.24 km^2 in 2017. As per number of HHs based model residential land use required is 33.60 km^2 and transport land use required is 15.00 km^2 in 2017. Land use map for 2017 indicates 27.08 km^2 residential land use and 15.13 km^2 transport land use. Which is less for residential and more for transport land use in comparison to predicted as per model.

Population density in 2017 observed as increase by 6148 persons per km^2 in comparison to 2011. Increase in FSI has accommodated increased population. Demand for HHs has been accommodated by increase in FSI. Flyovers and integrated corridor are increase in transport land use. Family size decreased from 4.5 in 2011 to 4.27 in 2017.Reduction in family size may be due to increase in number of HHs. There are social and economic factors which affects family size and life style of citizens.

6.8 Closure

Various univariate and multivariate regression models are developed as LUTI model for the study area as shown in TABLE 6.20. The defined research hypothesis is validated against null hypothesis. The statement of hypothesis is as below.

Research Hypothesis: There is relationship between /among land use parameters with transport parameter.

vs

Null Hypothesis: There is no relationship between /among land use parameters with transport parameter.

The transport parameter is produced trips and dependent variable. The land use parameters are land use area for residents and transportation as independent variable. The family size, vehicle ownership, number of persons going for education and employed in family are parameters induced from residential land use. They are introduced as independent variables in model development. Population, density and number of households in residential land use are parameters as independent variable.

The developed MNL model for mode choice is able to predict the utility of various modes in urban area along with probability of mode selection based on mode user's characteristics as per TT, TL, TC and income of urban residents.

To reject null hypothesis the R^2, Multiple R and Adjusted R should be more than 0.50 and near to 1. The test is with 95% confidence interval and for a significance level of 0.05. All the developed model are acceptable as per results obtained. As per availability of data in future it is used for future prediction.

Developed models include independent variables population, HH, VO, LU, density. Based on census data population can be forecasted for horizon year. Based on family size HH for horizon year obtained. For activities of increased population land use plan are prepared. LUT models for horizon year provide interaction activities for plans.

TABLE 6.20: LUTI Model Summary

Eq. No.	Trip Generation Model	R^2	RMSE	Validation
6.1	T_{HH} = 0.11xFS + 0.85xEMP + 0.81xSC +0.08xVO	0.92	0.85	Fig.6.1
6.2	T_{HH} = 0.16xFS + 0.84xEMP + 0.82xSC	0.92	0.78	Fig.6.2
6.3	T_{HH} = 0.44xFS + 0.48xSC+ 0.17xVO	0.90	0.83	Fig.6.3
6.4	T_{FS} = 0.64 x FS	0.86	1.08	Fig 6.4
6.5	T_{SC} = 1.77 x SC	0.68	1.69	Fig.6.5
6.6	T_{EMP} = 1.60 x EMP	0.78	1.76	Fig.6.6
6.7	T_{VO} = 0.97 x VO	0.75	1.50	Fig.6.7
6.17	T_Z = 21192 x LUR	0.85	4.37	Fig.6.19
6.18	T_Z = 34317 x LUT	0.75	5.55	Fig.6.21
6.19	T_S = 0.65 x HH + 0.45 x FS	1.00	7.00	Fig.6.22
6.20	T_S = 5.87+0.02 x HH + 0.20 xVO + 0.49 x FS	0.99	6.80	Fig.6.24
	Significance F for above all models is less than 0.05 and acceptable.			
	Ward wise trip generation models as shown in TABLE 6.5 and TABLE 6.6			
	MNL Models:			
6.8	U_{Walk} = -0.1994 (I) + 0.9417 (TT) -1.0770 (TL)			
6.9	$U_{Bicycle}$ = -0.5352 (I) + 0.8474(TT) -1.6367 (TL)			
6.10	U_{2W} = 0.3070 (I) +0.7053 (TT) + 0.8375 (TL) -1.1644 (TC)			
6.11	U_{3W} =-1.1673 (I) -0.1443 (TT) -1.1916 (TL) +1.6152 (TC)			
6.12	$U_{Car + Cab}$ =1.3162 (I) -2.8847(TT) -1.4954 (TL)+ 2.4796 (TC)			
6.13	$U_{AMTS+BRTS}$ = -0.8494 (I) +1.3906 (TT) +0.3470 (TL) -1.7702 (TC)			
6.14	$U_{(S+ C+ St) Bus}$ = -1.5149 (I) + 0.5072 (TT) + 0.2946 (TL) - 0.2192 (TC)			
6.15	$P_r(i) = \frac{\mathrm{Exp}(U_i)}{\sum_{j=1}^{J} \exp(U_j)}$			
	LUTI Model	R^2	Sig.F	Multiple R
6.16	T_Z =3.26 x Z_D	0.85	0.0002	0.92
6.21	T_S = 0.35 x P + 0.38 x VO + 186 x LUR	1.00	0.0000	1.00
6.22	T_S = 0.34 x P + 0.40 x VO + 341 x LUT	1.00	0.0000	1.00
6.23	LUR_{2011}= 127.72 x Number of HH_{2011}	0.86	0.0002	0.93
6.24	LUR_{2017}= 99.95 x Number of HH_{2017}	0.85	0.0003	0.92
6.25	LUR_{2011}= 28.19 x P_{2011}	0.86	0.0002	0.93
6.26	LUR_{2017}= 23.92 x P_{2017}	0.87	0.0001	0.94
6.27	LUT_{2011}= 57.02 x Number of HH_{2011}	0.72	0.0026	0.85
6.28	LUT_{2017}= 54.60 x Number of HH_{2017}	0.75	0.0018	0.86
6.29	LUT_{2011}= 12.69 x P_{2011}	0.74	0.0022	0.86
6.30	LUT_{2017}= 13.33 x P_{2017}	0.80	0.0007	0.90

CHAPTER - 7

Conclusion and Future Scope

7.1 Conclusion

There is good relationship between /among independent variables with dependent variables. Here, produced trips from household in study area are dependent variable. Population, density, vehicle ownership, family size, number of persons employed in household, number of persons going for education, residential land use area, transport land use area are independent variables. The developed LUTI models are calibrated and validated.

Population in 2011 for the study area west zone of Ahmedabad is 7,87,753 and added new population is 3,35,501 as in 2017, it is 11,23,254. There is 6% per annum growth. Population density i.e., number of persons per km^2 area is 14,384 in 2011 and 20,568 in 2017. There is increase of 6184 persons per km^2 area. The HH in 2011 were 1,74,251 numbers and 2,63,047 numbers in 2017. 88,800 new HH added in study area from 2011 to 2017. There is increase in population from 2011 to 2017 in study area is 42.59%. Increase in number of HH is 50.96%. Increase in population density by 43%. The cycle of LUTI initiating with increase in population and density causing increase in trips leading to increase or change in land use. Land use change again generates intensive trips.

The land use of 2011 and 2017 observed for the study. There is maximum area provided for residential land use is 37% of the total land in study area. Transport land use is 17% and mixed land use is 9% in 2011. The land use observed in 2017 is 39% residential, 22% transport and 12% mixed land use. The agricultural land available in 2011 was 14% and observed only 4% in 2017 land use map. The vacant plots available in 2011 was 7% which is consumed for development and only 1% left in 2017. If land not available for development, there is increase in Floor Space Index (FSI) to increase built up area to

accommodate population and to provide households for them. Widening of road for exclusive lane for BRTS and flyovers are observed change in transport land use in 2017 in comparison to 2011. Flyover and integrated corridor for public transportation system are observed increase in transport land use.

7.1.1 Findings from HIS data analysis

In study area as per HIS data analysis the following information derived for HH characteristics and trip characteristics.

The CCA table gives trip rate, which can be used for prediction of home based produced trips per HH. By CCA it is concluded that highest trip rate 5.62 is for the family size seven or more, number of school/college going children two or more and employed person two or more. Maximum trip rate 5.81 is for household with family size seven or more, vehicle ownership three or more and number of school/college going children two or more. All possible combination of family size, employed persons in family, family members going for education and vehicle ownership with trip rate is useful for future prediction.

Average vehicle ownership per HH is 2.36.

Family size was 5.15 in 1991, 5.02 in 2001, 4.5 in 2011 and 4.1 in 2017 in west zone of Ahmedabad.

2.5 is average produced trips per HH, which are regular trips and for work and education purpose. Trip rate is 0.6 per person originated from households for regular trip purpose.

(i) HH Characteristics:

The working persons are 36% , school college going persons are 26% and 38% are housewife and elderly people, generally non working persons in family.

Income group is divided in four class as per urban development and housing department. The trip makers from HIG (High Income Group) is 41%, from MIG (Middle Income Group) is 34%, from LIG (Low Income Group) is 18% and from EWS (Economically Weaker Section) 7%.

Vehicle ownership in family is 15.15% bicycle, 64.49% 2W and 20.36% car (4W). The preferred vehicle for urban area is 2W for trip making. Which demands less parking space compared to 4W. 2W is convenient mode on congested urban roads.

(ii) Trip Data Analysis:

The male made 76% of total trips and female made 24% of the total trips.

Age wise percentage trip makers analysis indicates that 17.44% of the total trips are made by age group up to 15 years. 32.36% trip makers are more than 15 years and up to 30 years. 25.03% are in age range of 31 to 45 years. 20.51% trip makers are of age 46 to 60 years. 4.14% trip makers are of age 61 to 75 years. Only 0.52% are of age more than 75 years. After 60 years of age mobility of person decreases.

The purpose based trip data analysis revealed 57.53% work trip, 34.79% education trip and 7.68% trips for shopping and other purpose.

(iii) Mode Choice in trip making:

Mode choice probability analysis based on utility function for different modes of trip can predict mode choice of users in future. The effect of travel time, travel distance, travel cost and income on mode choice is used for promoting public transport system and reduction in congestion on urban street. Mode split analysis for private and public transport can be predicted from the study. Scope for NMT can be plan as per utility function for walk and bicycle.

Mode choice for trip making as per home interview survey is 51.72% 2w, 2.52% 3w, 11.82% 4w (11.56% private car, 0.26% hired cab), 9.73% PT (3.47% AMTS, 6.26% BRTS), 5.33% Private bus (4.92% school college bus, 0.41% company bus), 9.24% bicycle and 9.64% by walk. Maximum mode choice is for 2W. There are 18.88% NMT. There is ample scope for NMT planning in urban area.

Mode choice probability using MNL model for category group 1-1-1-1 is 42.07% 2W, 8.72% 3W, 1.6% 4W, 8.78% PT, 8.34% Private bus, 15.32% Bicycles and 15.17% by Walk.

(iv) Trip Cost:

The trip cost is up to Rs. 20 for 81.93% of total trips surveyed. More than Rs. 20 and up to Rs. 40 is for 10.81% of trips. 3.65% trips have trip cost Rs. 40.1 to Rs. 60. 1.83% trips have Rs. 60.1 to Rs. 80. 0.86% trips are of trip cost Rs. 80.1 to Rs. 100.More than Rs. 100 cost is with a few trips, only 0.92% of total trips.

(v) Trip Length:

The trip length up to 4 km is of 53.07%; 4.1 to 8 km for 26.96%; 8.1 to 12 km for 11.25%; 12.1 to 16 km for 5.46% trips; 16.1 km to 20 km for 2.39%; 0.87% of total trips are more than 20 km trip length.

(vi) Trip Time:

The trip time measured in minutes is more than 60 minutes for 0.21% of total trips made by users of study area. Up to 20 minutes per trip by 67.68% of total trips. 20.1 minutes to 40 minutes for 26.51 % trips. 5.60% trip makers have trip making time more than 40.1 minutes and up to 60 minutes.

7.1.2 Findings from Public Transport User's Survey

Key findings obtained after data analysis. Purpose wise trips made in AMTS bus indicates that 41.93% trips for work, 20.84% for social work, 16.25% for education, 15.20% for shopping and remaining 5.78% for other purposes. Trips made in BRTS shows that 52.31% for work purpose, 6.22% for social work, 35.64% for education, 2.10% for shopping and 3.73% for other. Approximate 42% says that seat availability is there in public transport bus. 18% finds no seat availability in bus transit system in study area. Remaining 40% have experience of seat availability sometimes. Almost 50% trip makers believes that public transport system in study area is comfortable mode of journey. 5% finds it uncomfortable. 45% have mix feeling of comfort as average level.

9.73% of total trips are made by AMTS and BRTS bus transit public transportation system. Walk time from residence to nearest bus stop is up to 6 minutes for 59% of users. Walk time more than 6 minutes is generally not preferrable but it is observed for 41% users.

Waiting time for bus at bus stops is up to 6 minutes for 48% of users. More than 6 minutes waiting time for bus is observed for 52% and among them 9.5% has more than 12 minutes.

A location will have a higher PTAL if it is at a short walking distance to the nearest stations or stops and less waiting times. For any selected place, PTAL suggests how well the place is connected to public transport services. The greater number of bus stops and more frequency indicates higher AI as shown in Table 5.25 and Table 5.26. All wards have good local accessibility except SP Stadium. Highest AI is at Navrangpura. PTAL is excellent at Navrangpura and Paldi.

7.1.3 Achievements with respect to Objectives

Objective of the study is to develop LUTI model which shows relationship between land use and transport parameters. The socioeconomic characteristics gives parameters like family size, number of employed persons in family, Number of school college going persons in family and number of vehicles in household. The trips for work and education are regular trips produced from households are taken as transport parameter.

The land use area for residents and transport is taken as land use parameter. 3 Univariate LUTI Models, 4 Multivariate LUTI Models, 4 Univariate Trip production model, 3 Multivariate Trip production models, 9 Multivariate Trip production models (individual ward wise) and 8 land use models are developed. The home interview survey for sample size gives total 6070 produced trips from 2400 households in west zone. Ward wise data is compiled in tabular forms. 2/3rd data is taken for model development. Second objective of the study is to calibrate models. 1/3rd data is taken for validation of the model. There is good relationship between modelled/estimated/predicted trips with observed/surveyed trips.

The developed LUTI models with stastical parameters are as summerised in TABLE 6.20. Model validation strategy is as shown in FIGURE 7.1 below.

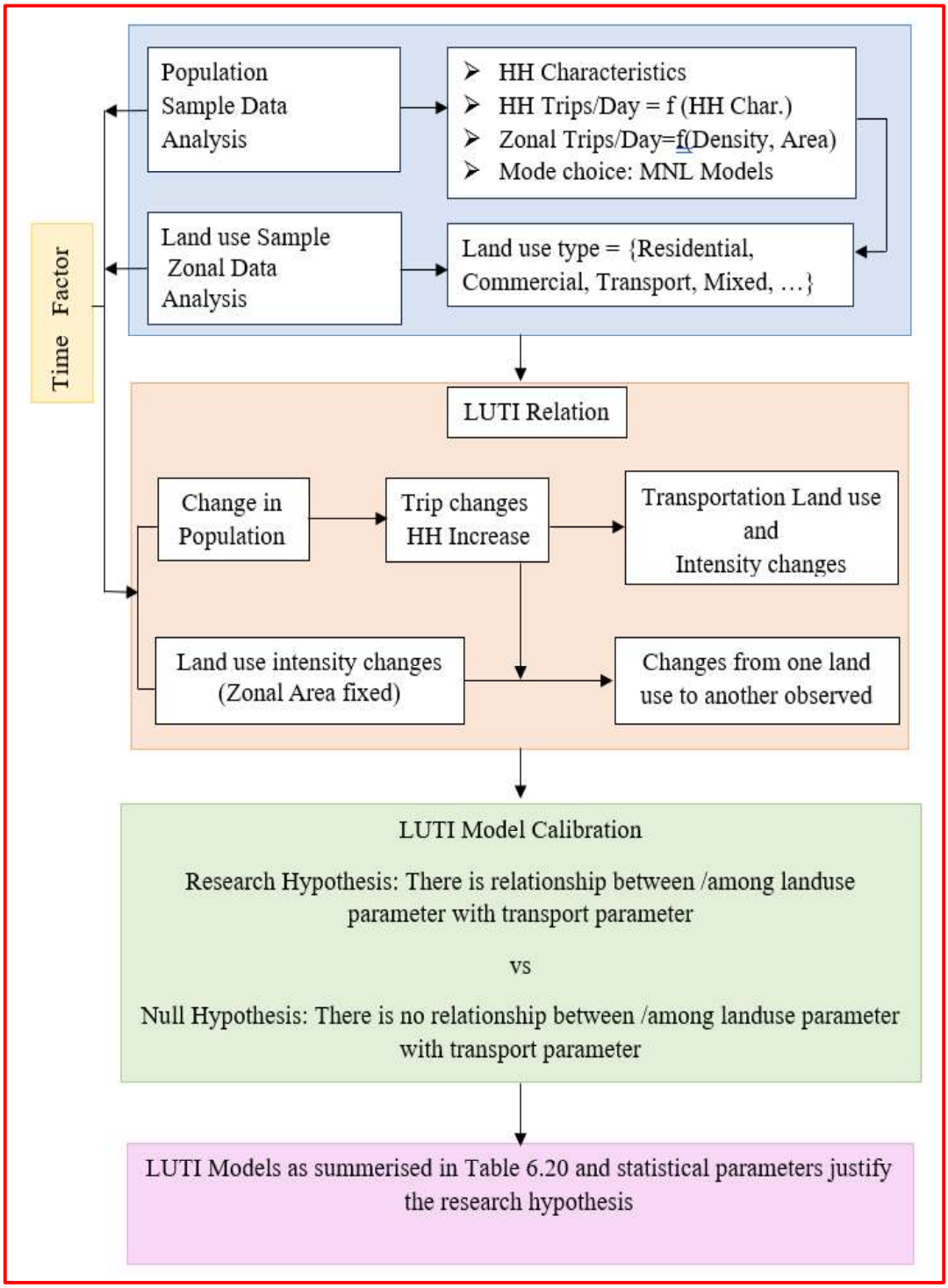

FIGURE 7.1: Model Validation Strategy and Outcome

7.2 Limitations of the Study

Significant limitations of the study include: The study was started in year 2017 onwards for data collection after course work of PhD. The decadal data of census available at that time is of 2011. Covid-19 has not allowed updating of data and census count for 2021. The 2017 population declared by AMC is taken for study in addition to 2011 census data. The vehicle purchase and registration are affected by lockdown. The traffic scenario on roads cannot observed in normal condition due to restrictions and fear of corona. The land use map for the base year 2011 and 2017 is taken for data related to land use area. Land use maps not revised frequently and at an instance at all the time. Change in land use is very slow process compared to change in population. The four stage modelling is not done for trip distribution and route assignment. Only Trip generation and mode choice analysis is included in the study. Accessibility to public transportation in west zone and real estate scenario is used for analysis and not for LUTI model development. Land use and corresponding trip generation/ attraction data could not be collected for all types of land use observed in urban area. This has resulted in LUTI model development, aggregate trips and land use (residential and transport) relationships. Further work can be done using identified land use which are generator and attractor of trips like malls, clubs, party plot, commercial land use. Only local (point) accessibility is calculated and not the network accessibility. Data collection and analysis for public transport facilities bus transit only is carried out. The study is limited to nine wards of west zone and not for whole Ahmedabad.

