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Research paper

Development of mode choice models of a trip maker for Hyderabad metropolitan city

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Abstract

The rapid development of urbanization, population growth and the rapid development of economy resulted in the rapid increase in the total number of motor vehicles in the modern cities of India. Consequently, the importance of forecasting of the travel demand model has been increased in the recent years. Forecasting of the travel demand model involves various stages of trip generation and distribution, mode choice and traffic assignment. Among these stages, the mode choice analysis is a prominent stage as it considers the travelers mode to reach their destination. Further, study of mode choice criteria has become a vital area of research as individual and household socio-demographics exert a strong influence on travel mode choice decisions. There is a huge literature on travel model choice modeling to predict the range of trade-offs of transportation of commuters considering travel time and travel cost. In such literature intercity mode choice behavior has gained significant attention by several authors. In this study an attempt has made in order to calculate the model share of the different modes between the circle to the circle, and it is found that the modal share of 2-wheeler is 70 %, bus is about 23 % and car is about 7% of the total trips.

Keywords: *Mode Choice Modeling; Binary Logit Models; Multinomial Logit Models; Trip Maker; And Travel Demand Modeling.*

1. Introduction

Mode choice analysis is the third step in the conventional four-step transportation planning model. Trip distribution's zonal interchange analysis yields a set of origin destination tables, which tells where the trips will be made; mode choice analysis allows the modeler to determine what mode of transport will be used. Mode choice is one of the most critical parts of the travel demand modeling process. It is the step where trips between a given origin and destination are split into trips using transit, trips by car pool or as automobile passengers and trips by automobile drivers. A utility function measures the degree of satisfaction that people derive from their choices, and a disutility function represents the generalized cost that is associated with each choice. The most commonly used process for mode split is to use the 'Logit' model. This involves a comparison of the "disutility" or "utility" of travel between two points for the different modes that are available. Disutility is a term used to represent a combination with the travel time, cost and convenience of a mode between an origin and a destination. It is found by placing multipliers (weights) on these factors and adding them together.
Disutility calculations may contain a "mode bias factor" which is used to represent other characteristics or travel modes, which may influence the choice of mode (such as a difference in privacy and comfort between transit and automobiles). The mode bias factor is used as a constant throughout the analysis and is found by an attempt to fit the model to actual travel behavior data. Generally, the disutility equations do not recognize differences within travel modes. For example, a bus system and a rail system with the same time and cost characteristics will have the same disutility values. There are no special factors that allow for the difference in attractiveness of alternative technologies.

2. Model split models

Selection of the transport mode choice[1] by the trip maker is depended upon the various factors like availability of the transport mode, travel time, travel cost, parking fees and availability and access point, etc. based on the above-mentioned factor. There are so many mathematical models developed to know the behavior of the trip maker. Mode Choice Models generally classified mainly intotwo categories which are shown in fig 1.

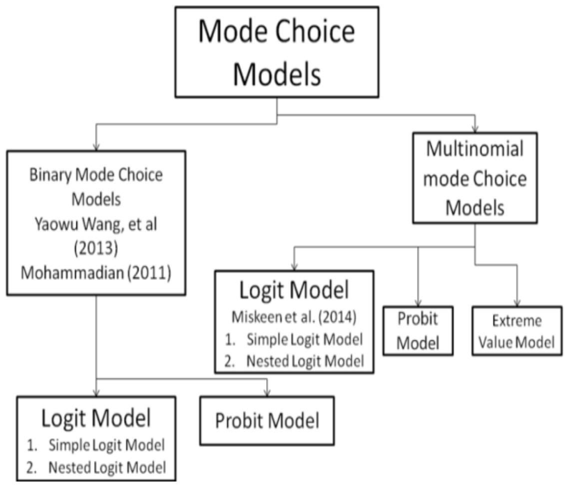

Fig. 1: Classification of Mode Choice Models.

Binary logit model is the simplest form of mode choice and it is categorized into simple and nested logit model. It is used when only two transport mode choices are there for trip maker. The higher utility value mode will be chosen by the trip maker in this case. But in transportation, we have disutility also. The disutility here is the travel cost. The general form of the binary logit model is in equation. 1

The probability of individual i selecting mode m out of two travelling modes available m and n

$$Pim= \frac{\exp(Vim)}{\exp(Vim)+\exp(Vin)} \quad (1)$$

Where,

Pim is the probability that alternative m will be selected by individual i

Vim is utility function associated to alternative m for individual i

Vin is utility function associated to alternative n for individual i

Binary logit model have the some limitations that the choice of alternatives in each set should be different. If there are groups of similar or correlated modes application of binary logit model is not valid. In such cases nested logit model can be used relaxes the constraints of the simple logit models allowing correlation between the utilities of the alternatives in common groups. Multinomial logit model [2] is also same as the binary logit model and it is categorized into simple and nested logit model based on the available travelling mode choice set characteristics. Equations of Multinomial logit model are Equations of binary simple and nested logit model only.

