LAND USE TRANSPORTATION INTERACTION MODEL DEVELOPMENT FOR URBAN AREA

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Contents

List of abbreviations and acronyms

Abbreviation	**Particulars**
%	Percentage
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
BRTS	Bus Rapid Transit System
CCA	Cross Category/Classification Analysis
DPR	Development Plan Reports
GIS	Geographic Information System
HH	Household
HIS	Home Interview Survey
LU	Land Use
LUTI	Land Use Transportation Interaction
MNL	Multinomial Logit
NML	Non-Motorised Transport
OHH	Other than Households
PTAL	Public Transport Accessibility Level
RMSE	Root Mean Squared Error
RTO	Road Transport Authority
SqKm	Square Kilometer
SqMt	Square Meter
TC	Travel Cost
TL	Travel Length
TT	Travel Time
2W	Two Wheeler
3W	Three Wheeler
4W	Four Wheeler
Cabs	Hired Taxies

1. Title of the thesis and abstract

Title: Land use transportation interaction model development for urban area

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 result 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 article presents a land use and transport interaction model for the urban system. The proposed system of interaction models based on regression techniques for land use and transport 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. 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. 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 RMSE (Root Mean Squared Error) and 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 to accept the model. 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 Square and Adjusted R Square 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 and have application for similar kind of study area.

2. Brief description on the state of the art of the research topic

Land-use and transportation interaction are fundamental concepts in the study of land development and the formulation of transport links (Manheim, 1979)

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. (L. Hellman, 1982)

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)

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)

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)

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)

Land use and transportation are mutually interdependent. (Moore et al., 2007)

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. (Russo & Musolino, 2007)

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)

Understanding the interaction between urban land-use change and transport is critical for urban planning as well as for transport planning, particularly in the case of rapidly growing and motorising cities. Dynamic land use and transport interaction models provide a good platform to study this mutual interaction. (Aljoufie et al., 2013)

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)

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. (Gaál, 2015).

By application of LUTI models resources could be focused on the most profitable investments. 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. (Gaál, 2015)

Lowry model is first land use transport model born as a result of pioneering researches conducted by Era S. in 1964. (S.Lowry, 1964).She concluded that the Pittsburg model as 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)

The estimation and adjustment of model parameters using a numerical method to minimize discrepancies between actual and modeled data. Trial and errors techniques have been conventionally used to calibrate LUTI models. (Gilquin et al., 2017)

Cities evolve in multiple dimensions: their size, density (jobs, population), land-uses, 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)

The LUTI models specifically consider the interaction between population, land-use/distribution of activities/gravitation of the individual areas and existing transport services. (Petri et al., 2019)

LUTI models are decision-making aid tools that simulate complex dynamic bilateral feedback between transportation and land-use within a territory. (Skandary et al., 2021)

3. 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 and 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.

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."

4. Objectives and scope of work

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

4.1 Objectives

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.

As the urban area have origin and history of development there are number of factors leading to expansion of boundaries and population attraction. There are number of opportunities in urban areas. There are number of parameters affecting the land use and transportation. Data collection is exhaustive and data handling is not easy. as a result, the scope of work to carry out the exploration was narrowed down.

4.2 Scope of work

The scope of research is limited to:

- 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.

5. Original contribution by the thesis

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 models as a LUTI model. 15 and more models developed. In future as per availability of data, applicable model can be used for horizon year.

The study area includes nine wards, and matching with any of ward's socio-economic condition can give more reliable prediction for application in any urban area. Ward wise models are developed. Calibrated and validated model have application for similar kind of development in any urban area.

The 2400 HH (household) data collected. Household characteristics analyzed. 6461 public transport user's data collected by interview at AMTS (Ahmedabad Municipal Transportation System) and BRTS (Bus Rapid Transit System) bus stops.