7.3 Usage of Results

The CCA trip rates and mode choice probability results can be applied in urban land use and transport planning. Accessibility of points can help to take accessibility improvement measures. Developed LUTI models have application in urban development planning. Planning policy framework to create balance among demand of population and supply of land for development. Results are useful in land use and transportation planning in urban area.

Overall research framework model is applicable for any other cities of the Gujarat state based on calibration of different sub models for specific study area.

7.4 Future Scope of the Work

A similar study may be taken up in future to develop LUTI models based on OHH (Other than Household) for the study area. Educational, Industrial, Commercial and other land use for development of trip generation models can be taken for study. The land use area for LUTI model is land area in this study. One can use multilayer built up as per FSI (Floor Space Index) as area available for development of HH to accommodate additional population. Network assignment and traffic generation scenario for planning in horizon year can be developed, which will guide for phased development.

7.5 Closure

The Chapter presents the summary of key findings, the conclusion, limitations of the study, recommendations and scope of further research.

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Appendices

Appendix – A: HIS Survey Form

Form No.	Name of Interviewer:	Date:

Household Information

Location:	**Total No. of Persons in HH:**	No. of Male:	No. of Female:		
Type of Building:	Type of Landuse:	No. of Floors:	**No. of Employed:**	No. of Male:	No. of Female:
No. of Children:	School going :	College/University going:			
Vehicle Ownership:	Cycle:	2W:	3W:	Car:	

Trip Information

Household Composition				Activity/Purpose			Rs.		Trip time						
Sr. No.	Name	Relationship	Sex (M/F)	Age	Service Business Workers Education	Other	**Income**	No. of trips / Day	Start	End	Trip length-km	**Mode of Travel**	**Origin ward**	**Destination ward**	Route	Travel Cost - Rs.

Public Transportation Facility Information

AMTS	Y/N If Yes, Name of Stand	Distance up to Stand	m	Walk Time:	minutes
BRTS	Y/N If Yes, Name of Stand	Distance up to Stand	m	Walk Time:	minutes

Mode of Travel: 1-walk, **2**-Bicycle, **3**- two-wheeler, **4**-car, **5**-AMTS, **6**-BRTS, **7**-Auto-ricksaw, **8**-Private cab, **9**-college/school bus, **10**-staff bus

Income group: A-< Rs. 20,000, **B**-Rs. 20,001 to 40,000, **C**–Rs. 40,001 to 60,000, **D**–Rs. 60,001 to 80,000, **E**–80,001 to 1 Lac, **F**–1 Lac to 1.5 Lac, **G**-> 1.5 Lac

Appendix – B1: Public Transport User's Survey Form

Accessibility to Public Transport System Survey

Date: ___ /___ /_____ Time : ___:___ am/pm to ___:___ am/pm

Type of Public Transport Facility:		AMTS		BRTS			
Ward name:		Ward No.	Name of Stand(SAP)				
Sex: M	F	Age: Yr	3-10	10-20	20-30	30-40	40-50	50-60	>60
Origin of trip: ward name:			Destination of trip: ward name:				
From where came? (POI) ward name:							
Home	Work	Education	Shopping	Social	Recreation	Other: Please Specify	
Is came by walk?	YES	How much distance: m			how much time: min		
Is came by walk?	NO	Tick from option given	Cycle	2W	Car	Rickshaw	Bus
Distance m		Time min	Expenditure : YES/NO: Rs.				
After travel by Bus, where will you go?							
Home	Work	Education	Shopping	Social	Recreation	Other: Please Specify	
Do you go by walk?	YES	How much distance: m			how much time: min		
Do you go by walk?	NO	Tick from option given	Cycle	2W	Car	Rickshaw	Bus
Distance: m		Time : min	Expenditure : YES/NO: Rs.				
What is waiting time for bus?: min			What is travel time through bus?: min				
Remarks:							

Designed by:Rena Narendrabhai Shukla(PhD Scholar-Civil Engg at GTU)

Appendix – B2: PT Bus BRTS User's Survey by Google form

1. **Service Access Point (SAP)** * ***Mark only one.***

- Commerce Six Road
- LD Engg. College
- Gulbai Tekra Approach
- Panjrapole Char Rasta
- L Colony
- Nehrunagar
- Jhansi Ki Rani
- Shivranjani
- Himmatlal Park
- University
- Shree Valinath Chowk
- Sola Cross Road
- Jaimangal
- Shastrinagar
- Pragatinagar
- Akhbarnagar
- Bhavsar Hostel
- Ranip Cross Road
- R.T.O. Extension
- Sabarmati Power House
- Rathi Apartment
- Sabarmati Municipal Swimming pool
- Sabarmati Police Station
- Motera Cross Road
- Visat Gandhinagar Junction
- ONGC
- Jantanagar
- Shivshaktinagar
- Chandkheda Gam
- Sarthi Bungalows
- DCIS Circle
- Vasna Bus Stop
- Dharnidhar
- Anjali
- Chandranagar

2. **Gender *Mark only one.**

- Male
- Female

3. **Age Group (years) *Mark only one.**

- 6-10
- 10-20
- 20-30
- 30-40
- 40-50
- 50-60
- >60

4. Origin of Trip * Mark only one.

- Paldi
- Vasna
- Navrangpura
- SP Stadium
- Naranpura
- Sabarmati
- Nava Vadaj
- Ranip
- Chandkheda

5. Destination of Trip * (Write ward name)

_____

6. Purpose of the Trip * Mark only one.

- Home
- Work
- Education
- Shopping
- Social
- Recreation
- Other

7. Walk Time from Origin to SAP (minutes) *Mark only one.

- 0-3 min
- 3-6 min
- 6-10 min
- >10 min
- 0-250 m
- 250-500 m
- 500-750 m
- >750 m

8. What is waiting time for Bus? (minutes) *Mark only one.

- 0-3 min
- 3-6 min
- 6-9 min
- 9-12 min
- >12 min

9. What is travel time through Bus? (minutes) * Mark only one.

- 0-15 min
- 15-30 min
- 30-45 min
- 45-60 min
- >60 min

10. Walk time from SAP to Destination (minutes) *Mark only one.

- 0-3 min
- 3-6 min
- 6-10 min
- >10 min

11. Walk Distance from SAP to Destination (meters) * Mark only one.

- 0-250 m
- 250-500 m
- 500-750 m
- >750 m

12. Seat Availability * Mark only one.

- Yes
- No
- Sometimes

13. Comfort * Mark only one.

- Poor
- Average
- Good

14. Remarks (If any)

Google Forms

Designed By 159997106014_Rena Narendrabhai Shukla-PhD Scholar-Civil Engg. at Gujarat Technological University

Appendix – C: Statistical Analysis for Grouping of Variables

Table V.1: Pearson Correlation for Ungrouped Variables

Ungrouped Variables		Produced Trips
Family size	Pearson Correlation	0.577**
	Sig. (2-tailed)	0.000
Employed person	Pearson Correlation	0.441**
	Sig. (2-tailed)	0.000
School/college Going Children	Pearson Correlation	0.571**
	Sig. (2-tailed)	0.000
Vehicle Ownership	Pearson Correlation	0.346**
	Sig. (2-tailed)	0.000
Income_1	Pearson Correlation	0.198**
	Sig. (2-tailed)	0.000

Table V.2: Pearson Correlation for Grouped Variables

Grouped Variables		Produced Trips
Family Size 1(1-7)	Pearson Correlation	0.569**
	Sig. (2-tailed)	0.000
Family Size 2(1-4)	Pearson Correlation	0.526**
	Sig. (2-tailed)	0.000
Family Size 3(1-3)	Pearson Correlation	0.525**
	Sig. (2-tailed)	0.000
Employed persons 1(1-4)	Pearson Correlation	0.433**
	Sig. (2-tailed)	0.000
Employed persons 2(1-3)	Pearson Correlation	0.380**
	Sig. (2-tailed)	0.000
School college going 1(1-4)	Pearson Correlation	0.551**
	Sig. (2-tailed)	0.000
School college going 2(1-3)	Pearson Correlation	0.507**
	Sig. (2-tailed)	0.000
Vehicle ownership 1(1-4)	Pearson Correlation	0.334**
	Sig. (2-tailed)	0.000
Vehicle ownership 2(1-3)	Pearson Correlation	0.321**
	Sig. (2-tailed)	0.000
**. Correlation is significant at the 0.01 level (2-tailed).		

Table V.3: ANOVA result of grouped variable (Family Size_1)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Family Size 1		993.014	6	165.502	158.711	0.000
		Residual	1760.228	1688	1.043		
		Total	2753.242	1694	1.625		

Table V.4: ANOVA result of grouped variable (Family Size_2)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Family Size 2		847.214	3	282.405	250.545	0.000
		Residual	1906.028	1691	1.127		
		Total	2753.242	1694	1.625		

Table V.5: ANOVA result of grouped variable (Family Size_3)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Family Size 3		860.628	2	430.314	384.701	0.000
		Residual	1892.614	1692	1.119		
		Total	2753.242	1694	1.625		

Table V.6: ANOVA result of grouped variable (Children_1)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	School/college going children_1		913.084	3	304.361	279.691	0.000
		Residual	1840.15	1691	1.088		
		Total	2753.24	1694	1.625		

Table V.7: ANOVA result of grouped variable (Children_2)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	School/college going children_2		726.320	2	363.160	303.153	0.000
		Residual	2026.922	1692	1.198		
		Total	2753.242	1694	1.625		

Table V.8: ANOVA result of grouped variable (Employed_1)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Employed 1		575.909	3	191.970	149.091	0.000
		Residual	2177.333	1691	1.288		
		Total	2753.242	1694	1.625		

Table V.9: ANOVA result of grouped variable (Employed_2)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Employed 2		437.580	2	218.790	159.865	0.000
		Residual	2315.662	1692	1.369		
		Total	2753.242	1694	1.625		

Table V.10: ANOVA result of grouped variable (Vehicle Ownership_1)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Vehicle 1		209.522	3	69.841	52.194	0.000
		Residual	2067.346	1545	1.338		
		Total	2276.868	1548	1.471		

Table V.11: ANOVA result of grouped variable (Vehicle ownership_2)

Dependent Variable	Independent variable	Variable	Sum of Squares	df	Mean Square	F	Sig.
Produced trips per household	Vehicle 2		306.611	2	153.306	106.020	0.000
		Residual	2446.631	1692	1.446		
		Total	2753.242	1694	1.625		

Note: F- F score, df- degree of freedom, Sig. – Significance

Appendix – D1: Accessibility Index (AI) Calculation for AMTS SAPs

Calculation of AI for **PALDI**

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Vikash Gruh	1	34-3	0.48	0.5	5.14	62.50	2.5	65.00	70.14	0.43	0.21
		2	34-4	3	1	5.14	10.00	2.5	12.50	17.64	1.70	1.70
		3	37-4	0.57	0.5	5.14	52.63	2.5	55.13	60.27	0.50	0.25
		4	39-3	0.29	0.5	5.14	103.45	2.5	105.95	111.09	0.27	0.14
Total												2.30
2	Niranjan Society	1	34-5	1.5	1	5.14	20.00	2.5	22.50	27.64	1.09	1.09
Total												1.09
3	Sharda Nagar	1	34-3	0.48	0.5	5.14	62.50	2.5	65.00	70.14	0.43	0.21
		2	34-4	3	1	5.14	10.00	2.5	12.50	17.64	1.70	1.70
		3	37-4	0.57	0.5	5.14	52.63	2.5	55.13	60.27	0.50	0.25
		4	39-3	0.29	0.5	5.14	103.45	2.5	105.95	111.09	0.27	0.14
Total												2.30
4	Dharnidhar Society	1	34-3	0.48	0.5	5.14	62.50	2.5	65.00	70.14	0.43	0.21
		2	34-4	3	1	5.14	10.00	2.5	12.50	17.64	1.70	1.70
		3	37-4	0.57	0.5	5.14	52.63	2.5	55.13	60.27	0.50	0.25
		4	39-3	0.29	0.5	5.14	103.45	2.5	105.95	111.09	0.27	0.14
Total												2.30
5	Jalaram Mandir	1	40	0.23	0.5	5.14	130.43	2.5	132.93	138.08	0.22	0.11
		2	42	2	0.5	5.14	15.00	2.5	17.50	22.64	1.32	0.66
		3	47	0.86	0.5	5.14	34.88	2.5	37.38	42.53	0.71	0.35
		4	49	0.87	0.5	5.14	34.48	2.5	36.98	42.13	0.71	0.36
		5	49/1	0.8	0.5	5.14	37.50	2.5	40.00	45.14	0.66	0.33
		6	49/2	2.4	1	5.14	12.50	2.5	15.00	20.14	1.49	1.49
		7	49/S	0.52	0.5	5.14	57.69	2.5	60.19	65.34	0.46	0.23
		8	58	1.5	0.5	5.14	20.00	2.5	22.50	27.64	1.09	0.54
		9	68	0.27	0.5	5.14	111.11	2.5	113.61	118.75	0.25	0.13
		10	142	1.2	0.5	5.14	25.00	2.5	27.50	32.64	0.92	0.46
		11	151/4	2.4	1	5.14	12.50	2.5	15.00	20.14	1.49	1.49
Total												6.15
6	Mahalakshmi Society	1	31-5	3	1	6.19	10.00	2.5	12.50	18.69	1.61	1.61
		2	31/4	3	1	6.19	10.00	2.5	12.50	18.69	1.61	1.61
		3	31/4S	0.4	0.5	6.19	75.00	2.5	77.50	83.69	0.36	0.18
		4	31S	0.92	0.5	6.19	32.61	2.5	35.11	41.30	0.73	0.36

		5	32	2	0.5	6.19	15.00	2.5	17.50	23.69	1.27	0.63
		6	34-3	0.48	0.5	6.19	62.50	2.5	65.00	71.19	0.42	0.21
		7	34-4	3	1	6.19	10.00	2.5	12.50	18.69	1.61	1.61
		8	35	2	0.5	6.19	15.00	2.5	17.50	23.69	1.27	0.63
Total												6.83
7	Mahalakshmi Chhar Rasta	1	34-5	1.5	0.5	6.19	20.00	2.5	22.50	28.69	1.05	0.52
		2	136	2	1	6.19	15.00	2.5	17.50	23.69	1.27	1.27
		3	204	1.33	0.5	6.19	22.56	2.5	25.06	31.25	0.96	0.48
Total												2.27
8	Jain Merchant	1	31-5	3	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		2	31/4	3	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		3	31/4S	0.4	0.5	5.90	75.00	2.5	77.50	83.40	0.36	0.18
		4	32	2	0.5	5.90	15.00	2.5	17.50	23.40	1.28	0.64
		5	34/4	3	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		6	35	2	0.5	5.90	15.00	2.5	17.50	23.40	1.28	0.64
		7	36/1	0.52	0.5	5.90	57.69	2.5	60.19	66.09	0.45	0.23
		8	38/1	0.33	0.5	5.90	90.91	2.5	93.41	99.31	0.30	0.15
		9	39-3	0.29	0.5	5.90	103.45	2.5	105.95	111.85	0.27	0.13
		10	40	0.23	0.5	5.90	130.43	2.5	132.93	138.83	0.22	0.11
		11	40-1	3.0	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		12	40-2	2.0	0.5	5.90	15.00	2.5	17.50	23.40	1.28	0.64
		13	123	3.0	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		14	150	3.0	0.5	5.90	10.00	2.5	12.50	18.40	1.63	0.82
		15	150S	0.50	0.5	5.90	60.00	2.5	62.50	68.40	0.44	0.22
		16	204	0.13	0.5	5.90	225.56	2.5	228.06	233.96	0.13	0.06
		17	401	6.0	1	5.90	5.00	2.5	7.50	13.40	2.24	2.24
Total												10.14
9	Paldi	1	32	2	0.5	6.67	15.00	2.5	17.50	24.17	1.24	0.62
		2	33	2.67	0.5	6.67	11.24	2.5	13.74	20.40	1.47	0.74
		3	33/1S	1.04	0.5	6.67	28.85	2.5	31.35	38.01	0.79	0.39
		4	33/2	1	0.5	6.67	30.00	2.5	32.50	39.17	0.77	0.38
		5	36/1	0.52	0.5	6.67	57.69	2.5	60.19	66.86	0.45	0.22
		6	37-4	0.57	0.5	6.67	52.63	2.5	55.13	61.80	0.49	0.24
		7	39-3	0.29	0.5	6.67	103.45	2.5	105.95	112.61	0.27	0.13
		8	40-1	3	1	6.67	10.00	2.5	12.50	19.17	1.57	1.57
		9	47	0.86	0.5	6.67	34.88	2.5	37.38	44.05	0.68	0.34
		10	49/1	0.8	0.5	6.67	37.50	2.5	40.00	46.67	0.64	0.32
		11	49/2	2.4	0.5	6.67	12.50	2.5	15.00	21.67	1.38	0.69
		12	40	0.23	0.5	6.67	130.43	2.5	132.93	139.60	0.21	0.11
		13	42	2	0.5	6.67	15.00	2.5	17.50	24.17	1.24	0.62

