Mode choice analysis of Trips of Urban Residents using Multinomial Logit Model

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***Abstract*:** An efficient transportation system is necessary for the development and growth of economy of a growing country like India. The population of developing cities like Ahmedabad in India are continuously increasing. Understanding the mode choice preferences of urban residents by identifying different parameters affecting the selection of a specific mode are necessary. Mode choice analysis forms an integral part of transportation planning. The private vehicle ownership as number of two-wheeler and four-wheeler increasing rapidly. Mode choice behaviour of urban inhabitants plays an important role in transportation planning decisions. Choice of a particular mode affect the general efficiency of travel within the city. For mode choice modelling different techniques are available. Use of Multinomial logit model (MNL) are found to be efficient in estimating the different mode shares in a scenario where more than two choices of modes of travel are available for a trip maker. Socio-economic parameters and trip information are important factors for development of the utility function model for different modes of travel. Travel time, Travel cost, Travel length and income of trip makers are major affecting parameters on selection of a particular modes in urban area. Utility functions are developed based upon these parameters. TransCAD software used for development of utility model. Probability of different mode of travel has been derived for selected study area.

Keywords: **Mode choice, Population, Probability, Transportation planning, Utility function**

I. INTRODUCTION

Transportation planning is an important part for development and growth of country's economy. Travel behavior analysis and modeling is essential in transportation planning. Increase in population of developing countries like India number of captive transit rider and choice transit riders are also increasing. Use of specific mode of travel of any area depends on Travel characteristics and socio-economic characteristics of urban inhabitants. Trip makers have choice to select the different mode based on these characteristics. The process of proportionate division of total number of persons trips between different modes of travel in terms of fraction, ratio or percentage is called as Mode choice analysis. Mode choice analysis is the process of arriving at a decision about which mode to use under a set of circumstances. More use of private vehicles increases the problems of traffic, congestion, vehicle parking, delay, air pollution, noise pollution and increase in travel time. Efficiency of road space reduces due to a greater number of private vehicle users. Use of public transport facilities can increase the efficiency of road and also solve the problems of traffic congestion and vehicle parking. To minimize various problems of urban area, mode shift from private vehicle to personal vehicle for transportation planning is required. For Transportation planning it is necessary to find out percentage of users with specific mode of travel.

Comparison of Public and Private Transportation modes are shown in figure 1 below. As number of private vehicle users are increasing more space is occupied by the vehicles and different problems of transportation arises.

Figure 1: Comparison of Public and Private Transportation

MULTINOMIAL LOGIT (MNL) MODEL

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. These are found to be efficient in estimating the different mode shares in a scenario where more than two choices of modes of travel are available for a trip maker. Discrete choice models statistically relate the choice made by each persons to the attributes of the person and the attributes of the alternatives available to the person. The MNL model gives the choice probabilities of each alternative as a function of the systematic portion of the utility of all the alternatives.

$$P_r(i) = \frac{\mathrm{Exp}(\mathrm{U_i})}{\sum_{j=1}^{J} \exp(U_j)}$$

Where, Pr(i) = probability of the decision maker choosing alternative "i" and Uj = systematic component of the utility of alternative "j".

Utility of different mode of travel can be derived by following equation

$$U = a_0 + a_1x_1 + a_2x_2 + \ldots\ldots\ldots + a_rx_r$$

Where, a_0, a_1, …a_r is the coefficient and x_1, x_2….x_r is the variables like income, travel cost, travel time, trip length etc.

II. STUDY AREA

Ahmedabad lies at 23.03°N, 72.58°E in western India at 53 meters (174 ft.) above sea level on the banks of the Sabarmati river, in North-Central Gujarat. It covers an area of 464 km^2 (179 sq. mi). Ahmedabad is the largest city and former capital of Gujarat state. It is the fifth largest city with 6.2 million populations and seventh largest metropolitan area of India. Ahmedabad is fastest growing cities in the world and rapid urbanization will lead to more people migrating from different parts of the state and the country. Ahmedabad is the fifth most populous city and seventh most populous urban agglomeration in India. According to the 2011 census, the population of Ahmedabad city was 55,77,967. While that of its urban agglomeration was 63,61,084. The city had a literacy rate of 89.62%; 93.96% of the men and 84.81% of the women were literate.