Mode choice analysis for various category of vehicles is conducted. Land plots rate, buy and rent rate for built up area for apartments, shops and offices collected. Local accessibility is calculated. PTAL (Public Transport Accessibility Level) and AI (Accessibility Index) is calculated. Public transport bus transit service AMTS and BRTS is studied.

Land use map analyzed and area in SqKm and in% of Residential, commercial, mixed, transport, institutional, industrial, recreational and waterbody land use computed. Agricultural land and vacant land in study area is computed for future use of land. Generally, population is forecasted and counted by census department decade wise. Local authority tracks birth and death rate to update population. Population data along with number of households (owned, rented, slum, kacha etc all) updated. Building in Use (BU) permission and various tax collection by authority also lead to area updation. Change in land use is very slow process compared to change in population. By considering all these, researcher have tried to develop model on various criteria.

RTO (Road Transport Authority) have data of vehicle registration for Ahmedabad. Ward wise

vehicle registration data is not available. Vehicle ownership obtained by survey of HH by HIS (Home Interview Survey) is reliable for study area.

Trip rate is estimated by CCA (Cross Category/Classification Analysis). As per family size, number of persons working in family and number of persons going for education and number of vehicles with family is grouped for trip rate estimation. Similar kind of household matching with future number of households can give more reliable trip rate prediction.

6. Methodology of research, results/comparisons

6.1 Methodology

The field Urban Transportation Planning and sub-domain Land use and Transportation Interaction is effective for existing situation and future prediction. Literature Review is done by searching the research papers, articles and books and outcome to use for the research project. 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 defined. To develop LUTI model and to calibrate and validate model. The study area is Ahmedabad urban area. Instead of considering Ahmedabad as a whole west zone of Ahmedabad is finalized as urban area study. West Zone of Ahmedabad as per Cencus 2011 and AMC map 2014-15 comprising of 9 wards namely-Chandkheda, Ranip, Sabarmati, Nava Wadaj, SP Stadium, Naranpura, Navrangpura, Paldi and Vasna. The study area is as shown in figure:1below. Study area is of 65.68 SqKm area. It is land use map developed in GIS (Geographical Information System) software by researcher. 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 focuson 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. Number of schools, college, university, aanaganwadi, hospital, primary health center, garden, playground, gymkhana, swimming pool, bank, rationing and other shops, community center etc. information is retrieved from secondary data sources.

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 from available sources. Exploration of secondary sources of information as per data availability by several means to use for analysis work. The secondary data is taken from AMC (Ahmedabad Municipal Corporation) office, AMC website and AUDA (Ahmedabad Urban Development Authority) report. Advancement in the literature review and exploration assisted for the identification of sources of data collection, analysis methods, results, and its interpretations continued.