		14	49	0.86	0.5	6.67	34.88	2.5	37.38	44.05	0.68	0.34
		15	49/S	0.52	0.5	6.67	57.69	2.5	60.19	66.86	0.45	0.22
		16	68	0.27	0.5	6.67	111.11	2.5	113.61	120.28	0.25	0.12
Total												7.07
10	Paldi Terminus	1	31-5	3	1	6.67	10.00	2.5	12.50	19.17	1.57	1.57
		2	31/4S	0.4	0.5	6.67	75.00	2.5	77.50	84.17	0.36	0.18
		3	32	2	0.5	6.67	15.00	2.5	17.50	24.17	1.24	0.62
		4	34/5	1.5	0.5	6.67	20.00	2.5	22.50	29.17	1.03	0.51
		5	36/1	0.52	0.5	6.67	57.69	2.5	60.19	66.86	0.45	0.22
		6	40-1	0.8	0.5	6.67	37.50	2.5	40.00	46.67	0.64	0.32
		7	40-2	2.4	0.5	6.67	12.50	2.5	15.00	21.67	1.38	0.69
		8	150S	0.5	0.5	6.67	60.00	2.5	62.50	69.17	0.43	0.22
Total												4.33
11	Pritam Nagar	1	14-1	0.67	0.5	5.45	44.78	2.5	47.28	52.73	0.57	0.28
		2	31-5	3	1	5.45	10.00	2.5	12.50	17.95	1.67	1.67
		3	31S	0.92	0.5	5.45	32.61	2.5	35.11	40.56	0.74	0.37
		4	33	2.67	0.5	5.45	11.24	2.5	13.74	19.19	1.56	0.78
		5	33/1S	1.04	0.5	5.45	28.85	2.5	31.35	36.80	0.82	0.41
		6	33/2	1	0.5	5.45	30.00	2.5	32.50	37.95	0.79	0.40
		7	34-3	0.48	0.5	5.45	62.50	2.5	65.00	70.45	0.43	0.21
		8	34-4	3	1	5.45	10.00	2.5	12.50	17.95	1.67	1.67
		9	34-5	1.5	0.5	5.45	20.00	2.5	22.50	27.95	1.07	0.54
Total												6.33
12	Arvind Sales Emporium	1	14-1	0.67	0.5	6.02	44.78	2.5	47.28	53.30	0.56	0.28
		2	31-5	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		3	31S	0.92	0.5	6.02	32.61	2.5	35.11	41.13	0.73	0.36
		4	33	2.67	0.5	6.02	11.24	2.5	13.74	19.76	1.52	0.76
		5	33/1S	1.04	0.5	6.02	28.85	2.5	31.35	37.37	0.80	0.40
		6	33/2	1	0.5	6.02	30.00	2.5	32.50	38.52	0.78	0.39
		7	34-3	0.48	0.5	6.02	62.50	2.5	65.00	71.02	0.42	0.21
		8	34-4	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		9	34-5	1.5	0.5	6.02	20.00	2.5	22.50	28.52	1.05	0.53
Total												6.17
13	Congress Bhawan	1	14-1	0.67	0.5	6.02	44.78	2.5	47.28	53.30	0.56	0.28
		2	31-5	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		3	31S	0.92	0.5	6.02	32.61	2.5	35.11	41.13	0.73	0.36
		4	33	2.67	0.5	6.02	11.24	2.5	13.74	19.76	1.52	0.76
		5	33/1S	1.04	0.5	6.02	28.85	2.5	31.35	37.37	0.80	0.40
		6	33/2	1	0.5	6.02	30.00	2.5	32.50	38.52	0.78	0.39
		7	34-3	0.48	0.5	6.02	62.50	2.5	65.00	71.02	0.42	0.21

		8	34-4	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		9	34-5	1.5	0.5	6.02	20.00	2.5	22.50	28.52	1.05	0.53
Total												6.17
14	V.S. Hospital	1	14-1	0.67	0.5	6.02	44.78	2.5	47.28	53.30	0.56	0.28
		2	31-5	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		3	31S	0.92	0.5	6.02	32.61	2.5	35.11	41.13	0.73	0.36
		4	33	2.67	0.5	6.02	11.24	2.5	13.74	19.76	1.52	0.76
Total												3.02
15	Madalpur	1	42	2	0.5	5.13	15.00	2.5	17.50	22.63	1.33	0.66
		2	43	0.75	0.5	5.13	40.00	2.5	42.50	47.63	0.63	0.31
		3	44-4	0.38	0.5	5.13	78.95	2.5	81.45	86.58	0.35	0.17
		4	45	1.09	0.5	5.13	27.52	2.5	30.02	35.15	0.85	0.43
		5	45/1	0.52	0.5	5.13	57.69	2.5	60.19	65.32	0.46	0.23
		6	52/2	4	1	5.13	7.50	2.5	10.00	15.13	1.98	1.98
		7	151-3	2.67	0.5	5.13	11.24	2.5	13.74	18.87	1.59	0.80
Total												4.59
16	Town Hall	1	42	2	0.5	5.13	15.00	2.5	17.50	22.63	1.33	0.66
		2	43	0.75	0.5	5.13	40.00	2.5	42.50	47.63	0.63	0.31
		3	44-4	0.38	0.5	5.13	78.95	2.5	81.45	86.58	0.35	0.17
		4	45	1.09	0.5	5.13	27.52	2.5	30.02	35.15	0.85	0.43
		5	45/1	0.52	0.5	5.13	57.69	2.5	60.19	65.32	0.46	0.23
		6	52/2	4	1	5.13	7.50	2.5	10.00	15.13	1.98	1.98
		7	151-3	2.67	0.5	5.13	11.24	2.5	13.74	18.87	1.59	0.80
Total												4.59
17	Fatehnagar	1	31-5	3	0.5	6.11	10.00	2.5	12.50	18.61	1.61	0.81
		2	31/4	3	0.5	6.11	10.00	2.5	12.50	18.61	1.61	0.81
		3	31/4S	0.4	0.5	6.11	75.00	2.5	77.50	83.61	0.36	0.18
		4	32	2	0.5	6.11	15.00	2.5	17.50	23.61	1.27	0.64
		5	35	2	0.5	6.11	15.00	2.5	17.50	23.61	1.27	0.64
		6	36/1	0.52	0.5	6.11	57.69	2.5	60.19	66.30	0.45	0.23
		7	38/1	0.33	0.5	6.11	90.91	2.5	93.41	99.52	0.30	0.15
		8	39-3	0.29	0.5	6.11	103.45	2.5	105.95	112.05	0.27	0.13
		9	40	0.23	0.5	6.11	130.43	2.5	132.93	139.04	0.22	0.11
		10	40-1	3	0.5	6.11	10.00	2.5	12.50	18.61	1.61	0.81
		11	40-2	2	0.5	6.11	15.00	2.5	17.50	23.61	1.27	0.64
		12	123	3	0.5	6.11	10.00	2.5	12.50	18.61	1.61	0.81
		13	150	3	0.5	6.11	10.00	2.5	12.50	18.61	1.61	0.81
		14	150S	0.5	0.5	6.11	60.00	2.5	62.50	68.61	0.44	0.22
		15	204	1.33	0.5	6.11	22.56	2.5	25.06	31.16	0.96	0.48
		16	401	6	1	6.11	5.00	2.5	7.50	13.61	2.20	2.20

Total												9.64
18	Viswakunj	1	33	2.67	1	5.79	11.24	2.5	13.74	19.53	1.54	1.54
		2	33/1S	1.04	0.5	5.79	28.85	2.5	31.35	37.14	0.81	0.40
		3	33/2	1	0.5	5.79	30.00	2.5	32.50	38.29	0.78	0.39
		4	200	0.35	0.5	5.79	85.71	2.5	88.21	94.00	0.32	0.16
		5	300	0.32	0.5	5.79	93.75	2.5	96.25	102.04	0.29	0.15
Total												2.64
19	Museum	1	14-1	0.67	0.5	5.79	44.78	2.5	47.28	53.07	0.57	0.28
		2	32	2	0.5	5.79	15.00	2.5	17.50	23.29	1.29	0.64
		3	33	2.67	0.5	5.79	11.24	2.5	13.74	19.53	1.54	0.77
		4	33/1s	1.04	0.5	5.79	28.85	2.5	31.35	37.14	0.81	0.40
		5	33/2	1	0.5	5.79	30.00	2.5	32.50	38.29	0.78	0.39
		6	36/1	0.52	0.5	5.79	57.69	2.5	60.19	65.98	0.45	0.23
		7	37-4	0.57	0.5	5.79	52.63	2.5	55.13	60.92	0.49	0.25
		8	39-3	0.29	0.5	5.79	103.45	2.5	105.95	111.74	0.27	0.13
		9	40-1	3	1	5.79	10.00	2.5	12.50	18.29	1.64	1.64
		10	47	0.86	0.5	5.79	34.88	2.5	37.38	43.17	0.69	0.35
		11	49	0.86	0.5	5.79	34.88	2.5	37.38	43.17	0.69	0.35
		12	49-1	0.8	0.5	5.79	37.50	2.5	40.00	45.79	0.66	0.33
		13	49-2	2.4	0.5	5.79	12.50	2.5	15.00	20.79	1.44	0.72
		14	49s	0.52	0.5	5.79	57.69	2.5	60.19	65.98	0.45	0.23
		15	58	1.5	0.5	5.79	20.00	2.5	22.50	28.29	1.06	0.53
		16	68	0.27	0.5	5.79	111.11	2.5	113.61	119.40	0.25	0.13
		17	136	2	0.5	5.79	15.00	2.5	17.50	23.29	1.29	0.64
		18	150	3	1	5.79	10.00	2.5	12.50	18.29	1.64	1.64
		19	150s	0.5	0.5	5.79	60.00	2.5	62.50	68.29	0.44	0.22
		20	900	1.04	0.5	5.79	28.85	2.5	31.35	37.14	0.81	0.40
Total												10.27
20	Lavanya Society	1	32	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
		2	34-3	0.48	0.5	6.23	62.50	2.5	65.00	71.23	0.42	0.21
		3	34-4	3	1	6.23	10.00	2.5	12.50	18.73	1.60	1.60
		4	37-4	0.57	0.5	6.23	52.63	2.5	55.13	61.36	0.49	0.24
		5	39-3	0.29	0.5	6.23	103.45	2.5	105.95	112.18	0.27	0.13
		6	40-1	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
Total												3.46
21	Jivraj Mehta Hospital	1	32	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
		2	34-3	0.48	0.5	6.23	62.50	2.5	65.00	71.23	0.42	0.21
		3	34-4	3	1	6.23	10.00	2.5	12.50	18.73	1.60	1.60
		4	37-4	0.57	0.5	6.23	52.63	2.5	55.13	61.36	0.49	0.24
		5	39-3	0.29	0.5	6.23	103.45	2.5	105.95	112.18	0.27	0.13

		6	40-1	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
Total												3.46
22	Bakeri Medical Research	1	32	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
		2	34-3	0.48	0.5	6.23	62.50	2.5	65.00	71.23	0.42	0.21
		3	34-4	3	1	6.23	10.00	2.5	12.50	18.73	1.60	1.60
		4	34-5	1.5	0.5	6.23	20.00	2.5	22.50	28.73	1.04	0.52
		5	37-4	0.57	0.5	6.23	52.63	2.5	55.13	61.36	0.49	0.24
		6	39-3	0.29	0.5	6.23	103.45	2.5	105.95	112.18	0.27	0.13
		7	40-1	2	0.5	6.23	15.00	2.5	17.50	23.73	1.26	0.63
		8	300	0.32	0.5	6.23	93.75	2.5	96.25	102.48	0.29	0.15
Total												4.12
23	Bhatta	1	31/4	3	0.5	6.90	10.00	2.5	12.50	19.40	1.55	0.77
		2	31/4s	0.4	0.5	6.90	75.00	2.5	77.50	84.40	0.36	0.18
		3	31s	0.92	0.5	6.90	32.61	2.5	35.11	42.00	0.71	0.36
		4	32	2	0.5	6.90	15.00	2.5	17.50	24.40	1.23	0.61
		5	35	2	0.5	6.90	15.00	2.5	17.50	24.40	1.23	0.61
		6	36/1	0.52	0.5	6.90	57.69	2.5	60.19	67.09	0.45	0.22
		7	38/1	0.33	0.5	6.90	90.91	2.5	93.41	100.30	0.30	0.15
		8	40	0.23	0.5	6.90	130.43	2.5	132.93	139.83	0.21	0.11
		9	40-1	3	0.5	6.90	10.00	2.5	12.50	19.40	1.55	0.77
		10	40-2	2	0.5	6.90	15.00	2.5	17.50	24.40	1.23	0.61
		11	123	3	0.5	6.90	10.00	2.5	12.50	19.40	1.55	0.77
		12	150	3	0.5	6.90	10.00	2.5	12.50	19.40	1.55	0.77
		13	150S	0.5	0.5	6.90	60.00	2.5	62.50	69.40	0.43	0.22
		14	204	1.33	0.5	6.90	22.56	2.5	25.06	31.95	0.94	0.47
		15	401	6	1	6.90	5.00	2.5	7.50	14.40	2.08	2.08
Total												8.72
24	Anand Nagar	1	31-5	3	0.5	5.45	10.00	2.5	12.50	17.95	1.67	0.84
		2	31/4	3	0.5	5.45	10.00	2.5	12.50	17.95	1.67	0.84
		3	31/4S	0.4	0.5	5.45	75.00	2.5	77.50	82.95	0.36	0.18
		4	32	2	0.5	5.45	15.00	2.5	17.50	22.95	1.31	0.65
		5	35	2	0.5	5.45	15.00	2.5	17.50	22.95	1.31	0.65
		6	36/1	0.52	0.5	5.45	57.69	2.5	60.19	65.64	0.46	0.23
		7	38/1	0.33	0.5	5.45	90.91	2.5	93.41	98.86	0.30	0.15
		8	39-3	0.29	0.5	5.45	103.45	2.5	105.95	111.40	0.27	0.13
		9	40	0.23	0.5	5.45	130.43	2.5	132.93	138.38	0.22	0.11
		10	40-1	3	0.5	5.45	10.00	2.5	12.50	17.95	1.67	0.84
		11	40-2	2	0.5	5.45	15.00	2.5	17.50	22.95	1.31	0.65
		12	123	3	0.5	5.45	10.00	2.5	12.50	17.95	1.67	0.84
		13	150	3	0.5	5.45	10.00	2.5	12.50	17.95	1.67	0.84

		14	150S	0.5	0.5	5.45	60.00	2.5	62.50	67.95	0.44	0.22
		15	204	1.33	0.5	5.45	22.56	2.5	25.06	30.51	0.98	0.49
		16	401	6	1	5.45	5.00	2.5	7.50	12.95	2.32	2.32
		17	205	1.33	0.5	5.45	22.56	2.5	25.06	30.51	0.98	0.49
Total												10.46
25	Malav Talav	1	32	2	0.5	5.45	15.00	2.5	17.50	22.95	1.31	0.65
		2	34-3	0.48	0.5	5.45	62.50	2.5	65.00	70.45	0.43	0.21
		3	34-4	3	1	5.45	10.00	2.5	12.50	17.95	1.67	1.67
		4	37-4	0.57	0.5	5.45	52.63	2.5	55.13	60.58	0.50	0.25
		5	39-3	0.29	0.5	5.45	103.45	2.5	105.95	111.40	0.27	0.13
		6	40-1	2	0.5	5.45	15.00	2.5	17.50	22.95	1.31	0.65
		7	200	0.35	0.5	5.45	85.71	2.5	88.21	93.66	0.32	0.16
Total												3.73
Total All SAPs for Paldi												132.15

Calculation of AI for **VASNA**

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Jawahar Nagar	1	31-5	3	0.5	7.04	10.00	2.5	12.50	19.54	1.54	0.77
		2	31/4	0.32	0.5	7.04	93.75	2.5	96.25	103.29	0.29	0.15
		3	31/4S	0.4	0.5	7.04	75.00	2.5	77.50	84.54	0.35	0.18
		4	31S	0.92	0.5	7.04	32.61	2.5	35.11	42.15	0.71	0.36
		5	32	2	0.5	7.04	15.00	2.5	17.50	24.54	1.22	0.61
		6	35	2	0.5	7.04	15.00	2.5	17.50	24.54	1.22	0.61
		7	38/1	0.33	0.5	7.04	90.91	2.5	93.41	100.45	0.30	0.15
		8	40	0.23	0.5	7.04	130.43	2.5	132.93	139.98	0.21	0.11
		9	40-1	3	0.5	7.04	10.00	2.5	12.50	19.54	1.54	0.77
		10	40-2	2	0.5	7.04	15.00	2.5	17.50	24.54	1.22	0.61
		11	123	3	0.5	7.04	10.00	2.5	12.50	19.54	1.54	0.77
		12	150	3	0.5	7.04	10.00	2.5	12.50	19.54	1.54	0.77
		13	150S	0.5	0.5	7.04	60.00	2.5	62.50	69.54	0.43	0.22
		14	160	2	0.5	7.04	15.00	2.5	17.50	24.54	1.22	0.61
		15	200	0.35	0.5	7.04	85.71	2.5	88.21	95.26	0.31	0.16
		16	204	1.33	0.5	7.04	22.56	2.5	25.06	32.10	0.93	0.47
		17	401	6	1	7.04	5.00	2.5	7.50	14.54	2.06	2.06
Total												9.35
2	Vasna Terminus	1	31-5	3	1	6.96	10.00	2.5	12.50	19.46	1.54	1.54
		2	31/4	0.32	0.5	6.96	93.75	2.5	96.25	103.21	0.29	0.15
		3	31/4S	0.4	0.5	6.96	75.00	2.5	77.50	84.46	0.36	0.18
		4	31S	0.92	0.5	6.96	32.61	2.5	35.11	42.07	0.71	0.36
		5	35	2	0.5	6.96	15.00	2.5	17.50	24.46	1.23	0.61
		6	36/1	0.51	0.5	6.96	58.82	2.5	61.32	68.28	0.44	0.22