If the utilities of some alternatives are correlated in a complex way, the multinomial logit models can make incorrect forecasts regarding the probabilities' mode choice when attributes are associated with one or more traveling alternatives. In this case probit, model is one of the possible methods to overcome this type of problems. This model is developed based on the normal distribution, and it will not work under the strict assumptions as that of logit models. The standard equation for the utility of an alternative i has the form (Horowitz 1991) as shown in equation 2.

$$Ui=V\ (xi,s)+\varepsilon i \quad (2)$$

Where,

Ui is the utility of alternative i

V is the systematic component of utility function

ε is the error component of utility function

xi is the vector of observed attributes of alternative i

s is the vector of observed characteristics of the individuals of the study area

In simplification of multinomial logit models generalized extreme value models have developed based on the utility maximization

3. Literature review

From the past few decades' lot of research has been done in the development of Mode Choice Modeling (MCM) area with different models, different parameters for different cities all over the globe. The present paper discusses the literature carried out in this specific area of research.

To develop the model for the mode choice behavior of a road user different researchers have adopted different methodologies among few are discussed here. Binary probit and logit models are developed to compare the modal behavior and to test the differences of mode choice among the different zones [13]. Evidential neural network (ENN) model is used for predicting an individual travel mode. This model can be also used to support management decision-making and build predictions under uncertainty related to changes in people's behavior, economic context or environment and policy. The presented model uses individuals' characteristics, transport mode specifications and data related to places of work and residence [17]. The fuzzy logic technique was developed in 1965 by LotfiZadeh. The fuzzy logic provides a mechanism for representing linguistic variables such as "many," "low," "medium," "often," "few," etc. On the contrary. The traditional binary set theory describes crisp events, events that either do or do not occur [8]. The theory of fuzzy logic [22] is based on the concept of relative graded membership. It is important to observe that there is an intimate connection between Fuzziness and Complexity [21]. Integrated Hierarchical Information Integration (HII-I) approach allows to include a larger number of attributes in choice experiments by summarizing similar attributes into constructs. In separate sub-experiments, one constructs is described by its attributes while the other constructs are included by summarizing construct values. This approach allows for testing of process equality in order to know if the different sub-experiments may be concatenated into an overall model.Cornelia Richter (2012).

Miskeen et al. (2014) have studied the MCM using a Multinomial logit model which helps in investigating mode choice behavior for non-business trips in the city of Libya and this study also investigates the interest of road users towards the intercity transport[3][4][5][6]. The study was conducted in all main metropolitan areas in Libya. The data required for defining, designing, and validating transferability, contain three categories, such as: (1) socio-economic variables, (2) level of services or supply variables, and (3) trip data.

Kumar et al. (2013) developed a MCM to explore the relationship between travel patterns of commuters and their willingness to adopt an alternate mode. The study also estimated public transport share along with private vehicles. A fuzzy logic model is applied on three work centers, NetajiSubhash Place, Nehru Place and Connaught Place in Delhi (India). The main emphasis of their study was to test the number of public transport policy variables to determine the modal share with respect to personalized and public transport modes. The technique mainly considered the trip characteristics of commuters by using the number of variables affecting the mode choice behavior of commuters with respect to various alternative modes.

JianchuanXianyu (2013)[18] has investigated the decision order of trip chaining and travel mode choice. A house-hold survey is conducted during this study, which can be applied on the co-evolutionary approach to capture the interrelationship between travel mode choice and trip chaining. A co-evolutionary logit model is used for modeling the MCM. Three categories of explanatory variables that influence the travel mode and trip chaining of a work tour are considered. Namely individual and household socio-demographics, transportation-relatedmeasures, and activity travel across characteristics. Results of this study provide the approaches for predicting commute mode and trip chaining behavior simultaneously. Cornelia Richter et al. (2012) [7] have done a research that the Hierarchical Information Integration approach is applied on MCM between a regional train, a (hypothetical) regional bus and a car (only available for car users). Lu et al. (2011) [10] have studied a multimodal corridor transportation system with trip-chain costs. The transportation system comprises a subway parallel to a bottleneck-constrained highway between a residential area and a workplace.

Zhihu Zhang, Hongzhi Guan, Huanmei Qin, and YunqiangXue (2013) have conducted a survey on the bus user groups in Jinan city and establish the MNL model as well as SP and RP model. This paper analyzes how the influencing factors such as parking fee, fuel cost, bus ticket price and bus travel time affect the choice proportion of bus travel mode for the bus user groups. A multinomial logit model is used for MCM, and the sensibility of the parking fee is analyzed when the fuel cost is unchanged or increased.