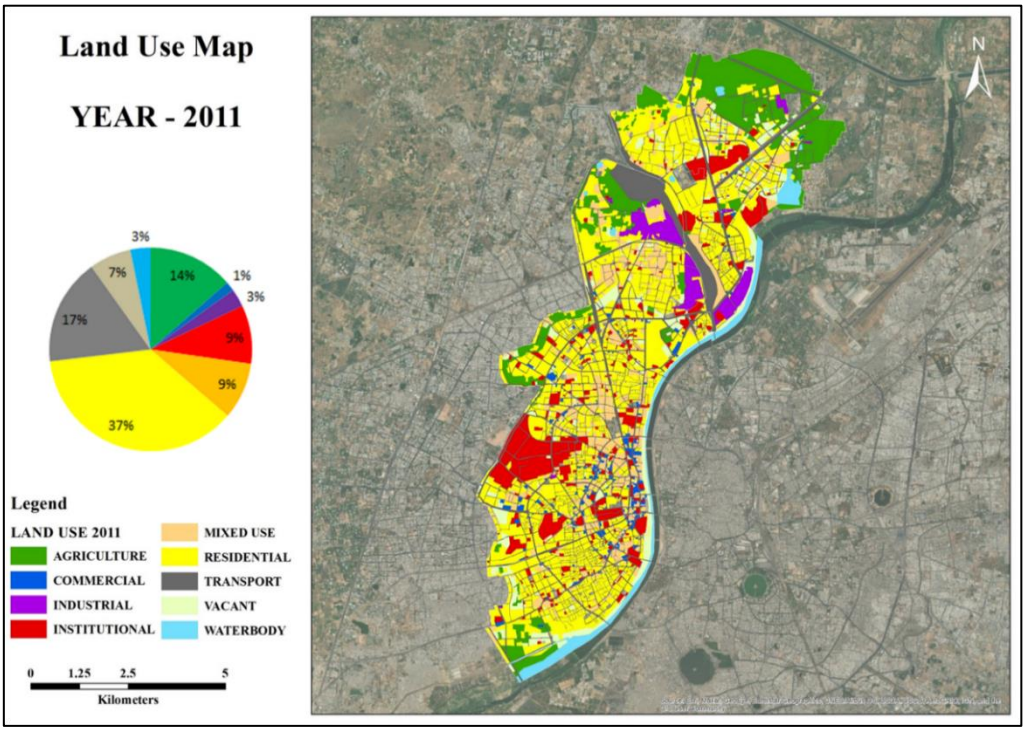

Figure:1 Study Area Delineation

Trip production model is developed by CCA (Cross Category Analysis) and regression analysis. The socio-economic characteristics and travel information is analyzed from primary data collected by HIS. Based upon same database 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 derived based on primary data collected for public transportation system.

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 above research steps presented in Figure 2 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.

6.2 Research Results

6.2.1 In study area as per HIS data analysis the following observations are found:

(i) HH Characteristics:

The working persons are 36% and school college going persons are 26% and remaining 38% are 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% are car (4w).

(ii) Trip Data Analysis:

There are 76% trip makers are male and remaining 24% are female. Age wise% trip makers are 17.44% is up to 15 years age. 32.36% is more than 15 years 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% is 61 to 75 years. Only 0.52% are of age more than 75 years. The purpose based trip data analysis revealed 57.53% work trip and 34.79% education trip and remaining 7.68% trips for shopping and other purpose.

(iii) Mode Choice in trip making:

Mode choice for trip making is 51.73% 2w, 2.52% 3w, 11.56% private car, 0.25% hired cab, 3.47% AMTS, 6.26% BRTS, 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 18.18% NMT.

(iv) Trip Length, Trip Cost and Trip Time

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.

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. More than Rs. 100 cost is with a few trips, only 0.92% of total 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.