		7	38/1	0.33	0.5	6.96	90.91	2.5	93.41	100.37	0.30	0.15
		8	40	0.23	0.5	6.96	130.43	2.5	132.93	139.89	0.21	0.11
		9	40-2	2	0.5	6.96	15.00	2.5	17.50	24.46	1.23	0.61
		10	150	3	1	6.96	10.00	2.5	12.50	19.46	1.54	1.54
		11	150S	0.5	0.5	6.96	60.00	2.5	62.50	69.46	0.43	0.22
		12	160	2	0.5	6.96	15.00	2.5	17.50	24.46	1.23	0.61
		13	202	0.32	0.5	6.96	93.75	2.5	96.25	103.21	0.29	0.15
Total												6.44
3	Kesariyaji	1	32	2	0.5	7.38	15.00	2.5	17.50	24.88	1.21	0.60
		2	34-3	0.48	0.5	7.38	62.50	2.5	65.00	72.38	0.41	0.21
		3	34-4	3	1	7.38	10.00	2.5	12.50	19.88	1.51	1.51
		4	37-4	0.57	0.5	7.38	52.63	2.5	55.13	62.51	0.48	0.24
		5	40-1	3	1	7.38	10.00	2.5	12.50	19.88	1.51	1.51
		6	300	0.32	0.5	7.38	93.75	2.5	96.25	103.63	0.29	0.14
Total												4.21
4	Gupta Nagar	1	31-5	3	1	5.93	10.00	2.5	12.50	18.43	1.63	1.63
		2	31/4	0.32	0.5	5.93	93.75	2.5	96.25	102.18	0.29	0.15
		3	31/4S	0.4	0.5	5.93	75.00	2.5	77.50	83.43	0.36	0.18
		4	31S	0.92	0.5	5.93	32.61	2.5	35.11	41.04	0.73	0.37
		5	35	2	0.5	5.93	15.00	2.5	17.50	23.43	1.28	0.64
		6	36/1	0.51	0.5	5.93	58.82	2.5	61.32	67.26	0.45	0.22
		7	38/1	0.33	0.5	5.93	90.91	2.5	93.41	99.34	0.30	0.15
		8	40	0.23	0.5	5.93	130.43	2.5	132.93	138.87	0.22	0.11
		9	40-2	2	0.5	5.93	15.00	2.5	17.50	23.43	1.28	0.64
		10	150	3	1	5.93	10.00	2.5	12.50	18.43	1.63	1.63
		11	150S	0.5	0.5	5.93	60.00	2.5	62.50	68.43	0.44	0.22
		12	160	2	0.5	5.93	15.00	2.5	17.50	23.43	1.28	0.64
		13	202	0.32	0.5	5.93	93.75	2.5	96.25	102.18	0.29	0.15
Total												6.71
5	Shiv Shakti Nagar	1	160	2	1	5.93	15.00	2.5	17.50	23.43	1.28	1.28
		2	202	0.32	0.5	5.93	93.75	2.5	96.25	102.18	0.29	0.15
Total												1.43
6	Pratap Kunj	1	31-5	3	1	5.55	10.00	2.5	12.50	18.05	1.66	1.66
		2	31/4	0.32	0.5	5.55	93.75	2.5	96.25	101.80	0.29	0.15
		3	31/4S	0.4	0.5	5.55	75.00	2.5	77.50	83.05	0.36	0.18
		4	31S	0.92	0.5	5.55	32.61	2.5	35.11	40.65	0.74	0.37
		5	35	2	0.5	5.55	15.00	2.5	17.50	23.05	1.30	0.65
		6	36/1	0.51	0.5	5.55	58.82	2.5	61.32	66.87	0.45	0.22
		7	38/1	0.33	0.5	5.55	90.91	2.5	93.41	98.95	0.30	0.15
		8	40	0.23	0.5	5.55	130.43	2.5	132.93	138.48	0.22	0.11
		9	40-2	2	0.5	5.55	15.00	2.5	17.50	23.05	1.30	0.65
		10	150	3	1	5.55	10.00	2.5	12.50	18.05	1.66	1.66
		11	150S	0.5	0.5	5.55	60.00	2.5	62.50	68.05	0.44	0.22
		12	160	2	0.5	5.55	15.00	2.5	17.50	23.05	1.30	0.65
		13	202	0.32	0.5	5.55	93.75	2.5	96.25	101.80	0.29	0.15
		14	204	1.33	0.5	5.55	22.56	2.5	25.06	30.60	0.98	0.49

Total												7.32
7	Ayyappa Mandir	1	33/1S	1.04	1	6.05	28.85	2.5	31.35	37.39	0.80	0.80
		2	38/1	0.33	0.5	6.05	90.91	2.5	93.41	99.45	0.30	0.15
		3	40	0.23	0.5	6.05	130.43	2.5	132.93	138.98	0.22	0.11
Total												1.06
8	Sorai Nagar	1	33/1S	1.04	1	6.05	28.85	2.5	31.35	37.39	0.80	0.80
		2	38/1	0.33	0.5	6.05	90.91	2.5	93.41	99.45	0.30	0.15
		3	40	0.23	0.5	6.05	130.43	2.5	132.93	138.98	0.22	0.11
Total												1.06
9	Ekta Tower	1	33	2.67	1	6.05	11.24	2.5	13.74	19.78	1.52	1.52
		2	33/1S	1.04	0.5	6.05	28.85	2.5	31.35	37.39	0.80	0.40
Total												1.92
10	Amar Flats	1	33	2.67	1	5.91	11.24	2.5	13.74	19.65	1.53	1.53
		2	33/1S	1.04	0.5	5.91	28.85	2.5	31.35	37.26	0.81	0.40
Total												1.93
11	Praveen Nagar	1	31-5	3	1	5.91	10.00	2.5	12.50	18.41	1.63	1.63
		2	31/4	0.32	0.5	5.91	93.75	2.5	96.25	102.16	0.29	0.15
		3	31/4S	0.4	0.5	5.91	75.00	2.5	77.50	83.41	0.36	0.18
		4	31S	0.92	0.5	5.91	32.61	2.5	35.11	41.02	0.73	0.37
		5	35	2	0.5	5.91	15.00	2.5	17.50	23.41	1.28	0.64
		6	36/1	0.51	0.5	5.91	58.82	2.5	61.32	67.23	0.45	0.22
		7	38/1	0.33	0.5	5.91	90.91	2.5	93.41	99.32	0.30	0.15
		8	40	0.23	0.5	5.91	130.43	2.5	132.93	138.84	0.22	0.11
		9	40-2	2	0.5	5.91	15.00	2.5	17.50	23.41	1.28	0.64
		10	150	3	1	5.91	10.00	2.5	12.50	18.41	1.63	1.63
		11	150S	0.5	0.5	5.91	60.00	2.5	62.50	68.41	0.44	0.22
		12	160	2	0.5	5.91	15.00	2.5	17.50	23.41	1.28	0.64
		13	202	0.32	0.5	5.91	93.75	2.5	96.25	102.16	0.29	0.15
		14	205	1.33	0.5	5.91	22.56	2.5	25.06	30.97	0.97	0.48
Total												7.21
Total All SAPs for Vasna												48.64

Calculation of AI for **NAVRANGPURA**

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Shivranjani	1	42	2	0.5	5.04	15.00	2.5	17.50	22.54	1.33	0.67
		2	45	1.09	0.5	5.04	27.52	2.5	30.02	35.06	0.86	0.43
		3	49/1	0.8	0.5	5.04	37.50	2.5	40.00	45.04	0.67	0.33
		4	151	2	0.5	5.04	15.00	2.5	17.50	22.54	1.33	0.67
		5	151-3	2.67	1	5.04	11.24	2.5	13.74	18.78	1.60	1.60
Total												3.69
2	Umiya Vijay Society	1	42	2	0.5	5.04	15.00	2.5	17.50	22.54	1.33	0.67
		2	44-4	0.38	0.5	5.04	78.95	2.5	81.45	86.49	0.35	0.17
		3	45	1.09	0.5	5.04	27.52	2.5	30.02	35.06	0.86	0.43
		4	45/1	0.52	0.5	5.04	57.69	2.5	60.19	65.23	0.46	0.23

		5	49	0.86	0.5	5.04	34.88	2.5	37.38	42.42	0.71	0.35
		6	49/1	0.8	0.5	5.04	37.50	2.5	40.00	45.04	0.67	0.33
		7	49S	0.52	0.5	5.04	57.69	2.5	60.19	65.23	0.46	0.23
		8	138-1	1	0.5	5.04	30.00	2.5	32.50	37.54	0.80	0.40
		9	151	2	0.5	5.04	15.00	2.5	17.50	22.54	1.33	0.67
		10	151-3	2.67	1	5.04	11.24	2.5	13.74	18.78	1.60	1.60
Total												5.08
3	Haridas Park (Zansi Ki Rani)	1	42	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
		2	44-4	0.38	0.5	5.94	78.95	2.5	81.45	87.38	0.34	0.17
		3	45	1.09	0.5	5.94	27.52	2.5	30.02	35.96	0.83	0.42
		4	45/1	0.52	0.5	5.94	57.69	2.5	60.19	66.13	0.45	0.23
		5	49	0.86	0.5	5.94	34.88	2.5	37.38	43.32	0.69	0.35
		6	49/1	0.8	0.5	5.94	37.50	2.5	40.00	45.94	0.65	0.33
		7	49S	0.52	0.5	5.94	57.69	2.5	60.19	66.13	0.45	0.23
		8	138-1	1	0.5	5.94	30.00	2.5	32.50	38.44	0.78	0.39
		9	151	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
		10	151-3	2.67	1	5.94	11.24	2.5	13.74	19.67	1.52	1.52
Total												4.91
4	L Colony	1	40/3	3	1	4.65	10.00	2.5	12.50	17.15	1.75	1.75
		2	44-4	0.38	0.5	4.65	78.95	2.5	81.45	86.10	0.35	0.17
		3	49/2	2.4	0.5	4.65	12.50	2.5	15.00	19.65	1.53	0.76
		4	160	2.5	0.5	4.65	12.00	2.5	14.50	19.15	1.57	0.78
		5	200	2	0.5	4.65	15.00	2.5	17.50	22.15	1.35	0.68
Total												4.15
5	Shefaly	1	40/3	3	1	4.65	10.00	2.5	12.50	17.15	1.75	1.75
		2	44/4	0.38	0.5	4.65	78.95	2.5	81.45	86.10	0.35	0.17
		3	47	0.86	0.5	4.65	34.88	2.5	37.38	42.03	0.71	0.36
		4	49/2	2.4	0.5	4.65	12.50	2.5	15.00	19.65	1.53	0.76
		5	50	1.4	0.5	4.65	21.43	2.5	23.93	28.58	1.05	0.52
		6	56	1.2	0.5	4.65	25.00	2.5	27.50	32.15	0.93	0.47
		7	151/4	2.4	0.5	4.65	12.50	2.5	15.00	19.65	1.53	0.76
		8	160	2.5	0.5	4.65	12.00	2.5	14.50	19.15	1.57	0.78
		9	300	0.35	0.5	4.65	85.71	2.5	88.21	92.86	0.32	0.16
Total												5.74
6	Gujarat University	1	40	0.23	0.5	4.83	130.43	2.5	132.93	137.76	0.22	0.11
		2	40/3	3	0.5	4.83	10.00	2.5	12.50	17.33	1.73	0.87
		3	46	0.86	0.5	4.83	34.88	2.5	37.38	42.21	0.71	0.36
		4	47	0.86	0.5	4.83	34.88	2.5	37.38	42.21	0.71	0.36
		5	49/2	2.4	0.5	4.83	12.50	2.5	15.00	19.83	1.51	0.76
		6	50	1.4	0.5	4.83	21.43	2.5	23.93	28.76	1.04	0.52
		7	52-2	4	1	4.83	7.50	2.5	10.00	14.83	2.02	2.02
		8	56	1.2	0.5	4.83	25.00	2.5	27.50	32.33	0.93	0.46
		9	56-1	0.32	0.5	4.83	93.75	2.5	96.25	101.08	0.30	0.15
		10	58	1.5	0.5	4.83	20.00	2.5	22.50	27.33	1.10	0.55
		11	68	0.27	0.5	4.83	111.11	2.5	113.61	118.44	0.25	0.13
		12	136	2	0.5	4.83	15.00	2.5	17.50	22.33	1.34	0.67

		13	142	1.2	0.5	4.83	25.00	2.5	27.50	32.33	0.93	0.46
		14	144	1.14	0.5	4.83	26.32	2.5	28.82	33.65	0.89	0.45
		15	151/4	2.4	0.5	4.83	12.50	2.5	15.00	19.83	1.51	0.76
		16	160	2.5	0.5	4.83	12.00	2.5	14.50	19.33	1.55	0.78
		17	200	2	0.5	4.83	15.00	2.5	17.50	22.33	1.34	0.67
		18	300	0.35	0.5	4.83	85.71	2.5	88.21	93.04	0.32	0.16
Total												10.22
7	Dadasaheb Na Pagla	1	40	0.23	0.5	4.83	130.43	2.5	132.93	137.76	0.22	0.11
		2	40/3	3	0.5	4.83	10.00	2.5	12.50	17.33	1.73	0.87
		3	46	0.86	0.5	4.83	34.88	2.5	37.38	42.21	0.71	0.36
		4	47	0.86	0.5	4.83	34.88	2.5	37.38	42.21	0.71	0.36
		5	49/2	2.4	0.5	4.83	12.50	2.5	15.00	19.83	1.51	0.76
		6	50	1.4	0.5	4.83	21.43	2.5	23.93	28.76	1.04	0.52
		7	52-2	4	1	4.83	7.50	2.5	10.00	14.83	2.02	2.02
		8	56	1.2	0.5	4.83	25.00	2.5	27.50	32.33	0.93	0.46
		9	56-1	0.32	0.5	4.83	93.75	2.5	96.25	101.08	0.30	0.15
		10	58	1.5	0.5	4.83	20.00	2.5	22.50	27.33	1.10	0.55
		11	68	0.27	0.5	4.83	111.11	2.5	113.61	118.44	0.25	0.13
		12	136	2	0.5	4.83	15.00	2.5	17.50	22.33	1.34	0.67
		13	142	1.2	0.5	4.83	25.00	2.5	27.50	32.33	0.93	0.46
		14	144	1.14	0.5	4.83	26.32	2.5	28.82	33.65	0.89	0.45
		15	151/4	2.4	0.5	4.83	12.50	2.5	15.00	19.83	1.51	0.76
		16	160	2.5	0.5	4.83	12.00	2.5	14.50	19.33	1.55	0.78
		17	200	2	0.5	4.83	15.00	2.5	17.50	22.33	1.34	0.67
		18	300	0.35	0.5	4.83	85.71	2.5	88.21	93.04	0.32	0.16
Total												10.22
8	Suchita Apartment	1	51S	0.39	0.5	4.52	76.92	2.5	79.42	83.94	0.36	0.18
		2	56	1.2	1	4.52	25.00	2.5	27.50	32.02	0.94	0.94
		3	56-1	0.32	0.5	4.52	93.75	2.5	96.25	100.77	0.30	0.15
Total												1.26
9	Saurabh Society	1	51S	0.39	0.5	4.52	76.92	2.5	79.42	83.94	0.36	0.18
		2	51R	1.5	0.5	4.52	20.00	2.5	22.50	27.02	1.11	0.56
		3	52-2	4	1	4.52	7.50	2.5	10.00	14.52	2.07	2.07
		4	58	1.5	0.5	4.52	20.00	2.5	22.50	27.02	1.11	0.56
		5	66/1	1	0.5	4.52	30.00	2.5	32.50	37.02	0.81	0.41
		6	136	2	0.5	4.52	15.00	2.5	17.50	22.02	1.36	0.68
		7	400	0.32	0.5	4.52	93.75	2.5	96.25	100.77	0.30	0.15
Total												4.59
10	Apang Manav Mandal	1	43	0.75	0.5	4.89	40.00	2.5	42.50	47.39	0.63	0.32
		2	56	1.2	0.5	4.89	25.00	2.5	27.50	32.39	0.93	0.46
		3	800	2	1	4.89	15.00	2.5	17.50	22.39	1.34	1.34
Total												2.12
11	Sahjanand College	1	40/3	3	1	4.89	10.00	2.5	12.50	17.39	1.73	1.73
		2	44-4	0.38	0.5	4.89	78.95	2.5	81.45	86.34	0.35	0.17
		3	49/2	2.4	0.5	4.89	12.50	2.5	15.00	19.89	1.51	0.75
		4	50	1.5	0.5	4.89	20.00	2.5	22.50	27.39	1.10	0.55