Yaowu Wang, et al (2013) developed the Binary probit and logit models for MCM and compared the modal behavior to verify the differences of mode choice behavior among the three zones in Maryland. They investigated unobserved factors influencing freight mode choices, including truck and rail. Based on the nature as the data source, there are two types of analytical methods in freight modal choice in the literatures: aggregated and disaggregated models (Winston, 1983). The aggregated model applies an aggregated share of a freight mode at a certain geographical level. This type of model focuses on describing the group behavior of firms, and it is useful to capture general trends and changes due to policies based on general characteristics observed (Shen and Wang, 2012). Disaggregated choice models focus more on individual behavioral aspects of the shipment decision makers. Data are collected from individual shipper, companies.

Arunotayanun and Polak (2011) used a mixed logit model to investigate the prevalence of observed and unobserved taste heterogeneity influencing shippers mode choice behavior based on stated preference data collected in Java, Indonesia. Samimi, Kawamura, and Mohammadian (2011) used binary logit and probit models to explain how truck and rail are chosen by the shippers.

Chandra R. Bhat et al (2010) studied the commute mode choice and the number of non-work stops during the commute using a multinomial logit formulation. Further, the number of commute stops is modeled using an ordered response formulation. Copula-based joint multinomial logit – ordered logit structure, and captures the observed effects of personal, household, residential location, and commute characteristics together with potential unobserved common effects impacting the two choices. The copula-based methodology facilitates model estimation without imposing restrictive distribution assumptions on the dependency structures between the errors in the discrete unordered and ordered choice components [19].

The results of their work indicate the substantial and statistically significant effects of individual and household characteristics on mode choice and stop-making behavior. On the other hand, residential location and commute characteristics seem to affect only to commute mode choice and not commute stop-making behavior. Earlier studies have also pointed out the relatively small or zero effect of commute distances and built environment variables on commute stop-making, especially relative to the effects of demographic variables.

Chandra R. Bhat et al. (2010) used an econometric structure to jointly model the commute mode choice and the number of commute stops in the Boston Metropolitan Area. The commute mode was modeled using a multinomial logit model and developed a copula-based joint framework of tour mode choice and number of stops during the commute.

The purpose of effectively managing demands of urban travel, it is essential to plan a suitable transport system, in addition to dealing with the issues of traffic jam, accidents and environmental pollution, as a result of overflowing number of vehicles.

4. Analysis and results

For the porpuse study Hyderabad metropolitan city area has been considered. The study area is mainly consists of 18 circles as given in the Table 1.

Table 1: Number of Circles in the Study Area

Circle No.	Name of the Zone / Circle	Latitude	Longitude
1.	Kapra	17.49 N	78.57 E
2.	Uppal	17.38 N	78.55 E
3.	L.B. Nagar / Gaddiannaram	17.34 N	78.55 E
4.	Erstwhile Circle – I	17.37 N	78.51 E
5.	Erstwhile Circle – II	17.32 N	78.47 E
6.	Rajendra Nagar	17.18 N	78.24 E
7.	Erstwhile Circle – IV	17.39 N	78.43 E
8.	Erstwhile Circle – VI	17.39 N	78.43 E
9.	Erstwhile Circle – III	17.38 N	78.47 E
10.	Erstwhile Circle – V	17.41 N	78.46 E
11.	Serilingampally (North)	17.48 N	78.31 E
12.	Serilingampally (South)	17.48 N	78.31 E
13.	RamachandraPuram and Patancheru	17.51 N	78.30 E
14.	Kukatpally	17.49 N	78.39 E
15.	Qutu-bullapur	17.49 N	78.46 E
16.	Alwal	17.49 N	78.50 E
17.	Malkajgiri	17.44 N	78.53 E
18.	Secunderabad Division	17.43 N	78.49 E

Once disutility are known for the various mode choices between an origin and a destination, the trips are split among various modes based on the relative differences between disutility. The logit equation is used in this step. A large advantage in disutility will mean a high percentage for that mode. Mode splits are calculated to match splits found from actual traveler data. Sometimes a fixed percentage is used for the minimum transit use (percent captive users) to represent travelers who have no automobile available or are unable to use an automobile for their trip.

In this step the matrix for travel time and travel cost is given to calculate the utilities for three modes- Car, Bus and Two wheelers Moreover utility functions for these three modes are also assumed. The utility functions are as follows:

$$U_{CAR} = -0.06VTT_{CAR} - 0.043TC_{CAR} + 0.01WT_{CAR} \quad (3)$$

$$U_{TW} = -0.06VTT_{TW} - 0.043TC_{TW} + 0.016WT_{TW} \quad (4)$$

$$U_{BUS} = -0.06VTT_{BUS} - 0.043TC_{BUS} + 0.012WT_{BUS} \quad (5)$$

Where VTT = Vehicle travel time, TC = Travel cost and WT = Walking time.

Using utility equations the utility matrices for Car, Bus and Two Wheeler were generated and are tabulated as shown in tables 3, 4 and 5.

The Origin- Destination Matrix (O-D) were developed by conducting the Origin-Destination survey at different locations in each circle to know the number of trips generated and number of trips attracted from circle to circle and the same has tabulated as shown in the table 2. From the table it has been observed that maximum number of trips generated and maximum number of trips attracted by circle 6 only.