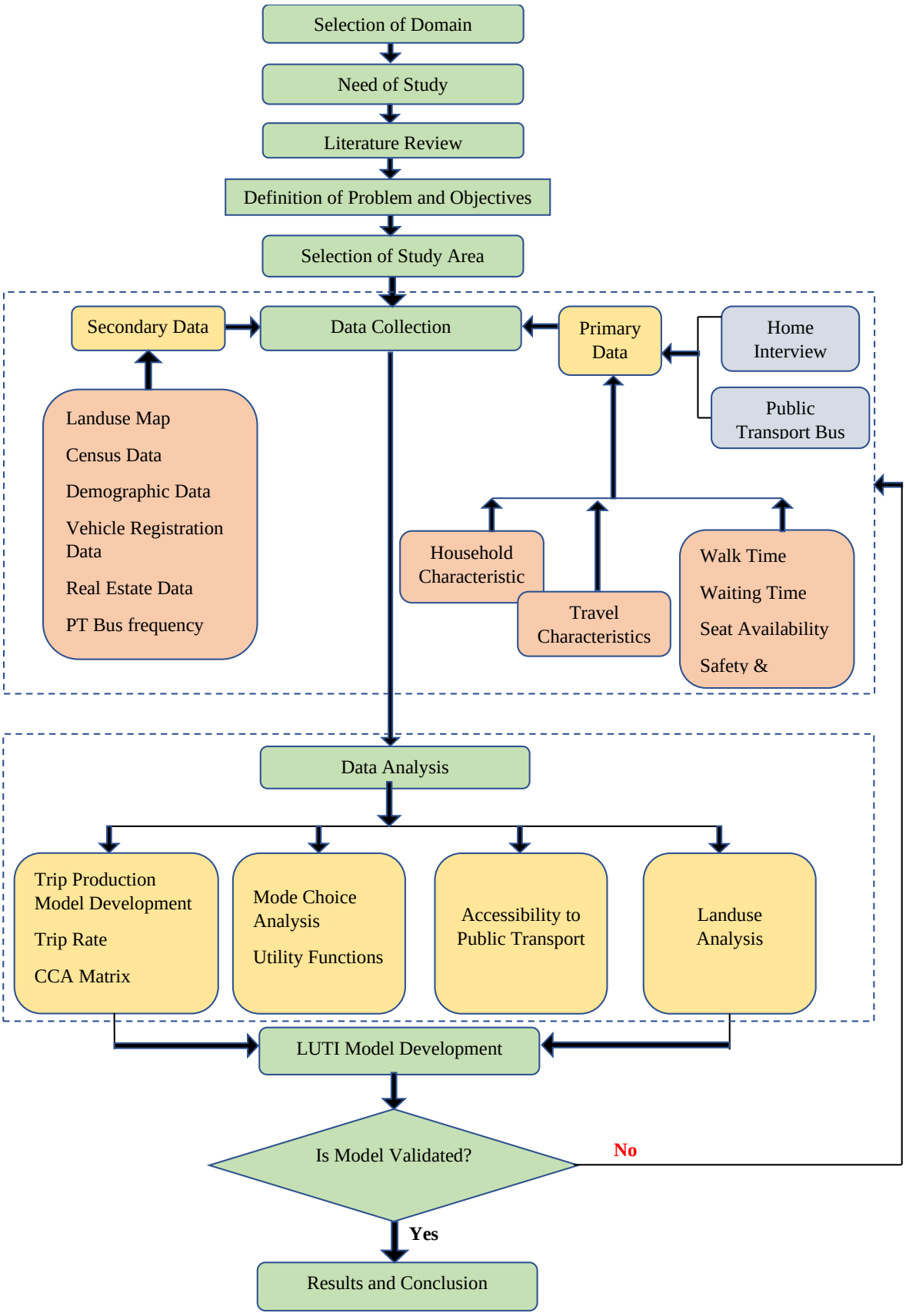

Figure 2 Research Methodology

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 this travel. (Patnam, 2003) In urban area 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 trips of total trips. More than 20.1 minutes to 40 minutes for 26.51 % trips. 5.6% trip makers have trip making time more than 40 minutes and up to 60 minutes.

6.2.2. From interview survey conducted at AMTS and BRTS bus stops, following findings are 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.

6.2.3 Findings for population growth and demand of HH along with density as below:

Population in 2011 for in 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. Population density i.e., number of persons per SqKm area is 14, 384 in 2011 and 20, 568 in 2017. There is increase of 6184 persons per SqKm 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. (Urban Profile 2017, Ward Patrak, Patrak-B, 2021) (AMC Website) (AUDA Website) 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%

6.2.4 Trip Rate Estimation:

Family size categorized in 3 groups. Sameway, number of school/college going persons (children) in the HH, number of employed person in the HH and vehicle ownership or number of vehicles with family in household is categorized in 3 groups. CCA carried out for trip rate estimation. Below table 1 and 2 shows results/findings for CCA. Cell values shows produced trip rate per HH

Table 1: Trip Rate by CCA Grouping 1

Number of persons Employed in HH	Number of persons going for education in in HH	Family Size -Number of persons		
		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

Table 2: Trip Rate by CCA Grouping 2

Number of vehicles in HH	Number of persons going for education in in HH	Family Size -Number of persons		
		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