		5	151/4	2.4	0.5	4.89	12.50	2.5	15.00	19.89	1.51	0.75
		6	160	2.5	0.5	4.89	12.00	2.5	14.50	19.39	1.55	0.77
		7	200	2	0.5	4.89	15.00	2.5	17.50	22.39	1.34	0.67
Total												5.40
12	Swastik Society	1	40/3	3	1	4.15	10.00	2.5	12.50	16.65	1.80	1.80
		2	46	0.86	0.5	4.15	34.88	2.5	37.38	41.53	0.72	0.36
		3	50	1.5	0.5	4.15	20.00	2.5	22.50	26.65	1.13	0.56
		4	51 S	0.39	0.5	4.15	76.92	2.5	79.42	83.57	0.36	0.18
		5	51R	1.5	0.5	4.15	20.00	2.5	22.50	26.65	1.13	0.56
		6	56	1.2	0.5	4.15	25.00	2.5	27.50	31.65	0.95	0.47
		7	56-1	0.32	0.5	4.15	93.75	2.5	96.25	100.40	0.30	0.15
		8	65/1	0.92	0.5	4.15	32.61	2.5	35.11	39.26	0.76	0.38
		9	144	1.14	0.5	4.15	26.32	2.5	28.82	32.97	0.91	0.46
		10	500	2	0.5	4.15	15.00	2.5	17.50	21.65	1.39	0.69
Total												5.62
13	Passport Office	1	40	0.23	0.5	4.83	130.43	2.5	132.93	137.76	0.22	0.11
		2	44-4	0.38	1	4.83	78.95	2.5	81.45	86.28	0.35	0.35
Total												0.46
14	Commerce college	1	40/3	3	1	4.55	10.00	2.5	12.50	17.05	1.76	1.76
		2	47	0.86	0.5	4.55	34.88	2.5	37.38	41.93	0.72	0.36
		3	50	1.5	0.5	4.55	20.00	2.5	22.50	27.05	1.11	0.55
		4	51S	0.39	0.5	4.55	76.92	2.5	79.42	83.97	0.36	0.18
		5	51R	1.5	0.5	4.55	20.00	2.5	22.50	27.05	1.11	0.55
		6	56	1.2	0.5	4.55	25.00	2.5	27.50	32.05	0.94	0.47
		7	56-1	0.32	0.5	4.55	93.75	2.5	96.25	100.80	0.30	0.15
		8	65/1	0.92	0.5	4.55	32.61	2.5	35.11	39.66	0.76	0.38
		9	144	1.14	0.5	4.55	26.32	2.5	28.82	33.37	0.90	0.45
		10	400	0.32	0.5	4.55	93.75	2.5	96.25	100.80	0.30	0.15
Total												5.00
15	Commerce College Hostel	1	40/3	3	1	4.55	10.00	2.5	12.50	17.05	1.76	1.76
		2	47	0.86	0.5	4.55	34.88	2.5	37.38	41.93	0.72	0.36
		3	50	1.5	0.5	4.55	20.00	2.5	22.50	27.05	1.11	0.55
		4	51S	0.39	0.5	4.55	76.92	2.5	79.42	83.97	0.36	0.18
		5	51R	1.5	0.5	4.55	20.00	2.5	22.50	27.05	1.11	0.55
		6	56	1.2	0.5	4.55	25.00	2.5	27.50	32.05	0.94	0.47
		7	56-1	0.32	0.5	4.55	93.75	2.5	96.25	100.80	0.30	0.15
		8	65/1	0.92	0.5	4.55	32.61	2.5	35.11	39.66	0.76	0.38
		9	144	1.14	0.5	4.55	26.32	2.5	28.82	33.37	0.90	0.45
		10	400	0.32	0.5	4.55	93.75	2.5	96.25	100.80	0.30	0.15
Total												5.00
16	Nehru Nagar Char Rasta	1	40/3	3	1	4.89	10.00	2.5	12.50	17.39	1.73	1.73
		2	44-4	0.38	0.5	4.89	78.95	2.5	81.45	86.34	0.35	0.17
		3	49/2	2.4	0.5	4.89	12.50	2.5	15.00	19.89	1.51	0.75
		4	151/4	2.4	0.5	4.89	12.50	2.5	15.00	19.89	1.51	0.75
		5	160	2.5	0.5	4.89	12.00	2.5	14.50	19.39	1.55	0.77
		6	200	2	0.5	4.89	15.00	2.5	17.50	22.39	1.34	0.67

Total												4.85
17	Government Quarter	1	45	1.09	0.5	5.10	27.52	2.5	30.02	35.12	0.85	0.43
		2	45/1	0.52	0.5	5.10	57.69	2.5	60.19	65.29	0.46	0.23
		3	49	0.86	0.5	5.10	34.88	2.5	37.38	42.48	0.71	0.35
		4	49/1	0.8	0.5	5.10	37.50	2.5	40.00	45.10	0.67	0.33
		5	49/2	2.4	0.5	5.10	12.50	2.5	15.00	20.10	1.49	0.75
		6	49S	0.52	0.5	5.10	57.69	2.5	60.19	65.29	0.46	0.23
		7	138-1	1	0.5	5.10	30.00	2.5	32.50	37.60	0.80	0.40
		8	151	2	0.5	5.10	15.00	2.5	17.50	22.60	1.33	0.66
		9	151-3	2.67	1	5.10	11.24	2.5	13.74	18.83	1.59	1.59
		10	151/4	2.4	0.5	5.10	12.50	2.5	15.00	20.10	1.49	0.75
Total												5.72
18	Satyakam Society	1	44-4	0.38	0.5	5.10	78.95	2.5	81.45	86.54	0.35	0.17
		2	45	1.09	0.5	5.10	27.52	2.5	30.02	35.12	0.85	0.43
		3	45/1	0.52	0.5	5.10	57.69	2.5	60.19	65.29	0.46	0.23
		4	49	0.86	0.5	5.10	34.88	2.5	37.38	42.48	0.71	0.35
		5	49/1	0.8	0.5	5.10	37.50	2.5	40.00	45.10	0.67	0.33
		6	49S	0.52	0.5	5.10	57.69	2.5	60.19	65.29	0.46	0.23
		7	138-1	1	0.5	5.10	30.00	2.5	32.50	37.60	0.80	0.40
		8	151	2	0.5	5.10	15.00	2.5	17.50	22.60	1.33	0.66
		9	151-3	2.67	1	5.10	11.24	2.5	13.74	18.83	1.59	1.59
Total												4.40
19	Panjrapol	1	40/3	3	1	5.22	10.00	2.5	12.50	17.72	1.69	1.69
		2	44-4	0.38	0.5	5.22	78.95	2.5	81.45	86.66	0.35	0.17
		3	46	0.86	0.5	5.22	34.88	2.5	37.38	42.60	0.70	0.35
		4	49/2	2.4	0.5	5.22	12.50	2.5	15.00	20.22	1.48	0.74
		5	50	1.5	0.5	5.22	20.00	2.5	22.50	27.72	1.08	0.54
		6	56	1.2	0.5	5.22	25.00	2.5	27.50	32.72	0.92	0.46
		7	151/4	2.4	0.5	5.22	12.50	2.5	15.00	20.22	1.48	0.74
		8	160	2.5	0.5	5.22	12.00	2.5	14.50	19.72	1.52	0.76
		9	200	2	0.5	5.22	15.00	2.5	17.50	22.72	1.32	0.66
Total												6.12
Total All SAPs for Navrangpura												94.55

Calculation of AI for S.P. STADIUM

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	R.T.O. Circle	1	13/1	3	0.5	5.02	10.00	2.5	12.50	17.52	1.71	0.86
		2	22	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		3	88	2	0.5	5.02	15.00	2.5	17.50	22.52	1.33	0.67
		4	202	1	0.5	5.02	30.00	2.5	32.50	37.52	0.80	0.40
		5	204	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		6	205	1.33	0.5	5.02	22.56	2.5	25.06	30.08	1.00	0.50
		7	401	6	1	5.02	5.00	2.5	7.50	12.52	2.40	2.40

Total											5.81
2	Shubhash Bridge Circle	1	13/1	3	0.5	5.00	10.00	2.5	12.50	17.50	1.71	0.86
		2	22	1.33	0.5	5.00	22.56	2.5	25.06	30.06	1.00	0.50
		3	88	2	0.5	5.00	15.00	2.5	17.50	22.50	1.33	0.67
		4	89-3S	1.5	0.5	5.00	20.00	2.5	22.50	27.50	1.09	0.55
		5	85-S	1.2	0.5	5.00	25.00	2.5	27.50	32.50	0.92	0.46
		6	202	1	0.5	5.00	30.00	2.5	32.50	37.50	0.80	0.40
		7	204	1.33	0.5	5.00	22.56	2.5	25.06	30.06	1.00	0.50
		8	401	6	1	5.00	5.00	2.5	7.50	12.50	2.40	2.40
Total												6.33
Total All SAPs for S.P Stadium												12.14

Calculation of AI for NARANPURA

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Pragatinagar AMTS Bus Stop	1	40	0.22	0.5	6.08	136.36	2.5	138.86	144.94	0.21	0.10
		2	64/3	1	1	6.08	30.00	2.5	32.50	38.58	0.78	0.78
		3	67/1S	0.6	0.5	6.08	50.00	2.5	52.50	58.58	0.51	0.26
		4	68	0.27	0.5	6.08	111.11	2.5	113.61	119.69	0.25	0.13
		5	202	0.32	0.5	6.08	93.75	2.5	96.25	102.33	0.29	0.15
Total												1.41
2	Harish Chandra Park	1	40	0.22	0.5	4.78	136.36	2.5	138.86	143.64	0.21	0.10
		2	64/3	1	0.5	4.78	30.00	2.5	32.50	37.28	0.80	0.40
		3	67/1S	0.6	0.5	4.78	50.00	2.5	52.50	57.28	0.52	0.26
		4	68	0.27	0.5	4.78	111.11	2.5	113.61	118.39	0.25	0.13
		5	63	1	0.5	4.78	30.00	2.5	32.50	37.28	0.80	0.40
		6	64	2.4	1	4.78	12.50	2.5	15.00	19.78	1.52	1.52
Total												2.81
3	Gujarat Housing Board	1	63	1	0.5	4.36	30.00	2.5	32.50	36.86	0.81	0.41
		2	64	2.4	1	4.36	12.50	2.5	15.00	19.36	1.55	1.55
		3	65/1	1	0.5	4.36	30.00	2.5	32.50	36.86	0.81	0.41
		4	69	2	0.5	4.36	15.00	2.5	17.50	21.86	1.37	0.69
		5	70	1	0.5	4.36	30.00	2.5	32.50	36.86	0.81	0.41
Total												3.46
4	Pallav Society	1	63	1	0.5	4.81	30.00	2.5	32.50	37.31	0.80	0.40
		2	64	2.4	1	4.81	12.50	2.5	15.00	19.81	1.51	1.51
		3	64-1	0.75	0.5	4.81	40.00	2.5	42.50	47.31	0.63	0.32
		4	64/2	0.75	0.5	4.81	40.00	2.5	42.50	47.31	0.63	0.32
		5	65/1	1	0.5	4.81	30.00	2.5	32.50	37.31	0.80	0.40
		6	69	2	0.5	4.81	15.00	2.5	17.50	22.31	1.34	0.67
		7	70	1	0.5	4.81	30.00	2.5	32.50	37.31	0.80	0.40
Total												4.03

5	Naranpura Char Rasta	1	63	1	0.5	5.25	30.00	2.5	32.50	37.75	0.79	0.40
		2	64	2.4	0.5	5.25	12.50	2.5	15.00	20.25	1.48	0.74
		3	64-1	0.75	0.5	5.25	40.00	2.5	42.50	47.75	0.63	0.31
		4	64/2	0.75	0.5	5.25	40.00	2.5	42.50	47.75	0.63	0.31
		5	65	0.57	0.5	5.25	52.63	2.5	55.13	60.38	0.50	0.25
		6	65/2	0.23	0.5	5.25	130.43	2.5	132.93	138.18	0.22	0.11
		7	65/3	1	0.5	5.25	30.00	2.5	32.50	37.75	0.79	0.40
		8	66-4	0.8	0.5	5.25	37.50	2.5	40.00	45.25	0.66	0.33
		9	66/3	3	1	5.25	10.00	2.5	12.50	17.75	1.69	1.69
		10	66/3S	2	0.5	5.25	15.00	2.5	17.50	22.75	1.32	0.66
		11	69	2	0.5	5.25	15.00	2.5	17.50	22.75	1.32	0.66
		12	70/1	1.2	0.5	5.25	25.00	2.5	27.50	32.75	0.92	0.46
		13	400	2	0.5	5.25	15.00	2.5	17.50	22.75	1.32	0.66
Total												6.98
6	Amikunj	1	40	0.22	0.5	4.49	136.36	2.5	138.86	143.35	0.21	0.10
		2	65/2	0.23	0.5	4.49	130.43	2.5	132.93	137.42	0.22	0.11
		3	65/3	1	0.5	4.49	30.00	2.5	32.50	36.99	0.81	0.41
		4	66/3	3	1	4.49	10.00	2.5	12.50	16.99	1.77	1.77
		5	66/3S	2	0.5	4.49	15.00	2.5	17.50	21.99	1.36	0.68
		6	70/1	1.2	0.5	4.49	25.00	2.5	27.50	31.99	0.94	0.47
		7	300	0.32	0.5	4.49	93.75	2.5	96.25	100.74	0.30	0.15
		8	500	2	0.5	4.49	15.00	2.5	17.50	21.99	1.36	0.68
Total												4.37
7	Devendra park	1	40	0.22	0.5	4.24	136.36	2.5	138.86	143.10	0.21	0.10
		2	65/2	0.23	0.5	4.24	130.43	2.5	132.93	137.17	0.22	0.11
		3	65/3	1	0.5	4.24	30.00	2.5	32.50	36.74	0.82	0.41
		4	66/3	3	1	4.24	10.00	2.5	12.50	16.74	1.79	1.79
		5	66/3S	2	0.5	4.24	15.00	2.5	17.50	21.74	1.38	0.69
		6	70/1	1.2	0.5	4.24	25.00	2.5	27.50	31.74	0.95	0.47
		7	300	0.32	0.5	4.24	93.75	2.5	96.25	100.49	0.30	0.15
		8	500	2	0.5	4.24	15.00	2.5	17.50	21.74	1.38	0.69
Total												4.42
8	AEC Zonal Office	1	65	0.57	0.5	5.94	52.63	2.5	55.13	61.07	0.49	0.25
		2	66/3	3	1	5.94	10.00	2.5	12.50	18.44	1.63	1.63
		3	65/2	0.23	0.5	5.94	130.43	2.5	132.93	138.88	0.22	0.11
		4	65/3	1	0.5	5.94	30.00	2.5	32.50	38.44	0.78	0.39
		5	66	0.36	0.5	5.94	83.33	2.5	85.83	91.77	0.33	0.16
		6	66-4	0.8	0.5	5.94	37.50	2.5	40.00	45.94	0.65	0.33
		7	70/1	1.2	0.5	5.94	25.00	2.5	27.50	33.44	0.90	0.45
		8	160	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
		9	400	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
Total												4.59
Total All SAPs for Naranpura												32.07

Calculation of AI for NAVA VADAJ

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Neel Complex	1	74	1.71	1	5.38	17.54	2.5	20.04	25.42	1.18	1.18
		2	79	1.5	0.5	5.38	20.00	2.5	22.50	27.88	1.08	0.54
Total												1.72
2	Bhavsar Hostel	1	74	1.71	1	5.38	17.54	2.5	20.04	25.42	1.18	1.18
		2	79	1.5	0.5	5.38	20.00	2.5	22.50	27.88	1.08	0.54
Total												1.72
3	Vyash Wadi	1	74	1.71	0.5	5.38	17.54	2.5	20.04	25.42	1.18	0.59
		2	79	1.5	0.5	5.38	20.00	2.5	22.50	27.88	1.08	0.54
		3	74/1	2	1	5.38	15.00	2.5	17.50	22.88	1.31	1.31
Total												2.44
4	Akhbar Nagar	1	800	1.14	0.5	6.00	26.32	2.5	28.82	34.82	0.86	0.43
		2	137	1	0.5	6.00	30.00	2.5	32.50	38.50	0.78	0.39
		3	137S	1.5	0.5	6.00	20.00	2.5	22.50	28.50	1.05	0.53
		4	146-1	4	1	6.00	7.50	2.5	10.00	16.00	1.88	1.88
		5	202	0.32	0.5	6.00	93.75	2.5	96.25	102.25	0.29	0.15
		6	40-2	2	0.5	6.00	15.00	2.5	17.50	23.50	1.28	0.64
		7	40-3	1.5	0.5	6.00	20.00	2.5	22.50	28.50	1.05	0.53
		8	82	1.2	0.5	6.00	25.00	2.5	27.50	33.50	0.90	0.45
		9	900	1.04	0.5	6.00	28.85	2.5	31.35	37.35	0.80	0.40
Total												5.38
5	Shrinath Apartment	1	74	1.71	0.5	5.08	17.54	2.5	20.04	25.12	1.19	0.60
		2	79	1.5	0.5	5.08	20.00	2.5	22.50	27.58	1.09	0.54
		3	74/1	2	1	5.08	15.00	2.5	17.50	22.58	1.33	1.33
Total												2.47
6	Chandrabhaga Row House	1	74	1.71	1	5.08	17.54	2.5	20.04	25.12	1.19	1.19
		2	79	1.5	0.5	5.08	20.00	2.5	22.50	27.58	1.09	0.54
Total												1.74
7	Hari Om apartment	1	74/1	2	1	5.08	15.00	2.5	17.50	22.58	1.33	1.33
Total												1.33
8	R.H. Patel College	1	74	1.71	1	4.52	17.54	2.5	20.04	24.56	1.22	1.22
		2	79	1.5	0.5	4.52	20.00	2.5	22.50	27.02	1.11	0.56
Total												1.78
9	Swaminarayan Mandir	1	74/1	2	1	4.52	15.00	2.5	17.50	22.02	1.36	1.36
Total												1.36
10	Nava Vadaj	1	40/3	1.5	0.5	6.19	20.00	2.5	22.50	28.69	1.05	0.52
		2	70-2	1	0.5	6.19	30.00	2.5	32.50	38.69	0.78	0.39
		3	71-1	2	0.5	6.19	15.00	2.5	17.50	23.69	1.27	0.63
		4	72	3	0.5	6.19	10.00	2.5	12.50	18.69	1.60	0.80
		5	82	1.2	0.5	6.19	25.00	2.5	27.50	33.69	0.89	0.45
		6	137	1	0.5	6.19	30.00	2.5	32.50	38.69	0.78	0.39
		7	137S	1.5	0.5	6.19	20.00	2.5	22.50	28.69	1.05	0.52