Table 2: Origin- Destination Matrix (O-D)

O-D	Circle 1	Circle 2	Circle 3	Circle 4	Circle 5	Circle 6	Circle 7	Circle 8	Circle 9	Circle 10	Circle 11	Circle 12	Circle 13	Circle 14	Circle 15	Circle 16	Circle 17	Circle 18	Pi
Circle 1	876	1106	1481	1393	1458	1929	1356	1251	1175	1308	1509	1440	1751	1275	1457	1080	978	1101	23924
Circle 2	1236	896	943	1085	1056	1202	1167	1038	953	1083	1225	1163	1463	1175	1314	1140	1050	1027	20214
Circle 3	1221	926	1018	981	1070	1460	1167	988	967	1112	1210	1336	1277	1295	1472	1177	1178	1086	20939
Circle 4	1413	988	937	958	1015	1316	1165	984	954	1133	1211	1389	1159	1247	1433	1228	1149	1071	20750
Circle 5	1303	1128	1066	965	998	1303	1236	1031	1025	1165	1171	1299	1680	1188	1415	1190	1092	1028	21282
Circle 6	1443	1341	845	1266	1072	862	1351	1261	1304	1424	1529	1768	1722	1511	1794	1718	1654	1457	25322
Circle 7	1254	1215	706	1179	1125	1019	1065	1005	1081	1101	1104	1307	1445	1190	1426	1289	1221	1088	20821
Circle 8	1307	944	950	923	1037	1013	1084	912	912	1003	1257	1282	1496	1118	1325	1185	1102	1025	19876
Circle 9	1246	892	1017	983	995	1076	1071	963	897	1051	1173	1287	1576	1131	1318	1200	1090	1014	19980
Circle 10	1201	1139	1199	1213	1129	1516	1190	1088	1071	951	1052	995	1144	1044	1261	1244	1214	1087	20736
Circle 11	1168	1183	1291	1290	1173	1538	1193	1095	1094	1069	1062	901	988	1066	1207	1209	1236	1099	20861
Circle 12	1417	1300	1365	1354	1385	1577	1427	1288	1213	1185	994	929	973	1121	1285	1400	1351	1207	22772
Circle 13	1183	1527	1701	1391	1584	1981	1640	1437	1344	1406	1118	1031	987	1165	1312	1428	1418	1450	25103
Circle 14	1290	1208	1292	1260	1241	1353	1233	1134	1152	1093	1109	1086	1128	1025	1107	1232	1236	1120	21299
Circle 15	1406	1321	1435	1333	1322	1601	1193	1249	1202	1283	1149	1373	1691	1153	1050	1312	1252	1161	23486
Circle 16	1213	1195	1259	1289	1268	1434	1263	1240	1105	1230	1639	1426	1700	1238	1288	976	1140	1101	23005
Circle 17	1127	1177	1142	1185	1262	1285	1268	1221	1053	1244	1233	1291	1811	1311	1415	1271	1163	1024	22482
Circle 18	1265	1215	1252	1220	1157	1498	1176	1108	1099	915	1004	949	1109	1024	1282	1311	1262	1120	20966
Aj	22568	20704	20899	21267	21345	24962	22246	20291	19602	20755	21747	22250	25103	21277	24161	22589	21786	20266	393816