6.2.5 PTAL Analysis:

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 for bus is observed for 52% and among them 9.5% has more than 12 minutes.AI calculated for 9 wards of west zone is as shown in figure 3 below. PTAL is level shown as per AI range as shown in Table 3. The reliability k is taken 1 for BRTS and 2.5 for AMTS. Average walk speed is taken 60 meters per minute. The data is collected during morning peak hour. Maximum walk time is 10 minutes and maximum distance is 600 meters for the analysis. Frequency and route information at each bus stop in the

ward is collected. Scheduled waiting time, average waiting time, equivalent door frequency and total access time is taken in consideration for AI estimation.

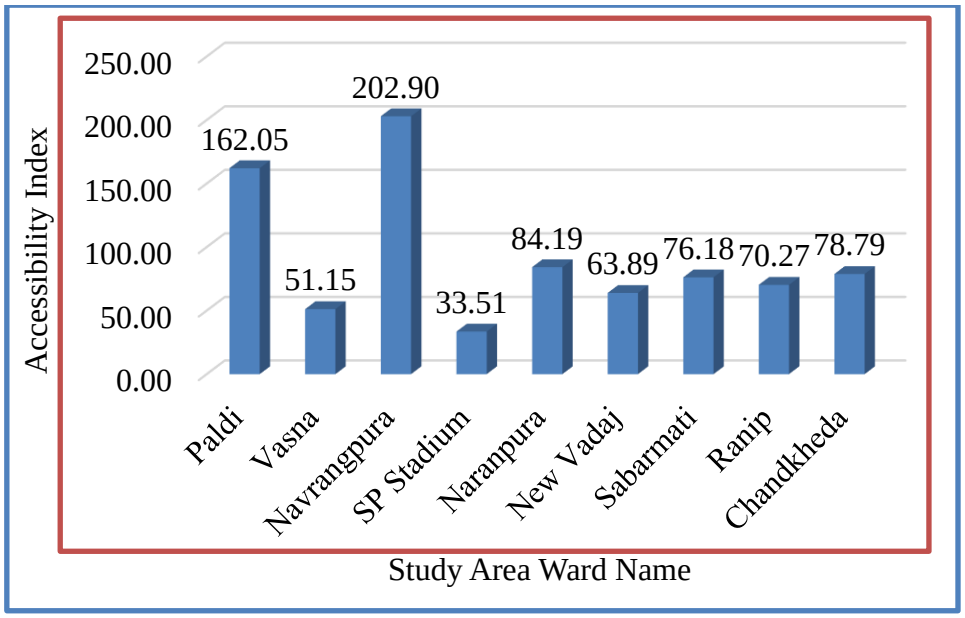

Figure 3: Ward wise Accessibility Index

Table 3: Description of PTAL and AI range

PTAL	1a (Low)	1b	2	3	4	5	6a	6b (High)
AI range	0-15.99	16-30.99	31-45.99	46-60.99	61-75.99	76-90.99	91-105	>105
Description	Very Poor	Very Poor	Poor	Moderate	Good	Very Good	Excellent	Excellent

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. All wards have good local accessibility except SP Stadium. Highest AI is at Navrangpura. PTAL is excellent at Navrangpura and Paldi. The land and built-up rate are high. Navrangpura has highest price rate of residential land plots, apartments, shops and offices. (*Real Estate Scenario, Ahmedabad, 2017-18*) (*Jantri Rates, Ahmedabad, 2011*) (Annual Statement of Rates)

6.2.6 MNL model for mode choice analysis and development of utility functions

Probability of mode choice is as per utility functions developed for various modes based on TT, TL, TC and income. Utility functions based on MNL model of mode choice for study area is as shown in Table:3 below. Data collected by HIS is used to develop model.