		8	146-1	4	1	6.19	7.50	2.5	10.00	16.19	1.85	1.85
		9	40-2	1	0.5	6.19	30.00	2.5	32.50	38.69	0.78	0.39
		10	77	2	0.5	6.19	15.00	2.5	17.50	23.69	1.27	0.63
		11	130/4	1.6	0.5	6.19	18.75	2.5	21.25	27.44	1.09	0.55
Total												7.12
11	Krushna Nagar	1	40/3	1.5	0.5	5.11	20.00	2.5	22.50	27.61	1.09	0.54
		2	70-2	1	0.5	5.11	30.00	2.5	32.50	37.61	0.80	0.40
		3	71-1	2	0.5	5.11	15.00	2.5	17.50	22.61	1.33	0.66
		4	72	3	1	5.11	10.00	2.5	12.50	17.61	1.70	1.70
		5	82	1.2	0.5	5.11	25.00	2.5	27.50	32.61	0.92	0.46
		6	137	1	0.5	5.11	30.00	2.5	32.50	37.61	0.80	0.40
		7	40-2	1	0.5	5.11	30.00	2.5	32.50	37.61	0.80	0.40
		8	77	2	0.5	5.11	15.00	2.5	17.50	22.61	1.33	0.66
		9	130/4	1.6	0.5	5.11	18.75	2.5	21.25	26.36	1.14	0.57
Total												5.80
12	Poonam Party Plot	1	40/3	1.5	0.5	4.96	20.00	2.5	22.50	27.46	1.09	0.55
		2	70-2	1	0.5	4.96	30.00	2.5	32.50	37.46	0.80	0.40
		3	71-1	2	1	4.96	15.00	2.5	17.50	22.46	1.34	1.34
		4	82	1.2	0.5	4.96	25.00	2.5	27.50	32.46	0.92	0.46
		5	137	1	0.5	4.96	30.00	2.5	32.50	37.46	0.80	0.40
		6	40-2	1	0.5	4.96	30.00	2.5	32.50	37.46	0.80	0.40
		7	77	2	1	4.96	15.00	2.5	17.50	22.46	1.34	1.34
		8	130/4	1.6	0.5	4.96	18.75	2.5	21.25	26.21	1.14	0.57
Total												5.45
13	N. R. Patel Park	1	74	1.71	1	4.96	17.54	2.5	20.04	25.00	1.20	1.20
		2	79	1.5	0.5	4.96	20.00	2.5	22.50	27.46	1.09	0.55
Total												1.75
14	Nava Vadaj Police Chowki	1	74	1.71	1	5.15	17.54	2.5	20.04	25.19	1.19	1.19
		2	79	1.5	0.5	5.15	20.00	2.5	22.50	27.65	1.09	0.54
Total												1.73
Total All SAPs for Nava Vadaj												41.79

Calculation of AI for SABARMATI

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Laxmi Nagar Bus Stand-1	1	75	0.83	0.5	4.74	36.14	2.5	38.64	43.38	0.69	0.35
		2	85-s	1.2	0.5	4.74	25.00	2.5	27.50	32.24	0.93	0.47
		3	89-3s	1.5	0.5	4.74	20.00	2.5	22.50	27.24	1.10	0.55
		4	89/1	1	0.5	4.74	30.00	2.5	32.50	37.24	0.81	0.40
		5	90-s	1.67	0.5	4.74	17.96	2.5	20.46	25.20	1.19	0.60
		6	401	6	1	4.74	5.00	2.5	7.50	12.24	2.45	2.45
Total												4.81
2	Laxmi Nagar Bus Stand-2	1	75	0.83	0.5	4.74	36.14	2.5	38.64	43.38	0.69	0.35
		2	85-s	1.2	0.5	4.74	25.00	2.5	27.50	32.24	0.93	0.47
		3	89-3s	1.5	0.5	4.74	20.00	2.5	22.50	27.24	1.10	0.55
		4	401	6	1	4.74	5.00	2.5	7.50	12.24	2.45	2.45

Total												3.81
3	Acher Depot	1	75	0.83	0.5	6.11	36.14	2.5	38.64	44.76	0.67	0.34
		2	85-s	1.2	0.5	6.11	25.00	2.5	27.50	33.61	0.89	0.45
		3	89-3s	1.5	0.5	6.11	20.00	2.5	22.50	28.61	1.05	0.52
		4	89/1	1	0.5	6.11	30.00	2.5	32.50	38.61	0.78	0.39
		5	90-s	1.67	0.5	6.11	17.96	2.5	20.46	26.58	1.13	0.56
		6	401	6	1	6.11	5.00	2.5	7.50	13.61	2.20	2.20
Total												4.46
4	Gandhi Bagh	1	22	1.33	1	5.07	22.56	2.5	25.06	30.13	1.00	1.00
Total												1.00
5	Gandhi Vas	1	22	1.33	0.5	5.07	22.56	2.5	25.06	30.13	1.00	0.50
		2	89/1	1	0.5	5.07	30.00	2.5	32.50	37.57	0.80	0.40
		3	90-s	1.67	1	5.07	17.96	2.5	20.46	25.54	1.17	1.17
Total												2.07
6	Sabarmati Toll Naka	1	22	1.33	0.5	5.32	22.56	2.5	25.06	30.38	0.99	0.49
		2	75	0.83	0.5	5.32	36.14	2.5	38.64	43.96	0.68	0.34
		3	85-s	1.2	0.5	5.32	25.00	2.5	27.50	32.82	0.91	0.46
		4	89-3s	1.5	0.5	5.32	20.00	2.5	22.50	27.82	1.08	0.54
		5	89/1	1	0.5	5.32	30.00	2.5	32.50	37.82	0.79	0.40
		6	90-s	1.67	1	5.32	17.96	2.5	20.46	25.78	1.16	1.16
Total												3.39
7	Abukala Cross Road	1	22	1.33	0.5	4.17	22.56	2.5	25.06	29.23	1.03	0.51
		2	84	1.09	0.5	4.17	27.52	2.5	30.02	34.19	0.88	0.44
		3	85-s	1.2	0.5	4.17	25.00	2.5	27.50	31.67	0.95	0.47
		4	89-3s	1.5	0.5	4.17	20.00	2.5	22.50	26.67	1.12	0.56
		5	89/1	1	0.5	4.17	30.00	2.5	32.50	36.67	0.82	0.41
		6	90-s	1.67	0.5	4.17	17.96	2.5	20.46	24.63	1.22	0.61
		7	401	6	1	4.17	5.00	2.5	7.50	11.67	2.57	2.57
Total												5.58
8	Chintamani Society	1	84	1.09	0.5	4.17	27.52	2.5	30.02	34.19	0.88	0.44
		2	85/s	1.2	0.5	4.17	25.00	2.5	27.50	31.67	0.95	0.47
		3	89-3s	1.5	0.5	4.17	20.00	2.5	22.50	26.67	1.12	0.56
		4	89/1	1	0.5	4.17	30.00	2.5	32.50	36.67	0.82	0.41
		5	401	6	1	4.17	5.00	2.5	7.50	11.67	2.57	2.57
Total												4.45
9	Dr. B.R. Ambedkar Chowk	1	84	1.09	0.5	4.88	27.52	2.5	30.02	34.90	0.86	0.43
		2	85/s	1.2	0.5	4.88	25.00	2.5	27.50	32.38	0.93	0.46
		3	89-3s	1.5	0.5	4.88	20.00	2.5	22.50	27.38	1.10	0.55
		4	89/1	1	0.5	4.88	30.00	2.5	32.50	37.38	0.80	0.40
		5	401	6	1	4.88	5.00	2.5	7.50	12.38	2.42	2.42
Total												4.27
10	Municipal Nagar	1	85/s	1.2	0.5	4.50	25.00	2.5	27.50	32.00	0.94	0.47
		2	89-3s	1.5	0.5	4.50	20.00	2.5	22.50	27.00	1.11	0.56
		3	89/1	1	0.5	4.50	30.00	2.5	32.50	37.00	0.81	0.41
		4	401	6	1	4.50	5.00	2.5	7.50	12.00	2.50	2.50
Total												3.93

11	Rathi Apartment	1	85/s	1.2	0.5	4.50	25.00	2.5	27.50	32.00	0.94	0.47
		2	89-3s	1.5	0.5	4.50	20.00	2.5	22.50	27.00	1.11	0.56
		3	89/1	1	0.5	4.50	30.00	2.5	32.50	37.00	0.81	0.41
		4	401	6	1	4.50	5.00	2.5	7.50	12.00	2.50	2.50
Total												3.93
12	Power House Quarter	1	85/s	1.2	0.5	5.47	25.00	2.5	27.50	32.97	0.91	0.45
		2	89-3s	1.5	0.5	5.47	20.00	2.5	22.50	27.97	1.07	0.54
		3	89/1	1	0.5	5.47	30.00	2.5	32.50	37.97	0.79	0.40
		4	401	6	1	5.47	5.00	2.5	7.50	12.97	2.31	2.31
Total												3.70
13	Power House AMTS STOP	1	85/s	1.2	0.5	5.47	25.00	2.5	27.50	32.97	0.91	0.45
		2	89-3s	1.5	0.5	5.47	20.00	2.5	22.50	27.97	1.07	0.54
		3	89/1	1	0.5	5.47	30.00	2.5	32.50	37.97	0.79	0.40
		4	401	6	1	5.47	5.00	2.5	7.50	12.97	2.31	2.31
Total												3.70
Total All SAPs for Sabarmati												49.10

Calculation of AI for RANIP

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Dr. B.R. Ambedkar Foundation	1	13/1	3	1	4.60	10.00	2.5	12.50	17.10	1.75	1.75
		2	88	2	0.5	4.60	15.00	2.5	17.50	22.10	1.36	0.68
		3	202	1	0.5	4.60	30.00	2.5	32.50	37.10	0.81	0.40
		4	204	1.33	0.5	4.60	22.56	2.5	25.06	29.66	1.01	0.51
Total												3.34
2	Vanraj Society	1	13/1	3	1	4.60	10.00	2.5	12.50	17.10	1.75	1.75
		2	88	2	0.5	4.60	15.00	2.5	17.50	22.10	1.36	0.68
		3	202	1	0.5	4.60	30.00	2.5	32.50	37.10	0.81	0.40
		4	205	1.33	0.5	4.60	22.56	2.5	25.06	29.66	1.01	0.51
Total												3.34
3	Umang Park Society	1	13/1	3	1	4.10	10.00	2.5	12.50	16.60	1.81	1.81
		2	88	2	0.5	4.10	15.00	2.5	17.50	21.60	1.39	0.69
		3	202	1	0.5	4.10	30.00	2.5	32.50	36.60	0.82	0.41
		4	205	1.33	0.5	4.10	22.56	2.5	25.06	29.16	1.03	0.51
Total												3.43
4	Hanuman Park Society	1	13/1	3	1	4.10	10.00	2.5	12.50	16.60	1.81	1.81
		2	88	2	0.5	4.10	15.00	2.5	17.50	21.60	1.39	0.69
		3	202	1	0.5	4.10	30.00	2.5	32.50	36.60	0.82	0.41
		4	205	1.33	0.5	4.10	22.56	2.5	25.06	29.16	1.03	0.51
Total												3.43
5	Radha Swami Satsang	1	13/1	3	1	5.82	10.00	2.5	12.50	18.32	1.64	1.64
		2	88	2	0.5	5.82	15.00	2.5	17.50	23.32	1.29	0.64
		3	202	1	0.5	5.82	30.00	2.5	32.50	38.32	0.78	0.39
		4	204	1.33	0.5	5.82	22.56	2.5	25.06	30.87	0.97	0.49
Total												3.16
6	Sarveshwar Mahadev	1	13/1	3	1	4.18	10.00	2.5	12.50	16.68	1.80	1.80

		2	88	2	0.5	4.18	15.00	2.5	17.50	21.68	1.38	0.69
		3	202	1	0.5	4.18	30.00	2.5	32.50	36.68	0.82	0.41
		4	205	1.33	0.5	4.18	22.56	2.5	25.06	29.24	1.03	0.51
Total												3.41
7	Sarveshwar Mandir	1	13/1	3	1	4.18	10.00	2.5	12.50	16.68	1.80	1.80
		2	88	2	0.5	4.18	15.00	2.5	17.50	21.68	1.38	0.69
		3	202	1	0.5	4.18	30.00	2.5	32.50	36.68	0.82	0.41
		4	204	1.33	0.5	4.18	22.56	2.5	25.06	29.24	1.03	0.51
Total												3.41
8	Shri Ram Chowk	1	13/1	3	1	4.18	10.00	2.5	12.50	16.68	1.80	1.80
		2	88	2	0.5	4.18	15.00	2.5	17.50	21.68	1.38	0.69
		3	202	1	0.5	4.18	30.00	2.5	32.50	36.68	0.82	0.41
		4	205	1.33	0.5	4.18	22.56	2.5	25.06	29.24	1.03	0.51
Total												3.41
9	Sarkari Press Colony	1	13/1	3	1	5.94	10.00	2.5	12.50	18.44	1.63	1.63
		2	88	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
		3	202	1	0.5	5.94	30.00	2.5	32.50	38.44	0.78	0.39
		4	205	1.33	0.5	5.94	22.56	2.5	25.06	31.00	0.97	0.48
Total												3.14
10	Sarkari Litho Press	1	13/1	3	1	5.94	10.00	2.5	12.50	18.44	1.63	1.63
		2	88	2	0.5	5.94	15.00	2.5	17.50	23.44	1.28	0.64
		3	202	1	0.5	5.94	30.00	2.5	32.50	38.44	0.78	0.39
		4	204	1.33	0.5	5.94	22.56	2.5	25.06	31.00	0.97	0.48
Total												3.14
11	Madan Pura Chowk	1	13/1	3	1	6.02	10.00	2.5	12.50	18.52	1.62	1.62
		2	88	2	0.5	6.02	15.00	2.5	17.50	23.52	1.28	0.64
		3	202	1	0.5	6.02	30.00	2.5	32.50	38.52	0.78	0.39
		4	205	1.33	0.5	6.02	22.56	2.5	25.06	31.08	0.97	0.48
Total												3.13
12	Ranip Gam	1	13/1	3	0.5	6.02	10.00	2.5	12.50	18.52	1.62	0.81
		2	88	2	0.5	6.02	15.00	2.5	17.50	23.52	1.28	0.64
		3	202	1	0.5	6.02	30.00	2.5	32.50	38.52	0.78	0.39
		4	204	1.33	0.5	6.02	22.56	2.5	25.06	31.08	0.97	0.48
		5	146-1	4	1	6.02	7.50	2.5	10.00	16.02	1.87	1.87
		6	205	1.33	0.5	6.02	22.56	2.5	25.06	31.08	0.97	0.48
Total												4.68
13	Sardar Patel Chowk	1	146-1	4	1	5.27	7.50	2.5	10.00	15.27	1.97	1.97
		2	202	1	0.5	5.27	30.00	2.5	32.50	37.77	0.79	0.40
		3	204	1.33	0.5	5.27	22.56	2.5	25.06	30.32	0.99	0.49
Total												2.86
14	Arvind Group	1	146-1	4	1	5.27	7.50	2.5	10.00	15.27	1.97	1.97
		2	202	1	0.5	5.27	30.00	2.5	32.50	37.77	0.79	0.40
		3	205	1.33	0.5	5.27	22.56	2.5	25.06	30.32	0.99	0.49
Total												2.86
15	Gayatri AMTS Stop	1	146-1	4	1	4.29	7.50	2.5	10.00	14.29	2.10	2.10
		2	202	1	0.5	4.29	30.00	2.5	32.50	36.79	0.82	0.41

		3	205	1.33	0.5	4.29	22.56	2.5	25.06	29.35	1.02	0.51
		4	40/3	1.5	0.5	4.29	20.00	2.5	22.50	26.79	1.12	0.56
		5	82	0.85	0.5	4.29	35.29	2.5	37.79	42.08	0.71	0.36
Total												3.93
16	Karan Complex	1	74/1	2	1	4.29	15.00	2.5	17.50	21.79	1.38	1.38
		2	74	1.71	0.5	4.29	17.54	2.5	20.04	24.33	1.23	0.62
Total												1.99
17	Balol Nagar	1	74/1	2	1	5.06	15.00	2.5	17.50	22.56	1.33	1.33
		2	74	1.71	0.5	5.06	17.54	2.5	20.04	25.10	1.20	0.60
Total												1.93
18	Natraj Shopping Center	1	40/3	1.5	0.5	5.06	20.00	2.5	22.50	27.56	1.09	0.54
		2	79	1.5	0.5	5.06	20.00	2.5	22.50	27.56	1.09	0.54
		3	82	0.85	0.5	5.06	35.29	2.5	37.79	42.85	0.70	0.35
		4	146-1	4	1	5.06	7.50	2.5	10.00	15.06	1.99	1.99
		5	202	1	0.5	5.06	30.00	2.5	32.50	37.56	0.80	0.40
		6	205	1.33	0.5	5.06	22.56	2.5	25.06	30.11	1.00	0.50
Total												4.33
19	Gangotri Amts Stop	1	40/3	1.5	0.5	4.91	20.00	2.5	22.50	27.41	1.09	0.55
		2	79	1.5	0.5	4.91	20.00	2.5	22.50	27.41	1.09	0.55
		3	82	0.85	0.5	4.91	35.29	2.5	37.79	42.71	0.70	0.35
		4	146-1	4	1	4.91	7.50	2.5	10.00	14.91	2.01	2.01
		5	202	1	0.5	4.91	30.00	2.5	32.50	37.41	0.80	0.40
		6	205	1.33	0.5	4.91	22.56	2.5	25.06	29.97	1.00	0.50
Total												4.36
20	Vrundavan Society	1	40/3	1.5	0.5	4.03	20.00	2.5	22.50	26.53	1.13	0.57
		2	82	0.85	0.5	4.03	35.29	2.5	37.79	41.82	0.72	0.36
		3	146-1	4	1	4.03	7.50	2.5	10.00	14.03	2.14	2.14
		4	202	1	0.5	4.03	30.00	2.5	32.50	36.53	0.82	0.41
		5	205	1.33	0.5	4.03	22.56	2.5	25.06	29.08	1.03	0.52
Total												3.99
Total All SAPs for Ranip												67.27