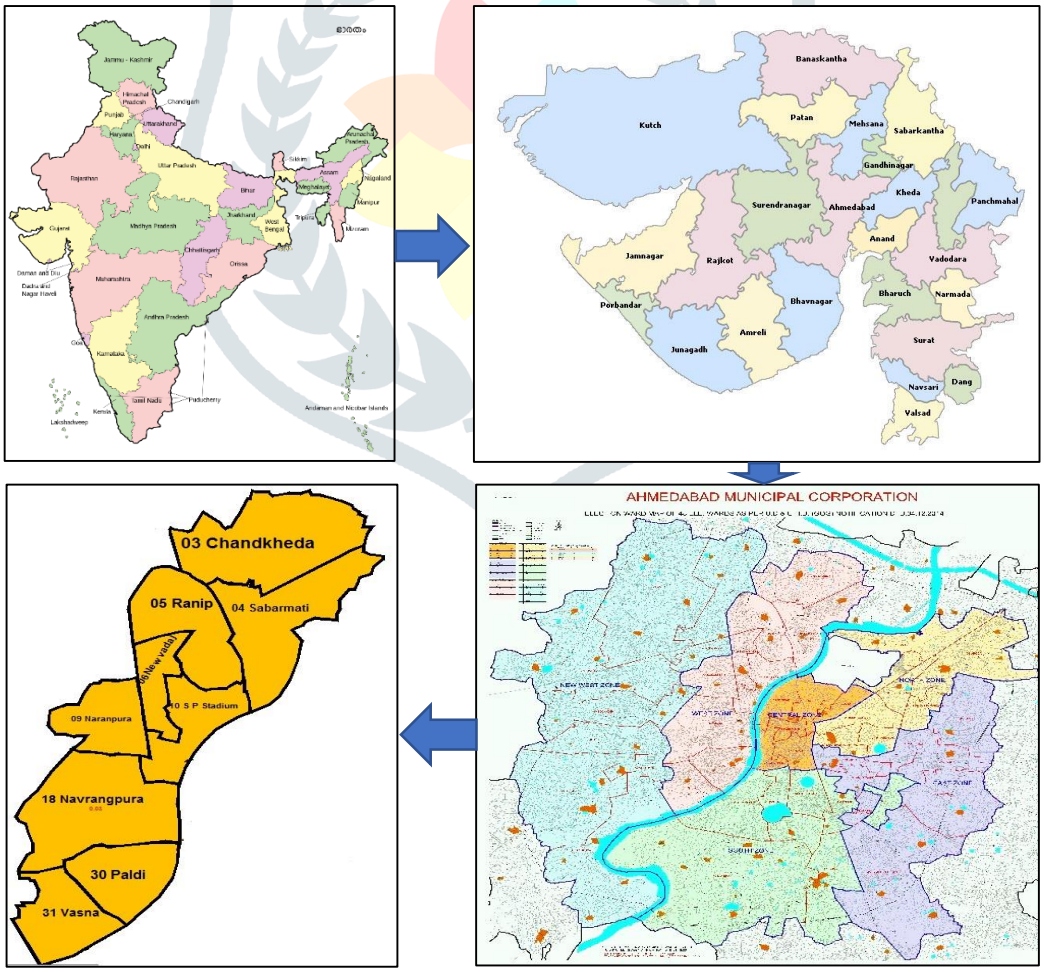

Figure 2: Digitize map of Study area using TransCAD software (Study area profile/Map source: www.inst.mhrd.gov.in and Ahmedabad Municipal Corporation)

Figure 2 shows the map of study area which is digitize using TransCAD software and ward boundaries of study area considered for mode choice analysis according to Ahmedabad Municipal Corporation Map.