Table 3: Utility Matrix for Car

O-D	Circle 1	Circle 2	Circle 3	Circle 4	Circle 5	Circle 6	Circle 7	Circle 8	Circle 9	Circle 10	Circle 11	Circle 12	Circle 13	Circle 14	Circle 15	Circle 16	Circle 17	Circle 18
Circle 1	-0.58	-5.76	-4.06	-8.27	-4.76	-5.97	-10.12	-7.77	-6.98	-9.34	-15.06	-14.41	-19.17	-8.47	-6.42	-3.46	-3.00	-4.90
Circle 2	-2.63	-1.14	-3.43	-3.37	-6.60	-8.90	-7.87	-4.16	-2.29	-8.46	-12.62	-12.31	-18.09	-8.58	-8.24	-7.41	-5.70	-3.62
Circle 3	-11.10	-3.25	-1.55	-3.16	-5.01	-7.34	-8.59	-4.88	-4.54	-10.89	-13.89	-14.30	-21.80	-9.97	-10.39	-9.55	-8.30	-6.37
Circle 4	-7.66	-3.48	-2.41	-1.32	-3.93	-6.53	-6.73	-2.29	-1.69	-7.43	-11.74	-12.33	-15.62	-9.16	-9.57	-8.44	-7.46	-4.88
Circle 5	-10.85	-6.55	-4.02	-4.04	-1.76	-3.63	-6.33	-4.42	-5.60	-8.89	-13.48	-13.30	-13.23	-11.97	-12.29	-12.18	-12.21	-9.30
Circle 6	-19.31	-9.45	-7.55	-6.67	-3.72	-0.64	-4.14	-6.17	-7.23	-7.62	-7.79	-10.75	-12.26	-9.96	-10.95	-10.97	-11.25	-8.68
Circle 7	-11.62	-10.21	-13.40	-7.44	-7.59	-3.08	-2.75	-5.61	-7.77	-5.47	-7.50	-8.06	-10.99	-9.30	-10.17	-10.91	-10.51	-7.47
Circle 8	-8.16	-4.97	-4.12	-2.27	-4.12	-5.75	-5.38	-0.87	-1.59	-5.91	-9.76	-10.66	-12.95	-8.61	-8.97	-8.27	-7.13	-4.22
Circle 9	-6.54	-2.68	-3.49	-1.94	-4.64	-6.79	-6.47	-2.39	-1.08	-6.62	-11.46	-11.24	-13.72	-9.40	-9.05	-7.81	-6.59	-4.14
Circle 10	-9.63	-8.78	-10.18	-6.99	-8.46	-10.03	-5.47	-5.44	-6.15	-1.48	-5.35	-4.77	-7.77	-4.81	-7.12	-8.26	-7.84	-5.21
Circle 11	-12.49	-12.97	-13.30	-10.65	-14.34	-12.62	-9.68	-9.89	-10.28	-6.25	-0.95	-1.44	-2.98	-5.19	-8.24	-10.46	-12.25	-10.34
Circle 12	-12.57	-12.49	-14.37	-11.44	-11.55	-10.92	-8.23	-10.30	-10.13	-5.80	-1.40	-1.26	-2.90	-4.21	-7.34	-9.54	-11.03	-9.83
Circle 13	-18.96	-20.76	-17.76	-16.60	-4.47	-10.64	-10.47	-15.05	-16.05	-8.18	-3.54	-3.02	-0.80	-6.39	-12.68	-13.16	-15.38	-13.55
Circle 14	-8.35	-9.06	-10.31	-8.20	-10.07	-8.64	-7.92	-7.13	-7.68	-4.56	-6.26	-4.56	-6.94	-1.37	-3.75	-6.23	-7.34	-5.53
Circle 15	-6.29	-8.59	-10.12	-9.13	-10.89	-12.03	-8.56	-7.18	-7.39	-5.87	-8.95	-7.49	-11.96	-4.38	-1.33	-3.41	-5.29	-5.12
Circle 16	-4.61	-7.85	-10.01	-9.76	-11.04	-11.59	-9.27	-7.35	-7.96	-7.77	-9.27	-9.18	-14.75	-6.31	-3.54	-1.59	-3.94	-5.06
Circle 17	-3.37	-5.86	-7.52	-8.08	-10.59	-10.75	-8.94	-7.27	-6.68	-7.65	-12.56	-11.34	-16.02	-9.20	-6.48	-3.90	-1.57	-3.67
Circle 18	-5.19	-4.10	-5.93	-5.84	-7.46	-8.18	-7.08	-4.03	-4.03	-5.04	-9.77	-9.03	-11.68	-5.74	-5.29	-4.14	-3.96	-1.71