Calculation of AI for CHANDKHEDA

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Jaswinder Auto	1	89/1	1	1	6.25	30.00	2.5	32.50	38.75	0.77	0.77
		2	109	0.75	0.5	6.25	40.00	2.5	42.50	48.75	0.62	0.31
Total												1.08
2	Shrupath Society	1	85/s	1.2	1	6.25	25.00	2.5	27.50	33.75	0.89	0.89
		2	89/1	1	0.5	6.25	30.00	2.5	32.50	38.75	0.77	0.39
		3	109	0.75	0.5	6.25	40.00	2.5	42.50	48.75	0.62	0.31
Total												1.58
3	Sarathi Bungalow	1	75	0.83	0.5	6.07	36.14	2.5	38.64	44.71	0.67	0.34
		2	84	1.09	0.5	6.07	27.52	2.5	30.02	36.09	0.83	0.42
		3	401	6	1	6.07	5.00	2.5	7.50	13.57	2.21	2.21
Total												2.96

4	Satyamev Hospital-1	1	84	1.09	1	6.68	27.52	2.5	30.02	36.70	0.82	0.82
		2	89/1	1	0.5	6.68	30.00	2.5	32.50	39.18	0.77	0.38
		3	109	0.75	0.5	6.68	40.00	2.5	42.50	49.18	0.61	0.31
Total												1.51
5	Satyamev Hospital-2	1	30/3	0.31	0.5	6.68	96.77	2.5	99.27	105.95	0.28	0.14
		2	75	0.83	0.5	6.68	36.14	2.5	38.64	45.32	0.66	0.33
		3	84	1.09	0.5	6.68	27.52	2.5	30.02	36.70	0.82	0.41
		4	85/s	1.2	0.5	6.68	25.00	2.5	27.50	34.18	0.88	0.44
		5	89-3s	1.5	0.5	6.68	20.00	2.5	22.50	29.18	1.03	0.51
		6	89/1	1	0.5	6.68	30.00	2.5	32.50	39.18	0.77	0.38
		7	109	0.75	0.5	6.68	40.00	2.5	42.50	49.18	0.61	0.31
		8	401	6	1	6.68	5.00	2.5	7.50	14.18	2.12	2.12
Total												4.64
6	Chandkheda Gam	1	30/3	0.31	0.5	6.96	96.77	2.5	99.27	106.24	0.28	0.14
		2	75	0.83	0.5	6.96	36.14	2.5	38.64	45.61	0.66	0.33
		3	84	1.09	0.5	6.96	27.52	2.5	30.02	36.99	0.81	0.41
		4	85/s	1.2	0.5	6.96	25.00	2.5	27.50	34.46	0.87	0.44
		5	89-3s	1.5	0.5	6.96	20.00	2.5	22.50	29.46	1.02	0.51
		6	89/1	1	0.5	6.96	30.00	2.5	32.50	39.46	0.76	0.38
		7	109	0.75	0.5	6.96	40.00	2.5	42.50	49.46	0.61	0.30
		8	401	6	1	6.96	5.00	2.5	7.50	14.46	2.07	2.07
Total												4.58
7	Shiv Shakti Nagar	1	22	1.33	0.5	6.42	22.56	2.5	25.06	31.48	0.95	0.48
		2	75	0.83	0.5	6.42	36.14	2.5	38.64	45.07	0.67	0.33
		3	85/s	1.2	0.5	6.42	25.00	2.5	27.50	33.92	0.88	0.44
		4	89-3s	1.5	0.5	6.42	20.00	2.5	22.50	28.92	1.04	0.52
		5	89/1	1	0.5	6.42	30.00	2.5	32.50	38.92	0.77	0.39
		6	90-s	1.67	0.5	6.42	17.96	2.5	20.46	26.89	1.12	0.56
		7	109	0.75	0.5	6.42	40.00	2.5	42.50	48.92	0.61	0.31
		8	401	6	1	6.42	5.00	2.5	7.50	13.92	2.15	2.15
Total												5.17
8	Santok Baa Hospital	1	22	1.33	0.5	6.15	22.56	2.5	25.06	31.21	0.96	0.48
		2	89/1	1	0.5	6.15	30.00	2.5	32.50	38.65	0.78	0.39
		3	90-s	1.67	1	6.15	17.96	2.5	20.46	26.61	1.13	1.13
		4	109	0.75	0.5	6.15	40.00	2.5	42.50	48.65	0.62	0.31
Total												2.30
9	Parshwanath Nagar	1	75	0.83	0.5	6.23	36.14	2.5	38.64	44.87	0.67	0.33
		2	85/s	1.2	0.5	6.23	25.00	2.5	27.50	33.73	0.89	0.44
		3	89-3s	1.5	0.5	6.23	20.00	2.5	22.50	28.73	1.04	0.52
		4	401	6	1	6.23	5.00	2.5	7.50	13.73	2.19	2.19
Total												3.49
10	Parshwanath Township	1	75	0.83	0.5	6.23	36.14	2.5	38.64	44.87	0.67	0.33
		2	85/s	1.2	0.5	6.23	25.00	2.5	27.50	33.73	0.89	0.44
		3	89-3s	1.5	0.5	6.23	20.00	2.5	22.50	28.73	1.04	0.52
		4	401	6	1	6.23	5.00	2.5	7.50	13.73	2.19	2.19
Total												3.49

11	ONGC Avani bhavan	1	75	0.83	0.5	7.05	36.14	2.5	38.64	45.69	0.66	0.33
		2	85/s	1.2	0.5	7.05	25.00	2.5	27.50	34.55	0.87	0.43
		3	89-3s	1.5	0.5	7.05	20.00	2.5	22.50	29.55	1.02	0.51
		4	401	6	1	7.05	5.00	2.5	7.50	14.55	2.06	2.06
Total												3.33
12	ONGC Office	1	75	0.83	0.5	7.05	36.14	2.5	38.64	45.69	0.66	0.33
		2	85/s	1.2	0.5	7.05	25.00	2.5	27.50	34.55	0.87	0.43
		3	89-3s	1.5	0.5	7.05	20.00	2.5	22.50	29.55	1.02	0.51
		4	401	6	1	7.05	5.00	2.5	7.50	14.55	2.06	2.06
Total												3.33
13	GH Road-1	1	75	0.83	0.5	7.24	36.14	2.5	38.64	45.89	0.65	0.33
		2	85/s	1.2	0.5	7.24	25.00	2.5	27.50	34.74	0.86	0.43
		3	89-3s	1.5	0.5	7.24	20.00	2.5	22.50	29.74	1.01	0.50
		4	401	6	1	7.24	5.00	2.5	7.50	14.74	2.03	2.03
Total												3.30
14	GH Road-2	1	89-3s	1.5	0.5	7.24	20.00	2.5	22.50	29.74	1.01	0.50
		2	401	6	1	7.24	5.00	2.5	7.50	14.74	2.03	2.03
Total												2.54
15	Visat GSRTC	1	89/1	1	0.5	6.25	30.00	2.5	32.50	38.75	0.77	0.39
		2	90-s	1.67	1	6.25	17.96	2.5	20.46	26.71	1.12	1.12
Total												1.51
16	Vishwakarma Mandir	1	89/1	1	0.5	6.25	30.00	2.5	32.50	38.75	0.77	0.39
		2	90-s	1.67	1	6.25	17.96	2.5	20.46	26.71	1.12	1.12
Total												1.51
17	Maruti Tenament	1	89/1	1	0.5	6.25	30.00	2.5	32.50	38.75	0.77	0.39
		2	90-s	1.67	1	6.25	17.96	2.5	20.46	26.71	1.12	1.12
Total												1.51
18	GEC	1	89/1	1	0.5	5.33	30.00	2.5	32.50	37.83	0.79	0.40
		2	90-s	1.67	1	5.33	17.96	2.5	20.46	25.79	1.16	1.16
Total												1.56
19	Ashok Vihar	1	22	1.33	0.5	5.33	22.56	2.5	25.06	30.38	0.99	0.49
		2	89/1	1	0.5	5.33	30.00	2.5	32.50	37.83	0.79	0.40
		3	90-s	1.67	1	5.33	17.96	2.5	20.46	25.79	1.16	1.16
Total												2.05
Total All SAPs for Chandkheda												51.44

- **Notations:**

Service Access Point: SAP
Frequency: f
Weightage: W
Walk Time: WT
Scheduled Waiting Time: SWT
Reliability: K
Average Waiting Time: AWT
Total Access Time: TAT
Equivalent Doorstep
Frequency: EDF
Accessibility Index: AI

Appendix – D_2: Accessibility Index (AI) Calculation for BRTS

Calculation of AI for **PALDI**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No.	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Chandranagar	1	1	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
		2	3	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
		3	5	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
Total												9.09
2	Anjali	1	1	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
		2	3	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
		3	5	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
Total												9.09
3	Dharnidhar	1	1	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
		2	3	8	1	5.14	3.75	1	4.75	9.89	3.03	3.03
Total												6.06
Total All SAPs for Paldi												24.24

Calculation of AI for **VASNA**

Sr.No. (SAP)	SAP (Stop Name)	Sr. No. (Route)	Route No.	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Vasna Bus Stop	1	5	8	1	6.96	3.75	1	4.75	11.71	2.56	2.56
Total												2.56
Total All SAPs for Vasna												2.56

Calculation of AI for **NAVRANGPURA**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No.	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	University	1	3	8	0.5	6.29	3.75	1	4.75	11.04	2.72	1.36
		2	4	8	0.5	6.29	3.75	1	4.75	11.04	2.72	1.36
		3	9	5	0.5	6.29	6.00	1	7.00	13.29	2.26	1.13
		4	10	5	0.5	6.29	6.00	1	7.00	13.29	2.26	1.13
		5	12	6	0.5	6.29	5.00	1	6.00	12.29	2.44	1.22
Total												6.20
2	Himmatlal Park	1	3	8	0.5	4.47	3.75	1	4.75	9.22	3.25	1.63
		2	4	8	0.5	4.47	3.75	1	4.75	9.22	3.25	1.63
		3	9	5	0.5	4.47	6.00	1	7.00	11.47	2.61	1.31
		4	10	5	0.5	4.47	6.00	1	7.00	11.47	2.61	1.31
		5	12	6	0.5	4.47	5.00	1	6.00	10.47	2.86	1.43
Total												7.31
3	Shivranjani	1	1	8	0.75	5.21	3.75	1	4.75	9.96	3.01	2.26
		2	3	8	0.75	5.21	3.75	1	4.75	9.96	3.01	2.26
		3	4	8	0.75	5.21	3.75	1	4.75	9.96	3.01	2.26
		4	8	17	0.75	5.21	1.76	1	2.76	7.98	3.76	2.82
		5	9	5	0.75	5.21	6.00	1	7.00	12.21	2.46	1.84
		6	10	5	0.75	5.21	6.00	1	7.00	12.21	2.46	1.84
		7	12	6	0.75	5.21	5.00	1	6.00	11.21	2.68	2.01
Total												15.29
4	Jhansi ki Rani	1	1	8	0.5	5.34	3.75	1	4.75	10.09	2.97	1.49
		2	3	8	0.5	5.34	3.75	1	4.75	10.09	2.97	1.49
		3	4	8	0.5	5.34	3.75	1	4.75	10.09	2.97	1.49
		4	8	17	0.5	5.34	1.76	1	2.76	8.11	3.70	1.85
		5	9	5	0.5	5.34	6.00	1	7.00	12.34	2.43	1.22
		6	10	5	0.5	5.34	6.00	1	7.00	12.34	2.43	1.22
		7	12	6	0.5	5.34	5.00	1	6.00	11.34	2.65	1.32
Total												10.08
5	Nehrunagar	1	1	8	0.5	4.08	3.75	1	4.75	8.83	3.40	1.70
		2	3	8	0.5	4.08	3.75	1	4.75	8.83	3.40	1.70
		3	4	8	0.5	4.08	3.75	1	4.75	8.83	3.40	1.70
		4	8	17	0.5	4.08	1.76	1	2.76	6.85	4.38	2.19
		5	9	5	0.5	4.08	6.00	1	7.00	11.08	2.71	1.35
		6	10	5	0.5	4.08	6.00	1	7.00	11.08	2.71	1.35
		7	12	6	0.5	4.08	5.00	1	6.00	10.08	2.98	1.49
Total												11.48
6	L Colony	1	4	8	0.5	4.78	3.75	1	4.75	9.53	3.15	1.57
		2	8	17	0.5	4.78	1.76	1	2.76	7.55	3.97	1.99
		3	9	5	0.5	4.78	6.00	1	7.00	11.78	2.55	1.27
Total												4.83

7	Panjarapol	1	4	8	0.5	4.78	3.75	1	4.75	9.53	3.15	1.57
		2	8	17	0.5	4.78	1.76	1	2.76	7.54	3.98	1.99
		3	9	5	0.5	4.78	6.00	1	7.00	11.78	2.55	1.27
Total												4.83
8	Gulbai Tekra	1	4	8	0.5	4.55	3.75	1	4.75	9.30	3.22	1.61
		2	8	17	0.5	4.55	1.76	1	2.76	7.32	4.10	2.05
		3	9	5	0.5	4.55	6.00	1	7.00	11.55	2.60	1.30
Total												4.96
9	LD Engineering College	1	4	8	1	4.13	3.75	1	4.75	8.88	3.38	3.38
		2	8	17	1	4.13	1.76	1	2.76	6.89	4.35	4.35
		3	9	5	1	4.13	6.00	1	7.00	11.13	2.70	2.70
Total												10.43
10	Commerce Six Road	1	4	8	0.5	5.23	3.75	1	4.75	9.98	3.01	1.50
Total												1.50
Total All SAPs for Navrangpura												76.91

Calculation of AI for **S.P. STADIUM**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	RTO	1	3	8	0.5	3.70	3.75	1	4.75	8.45	3.55	1.77
		2	4	8	.5	3.70	3.75	1	4.75	8.45	3.55	1.77
		3	7	5	0.5	3.70	6.00	1	7.00	10.70	2.80	1.40
		4	10	5	0.5	3.70	6.00	1	7.00	10.70	2.80	1.40
		5	12	6	0.5	3.70	5.00	1	6.00	9.70	3.09	1.55
Total												7.89
2	Bhavsar Hostel	1	2	6	0.5	3.70	5.00	1	6.00	9.70	3.09	1.55
		2	3	8	0.5	3.70	3.75	1	4.75	8.45	3.55	1.77
		3	4	8	0.5	3.70	3.75	1	4.75	8.45	3.55	1.77
		4	10	5	0.5	3.70	6.00	1	7.00	10.70	2.80	1.40
		5	12	6	0.5	3.70	5.00	1	6.00	9.70	3.09	1.55
Total												8.04
Total All SAPs for S.P Stadium												15.93

Calculation of AI for **NARANPURA**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Pragatinagar	1	2	6	0.5	5.04	5.00	1	6.00	11.04	2.72	1.36
		2	3	8	0.5	5.04	3.75	1	4.75	9.79	3.06	1.53
		3	4	8	0.5	5.04	3.75	1	4.75	9.79	3.06	1.53
		4	10	5	0.5	5.04	6.00	1	7.00	12.04	2.49	1.25
		5	12	6	0.5	5.04	5.00	1	6.00	11.04	2.72	1.36
Total												7.03
2	Shashtrinagar	1	2	6	0.5	4.53	5.00	1	6.00	10.53	2.85	1.42
		2	3	8	0.5	4.53	3.75	1	4.75	9.28	3.23	1.62
		3	4	8	0.5	4.53	3.75	1	4.75	9.28	3.23	1.62
		4	10	5	0.5	4.53	6.00	1	7.00	11.53	2.60	1.30
		5	12	6	0.5	4.53	5.00	1	6.00	10.53	2.85	1.42
Total												7.38
3	Jaimangal	1	2	6	0.5	3.86	5.00	1	6.00	9.86	3.04	1.52
		2	3	8	0.5	3.86	3.75	1	4.75	8.61	3.48	1.74
		3	4	8	0.5	3.86	3.75	1	4.75	8.61	3.48	1.74
		4	10	5	0.5	3.86	6.00	1	7.00	10.86	2.76	1.38
		5	12	6	0.5	3.86	5.00	1	6.00	9.86	3.04	1.52
Total												7.90
4	Sola Cross Road	1	3	8	0.5	5.25	3.75	1	4.75	10.00	3.00	1.50
		2	4	8	0.5	5.25	3.75	1	4.75	10.00	3.00	1.50
		3	9	5	0.5	5.25	6.00	1	7.00	12.25	2.45	1.22
		4	10	5	0.5	5.25	6.00	1	7.00	12.25	2.45	1.22
		5	12	6	0.5	5.25	5.00	1	6.00	11.25	2.67	1.33
Total												6.77
5	Valinath Chowk	1	3	8	0.5	4.77	3.75	1	4.75	9.52	3.15	1.58
		2	4	8	0.5	4.77	3.75	1	4.75	9.52	3.15	1.58
		3	9	5	0.5	4.77	6.00	1	7.00	11.77	2.55	1.27
		4	10	5	0.5	4.77	6.00	1	7.00	11.77	2.55	1.27
		5	12	6	0.5	4.77	5.00	1	6.00	10.77	2.79	1.39
Total												7.09
Total All SAPs for Naranpura												36.17

Calculation of AI for **NAVA VADAJ**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Akhbarnagar	1	2	6	0.75	4.63	5.00	1	6.00	10.63	2.82	2.12
		2	3	8	0.75	4.63	3.75	1	4.75	9.38	3.20	2.40
		3	4	8	0.75	4.63	3.75	1	4.75	9.38	3.20	2.40
		4	10	5	0.75	4.63	6.00	1	7.00	11.63	2.58	1.93
		5	12	6	0.75	4.63	5.00	1	6.00	10.63	2.82	2.12
Total All SAPs for Nava Vadaj												10.97