There are mainly two public transport systems exists in Ahmedabad which are: Ahmedabad municipal transport service (AMTS) and Bus rapid transit system (BRTS). The AMTS has maximum coverage in all the zones of the city. The mass transit metro system, for the cities of Ahmedabad and Gandhinagar is under construction since March 2015. The North-South and East-West corridors are expected to complete by 2019.

Mode share for Ahmedabad in the year is as shown in figure 3.

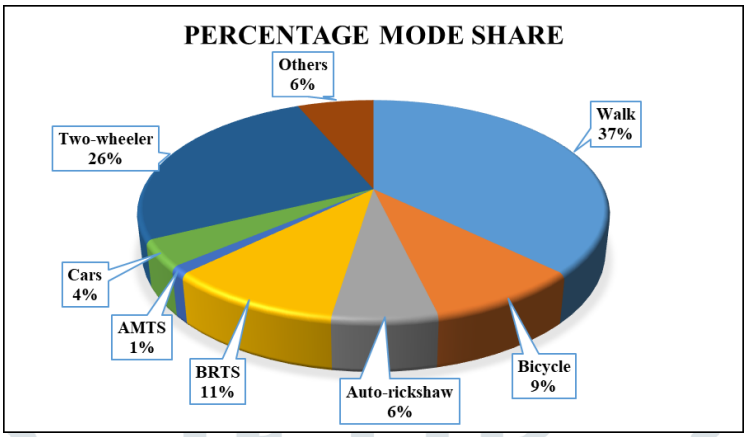

Figure 3: Mode share of residents of Ahmedabad (Source: DPR for Ahmedabad Metro Rail Project)

Number of two-wheeler and four-wheeler users are increasing rapidly in comparison to public transport in India. In Ahmedabad Gujarat, total 25.9% of two-wheeler and 3.9% four-wheeler users are there. More number of people uses private mode of transport than public transport in Ahmedabad. Ahmedabad having two bus transit system for public transportation namely Bus Rapid Transit System (BRTS) and Ahmedabad Municipal Transportation System (AMTS).

Table 1 shows the study area in sq.km, number of household and total population as per census 2011. population for the year of 2018 is derived from the growth pattern of the Ahmedabad. Final population for the year of 2018 is considered for sample size calculation and model development.

Table 1: Population and Number of Households of study area

Name of Ward	Ward no.	Area (Sq. Km)	Total no. of House Holds	Total Population
Paldi	07	5.58	18855	83109
Vasna	08	5.57	27754	123116
Navrangpura	10	11.98	12839	55647
S.P. Stadium	11	5.24	16979	75051
Naranpura	12	4.91	20829	88032
Nava vadaj	13	3.17	17237	77814
Sabarmati	15	9.78	14362	68566
Ranip	45	7.55	24960	120152
Chandkheda	57	11.9	20436	96266

III. DATA COLLECTION

Preliminary and secondary data has been collected for data analysis and model development. In preliminary data collection ward wise map of Ahmedabad city, population data as per census 2011 and population data for the year of 2018 has been derived from past census data of the study area and population growth.

SAMPLE SIZE CALCULATION

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

$$n = \frac{Z^2 * p * q}{C^2}$$

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% and n = sample size for infinite population

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

If family size is 4.5 then final sample size = 599.75/4.5 = 132. Required sample size for different wards of study area are calculated and shown in following Table 2. Sample size is taken more than required from the calculation to meet the standards of Bureau of Public Road Manual for Household Interview Survey.

Table 2: Number of households required and surveyed

Name of Ward	No. of Household surveyed	Household by calculation
Paldi	346	132
Vasna	149	132
Navrangpura	147	131
S.P. Stadium	297	132
Naranpura	333	132
Nava vadaj	140	132
Sabarmati	115	131
Ranip	221	132
Chandkheda	323	132
Total	2071	1186

IV. DATA ANALYSIS

Figure 4 shows the percentage trip makers and it represent 74.03% Male trips and 25.97 % Female trips.