Table 4: Utility Functions Developed by Mode Choice Analysis Based on HIS

Mode	**Utility Function**
Walk	U_W = - 0.20 (Income) + 0.94 (TT) - 1.08 (TL)
Bicycle	U_{BC} = - 0.54 (Income) + 0.85 (TT) - 1.64 (TL)
2W	U_{2W} = 0.31 (Income) + 0.71 (TT) + 0.84 (TL) -1.16 (TC)
3W	U_{3W} = -1.17 (Income) - 0.14 (TT) -1.19 (TL) + 1.62 (TC)
4W $_{CAR + CAB}$	U_{4W} = 1.32 (Income) - 2.88 (TT) -1.50 (TL) + 2.48 (TC)
Bus $_{AMTS + BRTS}$	U_{PT} = - 0.85 (Income) + 1.39 (TT) + 0.35 (TL) - 1.77 (TC)
Bus $_{(Sc/Co/Staff)}$	U_{SCS} = -1.51 (Income) + 0.51 (TT) + 0.29 (TL) - 0.22 (TC)

As the distance or trip length increases, walk and bicycle like NMT is less chosen. With increase in income walk and bicycle usage is decreasing. As the travel cost increases due to increase in fuel rate and parking rate, mode choice for 2W is reducing. As travel distance increases and income increase, mode choice for 3W is reducing. Due to congestion if travel time increases, mode choice for 4W is reduces. Due to unavailability of parking space, usage of 4W is reducing. Due to rise in fare in public transport, travel cost increases and hence, mode choice of bus is reducing. With increase in income, mode choice for bus is reducing.

6.2.7 Findings for land use analysis:

The land use of 2011 and 2017 observed for the study. Land use in 2011; maximum area provided for residential land use and it is 37% of the total land in study area. Transport land use is 17% and Mixed land use is 9%. The land use observed in 2017 is 39% residential, 22% transport and 12% mixed land use. The agricultural land available in 2011 was14%, which is consumed by 10% till 2017. Only 4% agricultural land left in study area is observed in 2017 land use map. The vacant plots available was 7% in 2011, which is consumed and left only 1% in 2017. 6% of the 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.Public gardens provided by AMC. Riverfront along Sabarmati River is observed. On one side of study area there is river body. Widening of road for exclusive lane for BRTS and flyovers are observed change in transport land use in 2017 compared to 2011.

7. 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 household is 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. 1600 data is taken for model development. 2/3rd data is taken as training data.

Second objective of the study is to calibrate and validate developed models. 770-800 data is taken for validation of the model. There is good relationship between modelled/estimated/predicted trips with observed/surveyed trips.

a. Univariate LUTI Models:

Produced trips is dependent variable and taken as 'y' in equation. Independent variables are taken as 'x'. Additive constant 'a' is taken as 0. Multiplying constants are denoted by 'b'

Produced trips increasing with increase in area provided for development and population density.

1. Produced Trips = 21192 (Residential Land use Area 2017 in SqKm)
   R^2 = 0.85 Significance F = 0.0003 RMSE = 4.37%
2. Produced Trips = 34317 (Transport Land use Area 2017 in SqKm)
   R^2 = 0.75 Significance F = 0.0017 RMSE = 5.55%
3. Produced Trips = 3.26 (Population Density)
   R^2 = 0.85 Significance F = 0.0002 RMSE = 3.64 %

b. Multivariate LUTI Models:

1. Produced Trips = 0.65 (Number of Households) + 0.45 (Family Size)
   R^2 = 1 Significance F = 0.0005 RMSE = 7%
2. Produced Trips = 5.87 + 0.02 (Number of Households) + 0.20 (Vehicle Ownership) + 0.49 (Family Size)
   R^2 = 0.99 Significance F = 0.000 RMSE = 6.80%
3. Produced Trips = 0.35 (Population) + 0.38 (Vehicle Ownership) + 186 (Residential Land use Area in SqKm)
   R^2 = 1 Significance F = 0.000 RMSE = 0.42%