Calculation of AI for **SABARMATI**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Visat	1	4	8	0.75	3.87	3.75	1	4.75	8.62	3.48	2.61
		2	7	5	0.75	3.87	6.00	1	7.00	10.87	2.76	2.07
Total												4.68
2	Motera Cross Road	1	4	8	0.5	5.06	3.75	1	4.75	9.81	3.06	1.53
		2	7	5	0.5	5.06	6.00	1	7.00	12.06	2.49	1.24
Total												2.77
3	Sabarmati Police Station	1	4	8	0.5	4.78	3.75	1	4.75	9.53	3.15	1.57
		2	7	5	0.5	4.78	6.00	1	7.00	11.78	2.55	1.27
Total												2.84
4	Sabarmati Municipal Swimming Pool	1	4	8	0.5	3.96	3.75	1	4.75	8.71	3.44	1.72
			7	5	0.5	3.96	6.00	1	7.00	10.96	2.74	1.37
Total												3.09
5	Rathi Apartment	1	4	8	0.5	3.95	3.75	1	4.75	8.70	3.45	1.72
		2	7	5	0.5	3.95	6.00	1	7.00	10.95	2.74	1.37
Total												3.09
6	Sabarmati Power House	1	4	8	0.5	6.22	3.75	1	4.75	10.97	2.73	1.37
		2	7	5	0.5	6.22	6.00	1	7.00	13.22	2.27	1.13
Total												2.50
Total All SAPs for Sabarmati												18.97

Calculation of AI for **RANIP**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Ranip Cross Road	1	3	8	0.75	5.10	3.75	1	4.75	9.85	3.05	2.28
		2	4	8	0.75	5.10	3.75	1	4.75	9.85	3.05	2.28
		3	7	5	0.75	5.10	6.00	1	7.00	12.10	2.48	1.86
		4	10	5	0.75	5.10	6.00	1	7.00	12.10	2.48	1.86
		5	12	6	0.75	5.10	5.00	1	6.00	11.10	2.70	2.03
Total												10.31
Total All SAPs for Ranip												10.31

Calculation of AI for **CHANDKHEDA**

Sr.No. SAP	SAP (Stop Name)	Sr.No. Route	Route No	f	W	WT	SWT	K	AWT	TAT	EDF	AI
1	Zundal Circle	1	4	8	0.5	4.83	3.75	1	4.75	9.58	3.13	1.57
		2	7	5	0.5	4.83	6.00	1	7.00	11.83	2.54	1.27
Total												2.84
2	Sarthi Bungalows	1	4	8	0.5	4.24	3.75	1	4.75	8.99	3.34	1.67
		2	7	5	0.5	4.24	6.00	1	7.00	11.24	2.67	1.33
Total												3.00
3	Chandkheda Gam	1	4	8	1	5.07	3.75	1	4.75	9.82	3.05	3.05
		2	7	5	1	5.07	6.00	1	7.00	12.07	2.49	2.49
Total												5.54
4	Shivshaktinagar	1	4	8	0.5	5.15	3.75	1	4.75	9.90	3.03	1.51
		2	7	5	0.5	5.15	6.00	1	7.00	12.15	2.47	1.23
Total												2.74
5	Jantanagar	1	4	8	0.75	4.51	3.75	1	4.75	9.26	3.24	2.43
		2	7	5	0.75	4.51	6.00	1	7.00	11.51	2.61	1.96
Total												4.39
6	ONGC	1	4	8	0.5	3.34	3.75	1	4.75	8.09	3.71	1.85
		2	7	5	0.5	3.34	6.00	1	7.00	10.34	2.90	1.45
Total												3.30
Total All SAPs for Chandkheda												21.81

Appendix – D_3: AI Summary for All Wards of West Zone

(Accessibility Index (AI) for Study Area)

AI for PALDI

Sr.No.	SAP/Stop Name	AI
1	Vikash Gruh	2.30
2	Niranjan Society	1.09
3	Sharda Nagar	2.30
4	Dharnidhar Society	2.30
5	Jalaram Mandir	6.15
6	Mahalakshmi Society	6.83
7	Mahalakshmi Rasta	2.27
8	Jain Merchant	10.14
9	Paldi	7.07
10	Paldi Turminus	4.33
11	Pritam Nagar	6.33
12	Arvind Sales	6.17
13	Congress Bhawan	6.17
14	V.S. Hospital	3.02
15	Madalpuar	4.59
16	Town Hall	4.59
17	Fateh Nagar	9.64
18	Viswakunj	2.64
19	Museum	10.27
20	Lavanya Society	3.46
21	Jivraj Mehta Hospital	3.46
22	Bakeri Medical	4.12
23	Bhatta	8.72
24	Anand Nagar	10.46
25	Malav Talav	3.73
	Total AMTS AI	132.15
B1	Chandranagar	9.09
B2	Anjali	9.09
B3	Dharnidhar	6.06
	Total BRTS AI	24.24
	Combined AI for Paldi	156.39

AI for NAVRANGPURA

Sr.No.	SAP/Stop Name	AI
1	Shivranjani	3.69
2	Umiya Vijay	5.08
3	Haridas Park	4.91
4	L Colony	4.15
5	Shefaly	5.74
6	Gujarat University	10.22
7	Dadasaheb Na Pagla	10.22
8	Suchita Apartment	1.26
9	Saurabh Society	4.59
10	Apang Manav Mandal	2.12
11	Sahjanand College	5.40
12	Swastik Society	5.62
13	Passport Office	0.46
14	Commerce college	5.00
15	Commerce Clg Hostel	5.00
16	Nehru Nagar	4.85
17	Government Quarter	5.72
18	Satyakam Society	4.40
19	Panjrapol	6.12
	Total AMTS AI	94.55
B1	University	6.20
B2	Himmatlal Park	7.31
B3	Shivranjani	15.29
B4	Jhansi ki Rani	10.08
B5	Nehrunagar	11.48
B6	L Colony	4.83
B7	Panjarapol	4.83
B8	Gulbai Tekra	4.96
B9	LD Engineering College	10.43
B10	Commerce Six Road	1.50
	Total BRTS AI	76.91
	Combined AI for Navrangpura	171.46

AI for VASNA

Sr.No.	SAP/Stop Name	AI
1	Jawahar Nagar	9.35
2	Vasna Terminus	6.44
3	Kesriyaji	4.21
4	Gupta Nagar	6.71
5	Shiv Shakti Nagar	1.43
6	Pratap Kunj	7.32
7	Ayyappa Mandir	1.06
8	Sorai Nagar	1.06
9	Ekta Tower	1.92
10	Amar Flats	1.93
11	Pravin Nagar	7.21
	Total AMTS AI	48.64
B1	Vasna Bus Stop	2.56
	Total BRTS AI	2.56
	Combined AI for Vasna	51.2

AI for NARANPURA

Sr.No.	SAP/Stop Name	AI
1	Pragatinagar	1.41
2	Harish Chandra	2.81
3	Housing Board	3.46
4	Pallav Society	4.03
5	Naranpura Char Ratsta	6.98
6	Amikunj	4.37
7	Devendra Park	4.42
8	AEC Zonal office	4.59
	Total AMTS AI	32.07
B1	Pragatinagar	7.03
B2	Shashtrinagar	7.38
B3	Jaimangal	7.90
B4	Sola Cross Road	6.77
B5	Valinath Chowk	7.09
	Total BRTS AI	36.17
	Combined AI for Naranpura	68.24

AI for SP STADIUM

Sr.No.	SAP/Stop Name	AI
1	R.T.O. Circle	5.81
2	Shubhash Bridge Circle	6.33
	Total AMTS AI	12.14
B1	RTO	7.89
B2	Bhavsar Hostel	8.04
	Total BRTS AI	15.93
	Combined AI for SP Stadium	28.07

AI for NAVA VADAJ

Sr.No.	SAP/Stop Name	AI
1	Neel Complex	1.72
2	Bhavsar Hostel	1.72
3	Vyash Wadi	2.44
4	Akhbar Nagar	5.38
5	Shrinath Apartment	2.47
6	Chandrabhaga House	1.74
7	Hari Om apartment	1.33
8	R.H. Patel College	1.78
9	Swaminarayan Mandir	1.36
10	Nava Vadaj	7.12
11	Krushna Nagar	5.80
12	Poonam Party Plot	5.45
13	N. R. Patel Park	1.75
14	Police Chowki	1.73
	Total AMTS AI	41.79
B1	Akhbarnagar	10.97
	Total BRTS AI	10.97
	Combined AI for Nava Vadaj	52.76

AI for SABARMATI

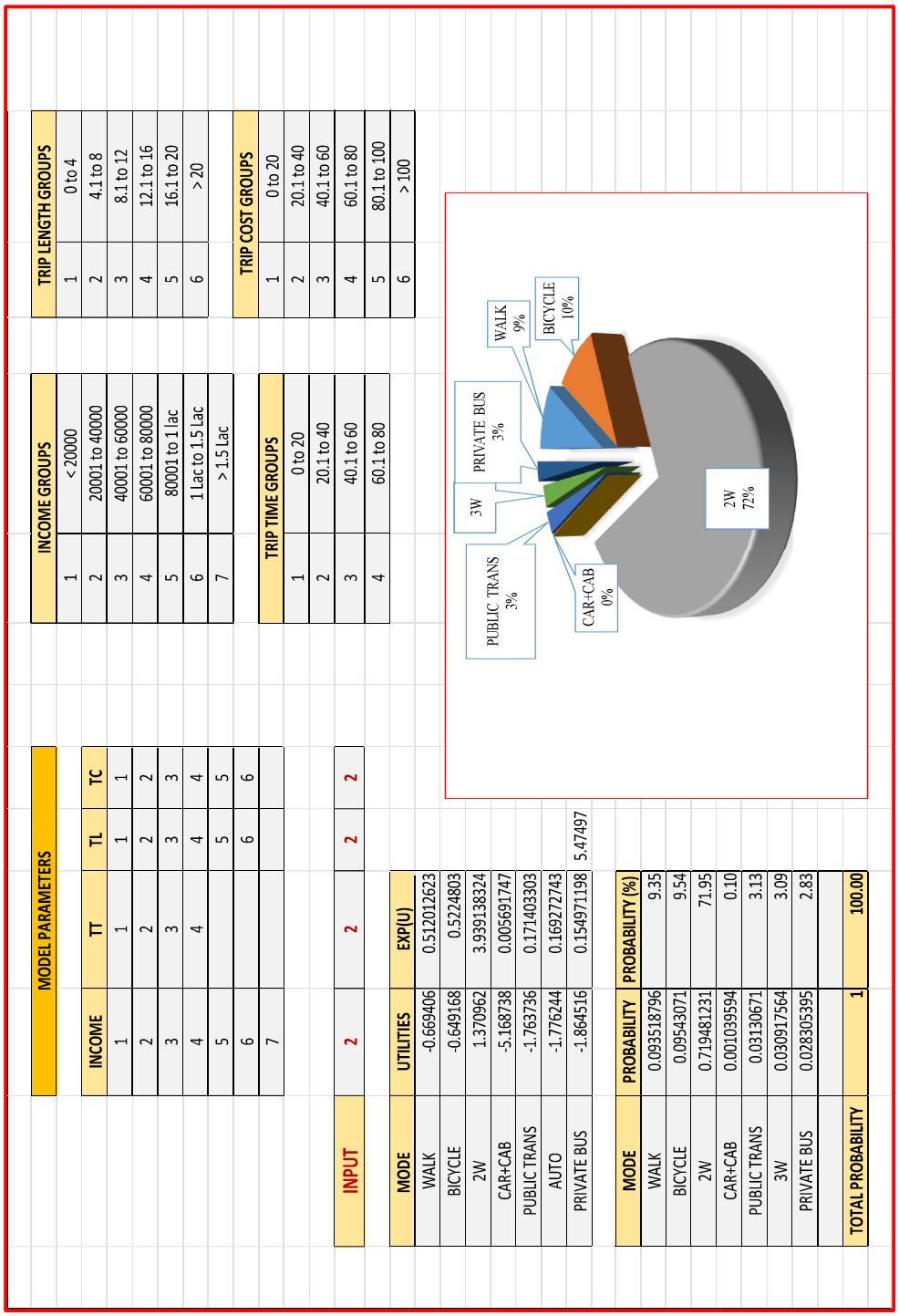
Sr.No.	SAP/Stop Name	AI
1	Laxmi Nagar-1	4.81
2	Laxmi Nagar-2	3.81
3	Acher Depot	4.46
4	Gandhi Bagh	1.00
5	Gandhi Vas	2.07
6	Toll Naka	3.39
7	Abukala	5.58
8	Chintamani	4.45
9	Ambedkar Chowk	4.27
10	Municipal Nagar	3.93
11	Rathi Apartment	3.93
12	Power House Quarter	3.70
13	Power House	3.70
	Total AMTS AI	49.10
B1	Visat	4.68
B2	Motera Cross Road	2.77
B3	Sabarmati Police Station	2.84
B4	Sabarmati Muncipal Swimming Pool	3.09
B5	Rathi Apartment	3.09
B6	Sabarmati Power House	2.50
	Total BRTS AI	18.97
	Combined AI for Sabarmati	68.07

AI for CHANDKHEDA

Sr.No.	SAP/Stop Name	AI
1	Jaswinder Auto	1.08
2	Shrupath Society	1.58
3	Sarathi Bungalow	2.96
4	Satyamev Hospital-1	1.51
5	Satyamev Hospital-2	4.64
6	Chandkheda Gam	4.58
7	Shiv Shakti Nagar	5.17
8	Santok Baa Hospital	2.30
9	Parshwanath Nagar	3.49
10	Parshwanath Township	3.49
11	ONGC Avanibhavan	3.33
12	ONGC Office	3.33
13	Gnagar Highway-1	3.30
14	Gnagar Highway-2	2.54
15	Visat GSRTC	1.51
16	Vishwakarma Mandir	1.51
17	New Maruti Tenament	1.51
18	GEC	1.56
19	Ashok Vihar	2.05
	Total AMTS AI	51.44
B1	Zundal Circle	2.84
B2	Sarthi Bungalows	3.00
B3	Chandkheda Gam	5.54
B4	Shivshaktinagar	2.74
B5	Jantanagar	4.39
B6	ONGC	3.30
	Total BRTS AI	21.81
	Combined AI for Chandkheda	73.25

Appendix – E : Mode Choice Excel Sheet

(Excel Sheet for All Possible Group Combination) (Group:2-2-2-2)



MODEL PARAMETERS			
INCOME	TT	TL	TC
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5		5	5
6		6	6
7			

INPUT			
	2	2	2

MODE	UTILITIES	EXP(U)
WALK	-0.669406	0.512012623
BICYCLE	-0.649168	0.5224803
2W	1.370962	3.939138324
CAR+CAB	-5.168738	0.005691747
PUBLIC TRANS	-1.763736	0.171403303
AUTO	-1.776244	0.169272743
PRIVATE BUS	-1.864516	0.154971198
		5.47497

MODE	PROBABILITY	PROBABILITY (%)
WALK	0.093518796	9.35
BICYCLE	0.09543071	9.54
2W	0.719481231	71.95
CAR+CAB	0.001039594	0.10
PUBLIC TRANS	0.03130671	3.13
3W	0.030917564	3.09
PRIVATE BUS	0.028305395	2.83
TOTAL PROBABILITY	1	100.00

INCOME GROUPS	
1	< 20000
2	20001 to 40000
3	40001 to 60000
4	60001 to 80000
5	80001 to 1 lac
6	1 Lac to 1.5 Lac
7	> 1.5 Lac

TRIP TIME GROUPS	
1	0 to 20
2	20.1 to 40
3	40.1 to 60
4	60.1 to 80

TRIP LENGTH GROUPS	
1	0 to 4
2	4.1 to 8
3	8.1 to 12
4	12.1 to 16
5	16.1 to 20
6	> 20

TRIP COST GROUPS	
1	0 to 20
2	20.1 to 40
3	40.1 to 60
4	60.1 to 80
5	80.1 to 100
6	> 100

List of Publications

List of Publications

Papers published and a list of all publications arising from the thesis

SCOPUS Indexed Publications (Research articles as papers)

(1) Shukla, R. N. (2021). Analysis of passenger trips by public transport-Bus transit in West Zone of Ahmedabad. *Psychology and Education* ISSN 1553–6939; Volume:58; No.5 (2021); Pg:139-144; DOI:http://psychologyandeducation.net/pae/index.php

Publication in UGC Approved journals (Research articles as papers)

(2) Shukla, R. N., Bhola, A. D., Gundaliya, P. J., Zala L. B. (2019). Mode choice analysis of Trips of Urban Residents using Multinomial Logit Model. *Journal of Emerging Technologies and Innovative Research*, An International Open Access Journal (www.jetir.org) ISSN:2349-5162 UGC Approved & 5.57 Impact Factor Volume 6 Issue 5, Pg:368-375

Conference Presentations

(1) Shukla, R. N. & Shah, Kavisha (2020). Analysis of private vehicle ownership and IPT vehicle scenario in Ahmdedabad .*ICRISET-2020 International Conference on Research and Innovations in Science, Engineering & Technology*; organized by B.V.M. Engineering College, V. V. Nagar, Gujarat.

(2) Shukla, R. N. (2020). Analysis of passenger trips by public transport-Bus transit in West Zone of Ahmedabad. ICRISET-2020 International Conference on Research and Innovations in Science, Engineering & Technology; organized by B.V.M. Engineering College, V. V. Nagar, Gujarat.

(3) Shukla, R. N., Zala L. B. (2023). Estimation of reliability factor for public transportation bus system. GESST-26th ISTE Gujarat State Annual Faculty Convention 2022 & Conference; organised by Indian Society for Technical Education (ISTE)- Gujarat State and Indus Institute of Technology & Engineering (IITE) , Indus University, Ahmedabad