Table 4: Utility Matrix for Two Wheeler

O-D	Circle 1	Circle 2	Circle 3	Circle 4	Circle 5	Circle 6	Circle 7	Circle 8	Circle 9	Circle 10	Circle 11	Circle 12	Circle 13	Circle 14	Circle 15	Circle 16	Circle 17	Circle 18
Circle 1	-0.65	-2.23	-2.49	-3.91	-3.73	-4.28	-4.56	-3.69	-3.12	-4.95	-6.88	-6.35	-6.35	-3.78	-3.08	-1.39	-1.12	-2.22
Circle 2	-1.79	-0.53	-1.17	-1.61	-2.93	-4.10	-3.82	-1.90	-0.85	-3.85	-6.16	-5.62	-7.02	-4.18	-3.92	-3.39	-2.06	-1.33
Circle 3	-4.32	-1.09	-0.71	-1.28	-2.24	-2.87	-4.03	-2.34	-2.19	-5.01	-5.48	-6.64	-9.52	-5.43	-5.26	-4.74	-3.71	-2.80
Circle 4	-3.53	-1.47	-1.01	-0.59	-1.74	-2.95	-3.19	-1.06	-0.76	-4.24	-5.14	-6.76	-8.23	-5.34	-5.54	-4.53	-3.43	-2.41
Circle 5	-6.07	-3.18	-1.74	-1.43	-0.77	-1.32	-3.12	-2.15	-2.66	-4.18	-4.63	-5.08	-5.48	-5.63	-7.16	-7.32	-5.61	-4.73
Circle 6	-6.72	-4.45	-3.10	-2.78	-1.32	-0.56	-2.34	-2.94	-3.62	-3.49	-2.89	-3.16	-4.33	-4.60	-3.90	-5.97	-6.09	-4.71
Circle 7	-6.15	-5.02	-5.71	-3.28	-2.64	-1.08	-1.32	-2.65	-3.71	-2.64	-2.77	-3.38	-4.11	-4.43	-5.33	-6.42	-6.17	-4.26
Circle 8	-4.21	-2.21	-2.18	-0.87	-2.06	-2.96	-2.87	-0.52	-1.08	-2.96	-4.98	-5.84	-6.15	-4.17	-4.81	-4.21	-3.27	-1.92
Circle 9	-3.02	-1.04	-1.70	-1.27	-2.35	-3.70	-3.62	-1.18	-0.55	-3.63	-6.26	-6.09	-7.10	-4.69	-5.01	-4.32	-2.81	-1.77
Circle 10	-4.70	-3.94	-4.61	-3.75	-3.97	-6.40	-2.99	-2.35	-3.04	-0.78	-1.91	-1.97	-3.77	-2.40	-3.60	-3.82	-3.90	-2.59
Circle 11	-5.97	-6.21	-6.83	-5.31	-5.27	-7.49	-4.48	-4.70	-4.84	-3.47	-0.63	-0.66	-1.04	-2.85	-4.07	-28.14	-6.03	-4.65
Circle 12	-6.66	-6.46	-7.06	-5.93	-4.98	-4.49	-6.17	-5.05	-5.14	-2.79	-0.64	-0.46	-1.03	-2.25	-3.76	-4.83	-5.61	-4.95
Circle 13	-6.21	-5.77	-6.02	-6.56	-5.29	-3.60	-4.05	-5.96	-6.67	-3.83	-1.37	-1.19	-0.50	-2.95	-4.59	-5.22	-6.08	-6.57
Circle 14	-4.16	-4.12	-5.28	-4.64	-4.58	-3.63	-23.30	-3.52	-3.61	-1.98	-2.73	-2.45	-2.47	-0.76	-1.53	-3.26	-4.11	-3.16
Circle 15	-2.86	-4.07	-4.69	-4.66	-5.25	-5.95	-3.95	-3.64	-3.80	-2.86	-4.07	-3.53	-5.28	-1.94	-0.84	-1.56	-2.69	-2.36
Circle 16	-2.43	-4.19	-5.12	-5.59	-5.53	-6.67	-4.89	-3.91	-3.94	-4.08	-5.07	-4.79	-6.22	-3.36	-1.87	-0.55	-2.20	-2.75
Circle 17	-1.94	-2.49	-3.72	-4.18	-5.38	-5.20	-4.64	-3.32	-3.21	-4.05	-5.93	-5.61	-7.47	-4.24	-3.63	-2.13	-0.67	-1.73
Circle 18	-2.89	-1.91	-2.96	-3.19	-3.24	-4.08	-3.31	-1.91	-1.60	-2.10	-4.54	-4.10	-5.32	-2.54	-2.62	-1.92	-1.73	-0.92