4. Produced Trips = 0.34 (Population) + 0.40 (Vehicle Ownership) + 341 (Transport Land use Area in SqKm)

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

c. Univariate Trip Production Models

1. Produced Trips = 0.64 (Family Size) $R^2 = 0.86$ Significance F = 0.00
2. Produced Trips = 1.77 (Number of school college going persons in family)

   $R^2 = 0.68$ Significance F = 0.00
3. Produced Trips = 1.60 (Number of employed persons in family)

   $R^2 = 0.78$ Significance F = 0.00
4. Produced Trips = 0.97 (Number of vehicles in household)

   $R^2 = 0.75$ Significance F = 0.00

d. Multivariate Trip Production Models

1. 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)

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

   $R^2 = 0.92$ Significance F = 0.00 RMSE = 0.78
3. Produced Trips = 0.44 (Family Size) + 0.48 (Number of school college going persons in family) + 0.17 (Number of vehicles in household)

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

Correlation among variables is positive, non-zero and up to 1. R^2 = Coefficient of correlation: more than 0.50 and near to 1 shows good relationship among dependent and independent variables.

e. Ward wise Models for Trip Production:

Multivariate Regression Models: For study area Paldi:

Produced Trips = 1.33 (Number of school college going persons in family) + 1.62 (Number of Employed Persons in Family) + 0.32 (Number of Persons in Family) Likewise for all 9 wards of west zone models are developed.

f. Land Use Models: The models showing relationship among population and number of households with residential and transport land use area.

1. Residential land use area in 2011 in SqMt = 127.72 (Number of households in 2011)

   Multiple R = 0.93 $R^2 = 0.86$ Significance F = 0.0002
2. Residential land use area in 2011 in SqMt = 28.29 (Population in 2011)

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

3. Residential land use area in 2017 in SqMt = 99.95 (Number of households in 2017)
   Multiple R = 0.92 R^2 = 0.85 Significance F = 0.0003
4. Residential land use area in 2017 in SqMt = 23.92 (Population in 2017)
   Multiple R = 0.94 R^2 = 0.87 Significance F = 0.0001
5. Transportation land use area in 2011 in SqMt = 57.02 (Number of households in 2011)
   Multiple R = 0.85 R^2 = 0.72 Significance F = 0.0026
6. Transportation land use area in 2011 in SqMt = 12.69 (Population in 2011)
   Multiple R = 0.86 R^2 = 0.74 Significance F = 0.002
7. Transportation land use area in 2017 in SqMt = 54.60 (Number of households in 2017)
   Multiple R = 0.86 R^2 = 0.75 Significance F = 0.0018
8. Transportation land use area in 2017 in SqMt = 13.33 (Population in 2017)
   Multiple R = 0.90 R^2 = 0.80 Significance F = 0.0007

The test is with 95% confidence interval. The developed models are calibrated and acceptable as per values of R^2, Significance F and RMSE. The regression among observed trips and modelled/predicted/estimated trips showing value of R^2 more than 0.60 then it is showing validation of the model. All developed models are validated.

8. 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.

There is increase in population density by 6148 persons per SqKm area from 2011 to 2017. The cycle of LUTI initiating with increase in population and density causing increase in trips leading to increase or change in land use. Which 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 mix 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 compared to 2011. Flyover and Integrated Corridor for public transportation system are observed increase in transport land use.

Mode choice probability analysis based on utility function for different modes of trip can predict mode choice of users in future.

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.

Family size is reducing day by day. It was 5.15 in 1991 and 5.02 in 2001. It is 4.5 in 2011 and 4.1 in 2017 in study area west zone of Ahmedabad.

Average vehicle ownership per HH is 2.36.

2.5 is average produced trips per HH, which are regular trips and for work and education purpose.

9. 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. Only local 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. The data analysis and model development are carried out in MS excel. The data collection by home interview survey and public transport users survey is in collaboration with Post Graduate Students of Transportation Engineering of L.D. College of

Engineering, Ahmedabad.

10. Future scope of 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, 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.

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

11.1 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

11.2 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

11.3 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.

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