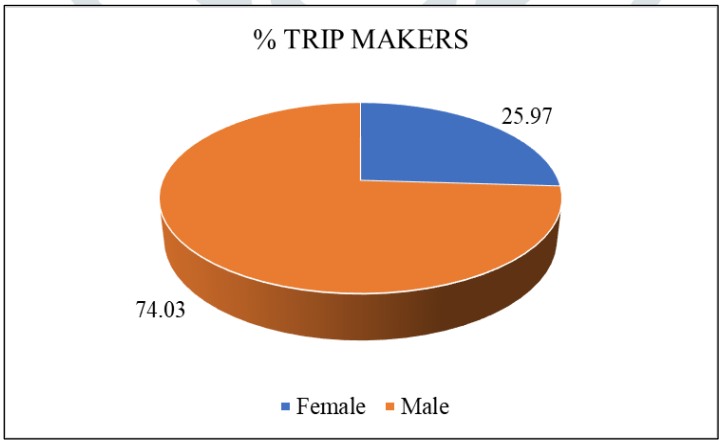

Figure 4: Percentage of Male and Female trip makers

Classification of percentage of male and female trips for different age groups are shown in figure 5 below. Among all age groups 16 to 30 years' age groups shows the highest number of trips for both male and female.

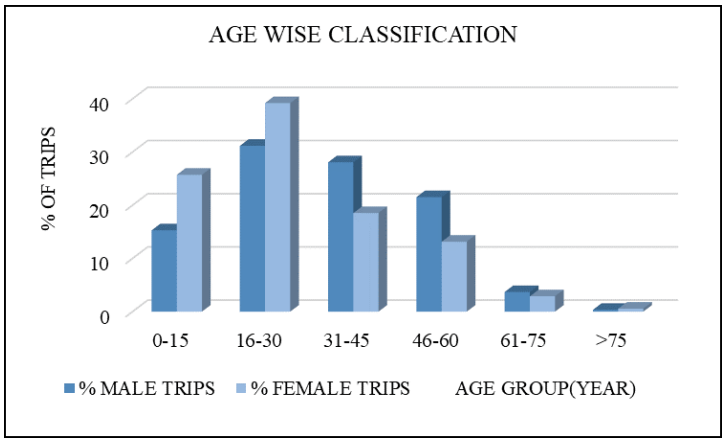

Figure 5: Age group (years) wise percentage of Male and Female trip makers

Figure 6 shows the classification for different income groups. Maximum percentage of trips occurs for income group of less than 20000 Rupees.

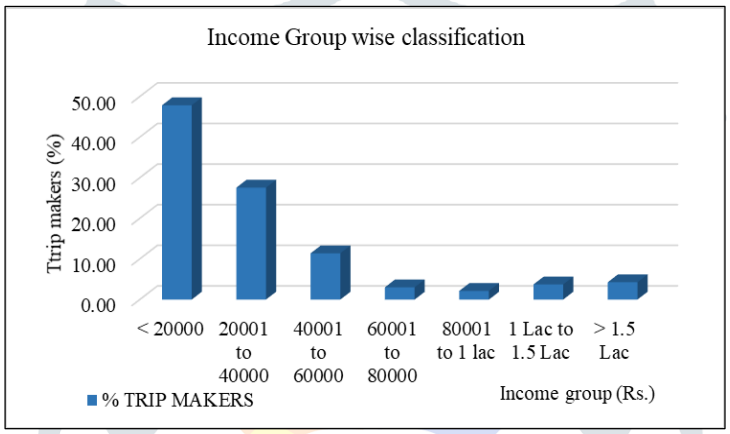

Figure 6: Income group (Rupees) wise percentage of trip makers

Trip length is major affecting parameter on selection of specific mode. Figure 7 represent the percentage of trip makers based on trip length. As trip length increases percentage of trips decreases and maximum and minimum percentage of trips observed for the trip length group of 0 to 4 and greater than 20 respectively.