Table 5: Utility Matrix for Bus

O-D	Circle 1	Circle 2	Circle 3	Circle 4	Circle 5	Circle 6	Circle 7	Circle 8	Circle 9	Circle 10	Circle 11	Circle 12	Circle 13	Circle 14	Circle 15	Circle 16	Circle 17	Circle 18
Circle 1	-0.74	-3.89	-6.09	-6.61	-5.91	-8.94	-6.23	-5.52	-4.95	-6.06	-7.40	-7.64	-9.90	-6.34	-6.84	-3.64	-2.48	-3.98
Circle 2	-4.11	-0.91	-1.97	-3.22	-3.81	-5.52	-5.23	-3.02	-1.81	-5.07	-6.64	-6.34	-9.19	-5.61	-6.47	-4.52	-3.66	-2.85
Circle 3	-6.78	-1.85	-2.25	-2.10	-3.36	-7.15	-5.18	-2.60	-2.38	-5.36	-7.27	-8.03	-6.79	-6.06	-7.93	-5.97	-5.14	-3.80
Circle 4	-6.63	-2.48	-1.66	-1.64	-2.83	-5.92	-4.67	-2.05	-1.58	-4.35	-6.21	-7.57	-5.96	-5.37	-6.96	-5.13	-4.45	-3.29
Circle 5	-6.92	-4.46	-3.31	-2.45	-2.19	-5.35	-5.21	-2.98	-3.24	-5.06	-7.18	-7.36	-9.60	-6.36	-8.02	-6.36	-5.13	-4.03
Circle 6	-8.27	-6.62	-1.93	-5.72	-3.37	-0.61	-5.42	-5.29	-5.78	-6.72	-7.82	-9.27	-10.72	-8.08	-10.31	-9.60	-8.39	-7.35
Circle 7	-6.29	-5.74	-1.18	-4.72	-4.64	-2.84	-2.91	-3.01	-4.34	-3.91	-4.54	-6.45	-8.37	-5.48	-7.02	-6.24	-5.92	-4.26
Circle 8	-5.87	-2.19	-2.09	-1.41	-3.01	-3.22	-3.84	-1.08	-1.26	-2.81	-5.75	-6.56	-7.79	-4.35	-6.43	-4.97	-3.98	-2.73
Circle 9	-5.13	-1.34	-2.82	-1.93	-2.68	-3.93	-3.62	-1.78	-0.92	-3.47	-5.49	-6.33	-7.93	-4.73	-6.33	-5.24	-4.12	-2.84
Circle 10	-5.57	-5.09	-5.44	-4.93	-4.89	-7.29	-4.51	-3.80	-3.91	-1.59	-3.63	-2.74	-4.44	-3.07	-5.39	-5.80	-5.20	-3.57
Circle 11	-6.13	-6.08	-7.22	-6.53	-6.31	-8.21	-5.83	-4.95	-4.99	-3.71	-2.68	-1.04	-2.36	-3.26	-5.36	-6.25	-5.98	-4.92
Circle 12	-7.63	-6.53	-8.03	-7.32	-7.48	-8.92	-6.82	-6.13	-5.88	-4.55	-2.00	-1.39	-2.15	-3.57	-5.70	-7.07	-6.61	-5.58
Circle 13	-6.22	-9.26	-9.26	-9.23	-9.02	-10.67	-9.58	-8.02	-8.71	-6.90	-3.60	-2.80	-1.88	-4.38	-7.56	-8.29	-8.78	-8.05
Circle 14	-6.01	-5.63	-6.23	-5.97	-5.96	-6.63	-5.81	-4.68	-4.78	-3.58	-3.97	-3.39	-4.10	-2.33	-3.69	-5.00	-5.31	-4.23
Circle 15	-6.54	-6.51	-7.37	-6.37	-7.16	-8.88	-5.30	-5.67	-5.30	-5.58	-5.16	-6.59	-9.31	-4.18	-2.58	-5.09	-5.04	-4.34
Circle 16	-4.63	-5.21	-5.60	-5.99	-6.54	-7.95	-6.17	-5.43	-4.53	-5.28	-8.33	-7.03	-9.15	-5.27	-4.87	-1.87	-3.77	-3.60
Circle 17	-3.40	-3.63	-4.89	-5.01	-5.82	-6.65	-5.87	-4.98	-3.72	-5.46	-6.50	-6.25	-10.32	-6.10	-6.25	-4.73	-3.52	-2.77
Circle 18	-5.21	-4.59	-5.35	-4.79	-4.65	-7.32	-4.67	-3.55	-3.60	-1.83	-3.90	-3.18	-4.82	-3.12	-5.15	-5.14	-4.84	-3.13

The probability of selection of different modes has been calculated using the following equations and the Probability of different modes are as shown in figures 6, 7 and 8 for different modes. The Probability of modes selection depends on the vehicle operation cost, purpose of the trip, traffic congestion and size of the family etc. In this study total travel cost for the individual mode has been consider to know the probability of each mode.

$$\text{Probability Of CAR} = \frac{e^{\text{TTC(CAR)}}}{e^{\text{TTC (CAR)}} + e^{\text{TTC (BUS)}} + e^{\text{TTC (TW)}}}$$

$$\text{Probability Of BUS} = \frac{e^{\text{TTC(BUS)}}}{e^{\text{TTC (CAR)}} + e^{\text{TTC (BUS)}} + e^{\text{TTC (TW)}}}$$

$$\text{Probability Of TW} = \frac{e^{\text{TTC(TW)}}}{e^{\text{TTC (CAR)}} + e^{\text{TTC (BUS)}} + e^{\text{TTC (TW)}}}$$

Where TTC is the Total Travel Cost

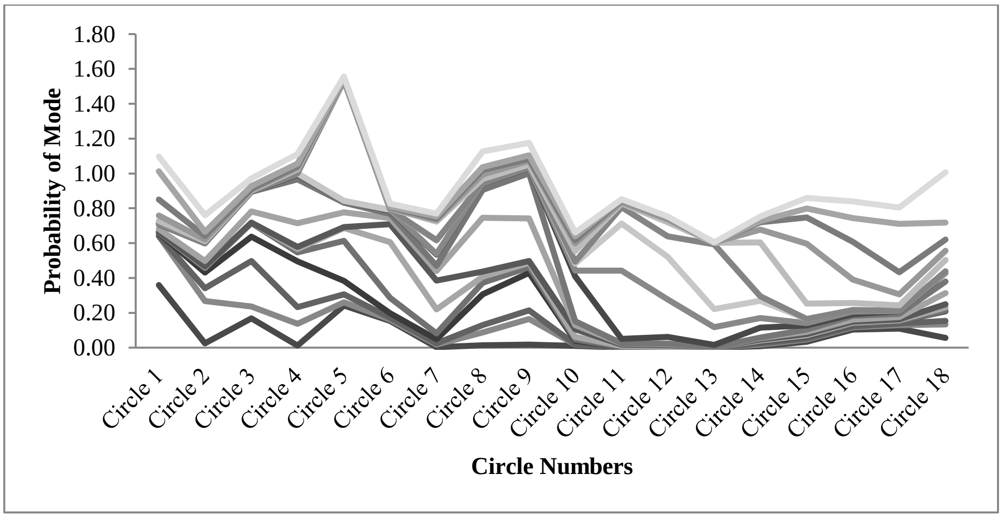

Fig. 2: Probability of Car.