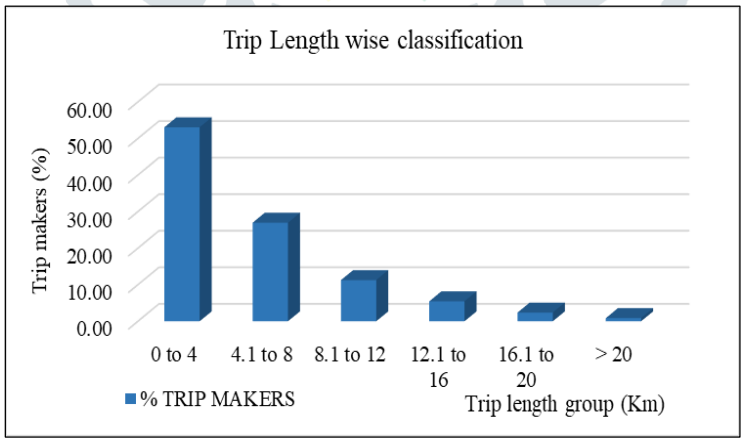

Figure 7: Trip Length (km) wise percentage of trip makers

Figure 8 shows the percentage of trip makers for different trip cost groups. For the cost of 0 to 20 Rupees highest number of trip makers are there and fewer trips observed for cost of more than 100 Rupees.

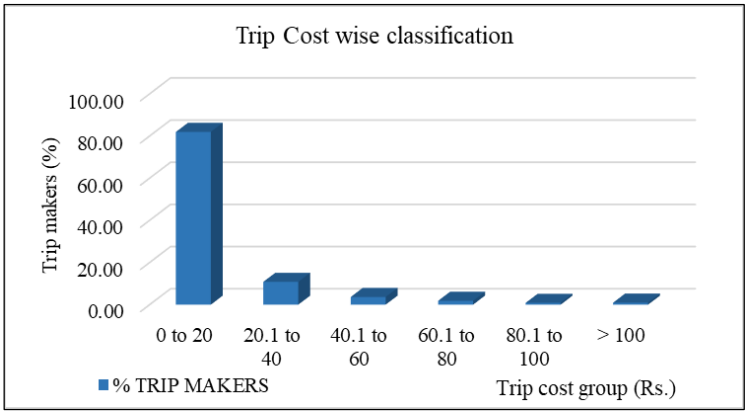

Figure 8: Trip Cost (Rupees) wise percentage of Trip makers

To reach at specific destination different mode can be used by trip makers. Percentage of trip makers for different category of vehicles is as shown in figure 9. Two-wheeler has highest number of trips. Private cab and staff bus users has been observed very less for selected study area. For model development private cab is club with car. AMTS and BRTS as public transportation. School bus and staff bus as private bus.

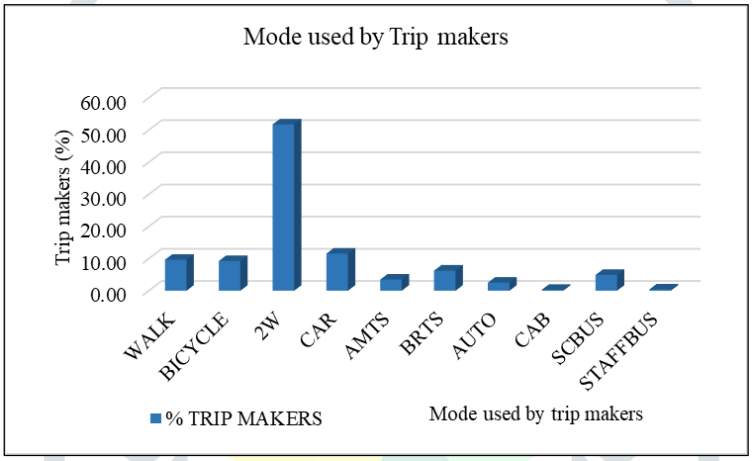

Figure 9: Percentage of trip makers by different vehicular mode

V. Model Development

Multinomial logit model (MNL) was developed for mode choice analysis. The dependent variable used for model development is mode of travel. The independent variables like income group, trip time, trip cost, and trip distance were mainly used for development of utility model. Model is developed using TransCAD software and Utility functions has been developed for considered modes of travel as following.

$$U_{Walk} = -0.5587\,(INCOME) - 0.4651\,(TT) - 0.7412\,(TL)$$

$$U_{two\text{-}wheeler} = 0.3070\,(INCOME) + 0.7054\,(TT) + 0.8375\,(TL) - 1.1645\,(TC)$$

$$U_{Car} = 1.3162\,(INCOME) - 6.8842\,(TT) - 1.4954\,(TL) + 4.4796\,(TC)$$

$$U_{Bus\ (Public\ Transport)} = -0.8494\,(INCOME) + 1.3906\,(TT) + 0.3470\,(TL) - 1.7702\,(TC)$$

VI. Probability Analysis

Probability of different modes used by trip makers are derived from the following equation using utility function for different modes of travel.

$$P_r(i) = \frac{\mathrm{Exp}(U_i)}{\sum_{j=1}^{J} \exp(U_j)}$$

Where, $P_r(i)$ is the probability of different modes and U_i is the utility of specific modes.

Figure 10 shows the mode choice analysis for different modes from the developed utility model. Maximum 42 % of trips are observed for two-wheeler modes and minimum 2 % trips observed for car and cab mode.

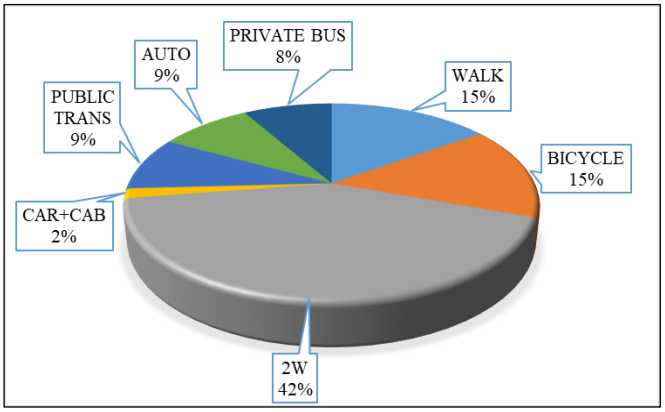

Figure 10: Probability of selection of different vehicular mode

VII. Conclusion

from the study area 2071 households has been selected as per sample size trip characteristics and socio-economic characteristics are collected by Home Interview survey. Data analysis carried out in TransCAD software for development of utility model. MNL model developed from 7586 trips of different modes used by trip makers. Mode of trips are taken as dependent variable and income(Rupees), travel time(Minutes), trip length(Km) and trip cost(Rupees) are taken as independent variables by arranging them in groups/ranges. Probability of different vehicle use are analyzed based upon Utility functions.

Following are the outcomes derived from the utility model.

- As income increases the use of two-wheeler and car users are increases in comparison to public transport bus.
- As income increases mode shift from two-wheeler to car increases.
- Increase in trip length results into the decrease in utility of walking trips and bicycle trips. Up to four km of travel active mode (walk and bicycle) of transportation is preferred.
- On other side more number of people uses the two-wheeler mode to reach at specific destination.
- Utility of two-wheeler mode decrease as increase in trip cost. As fuel charges increase percentage of two-wheeler users decreases due to increase in trip cost.
- Utility of car is affected by increase in total travel time if parking availability is questionable.
- Probability of public transportation bus mode is decreasing by increase in income and travel cost (bus fair).
- Highest probability based upon utility function for mode choice is 42% for two-wheeler.

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