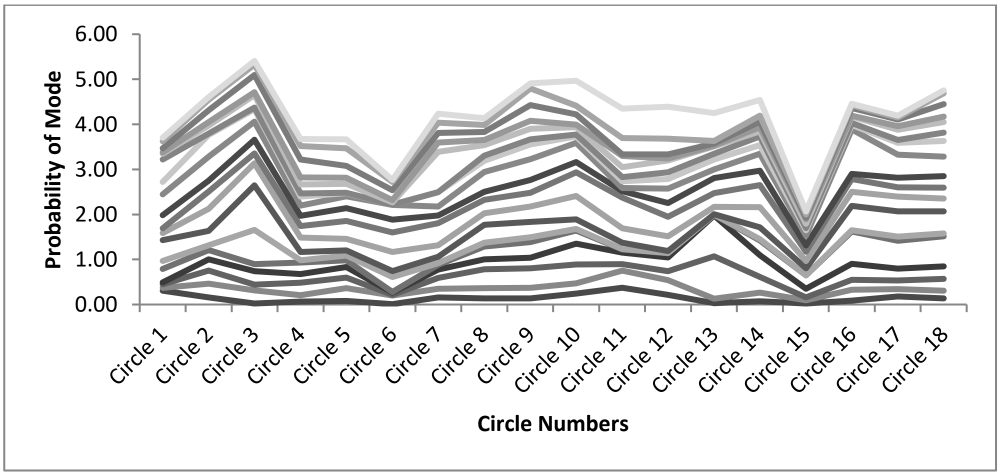

Fig. 3: Probability of Bus.

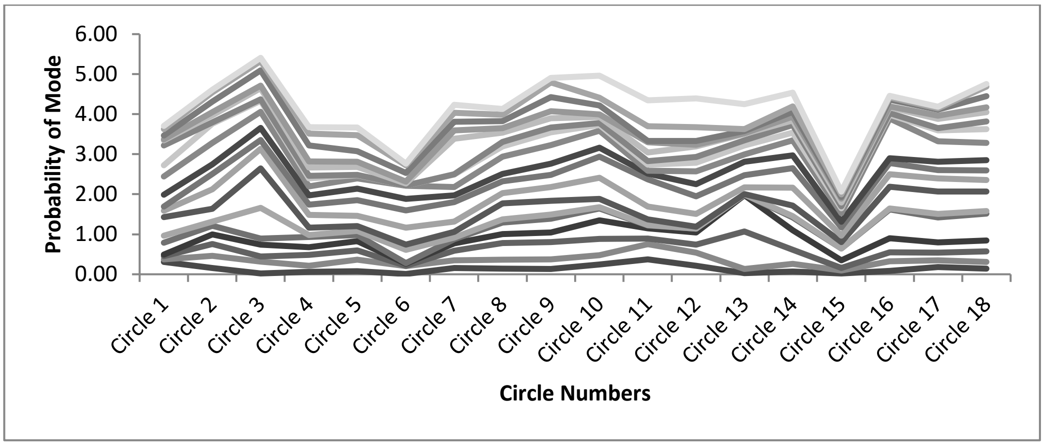

Fig. 4: Probability of Two Wheeler.

Modal Share of any Mode = Total Trips × Probability of that mode

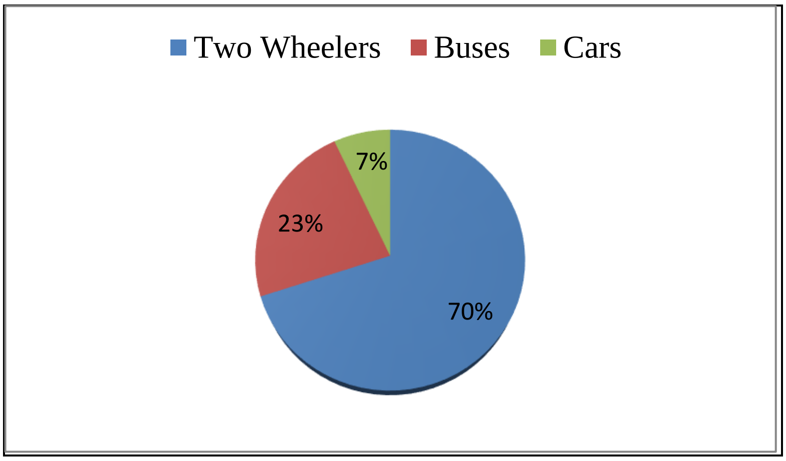

Fig. 5: Modal Share of the Trips.

5. Conclusions

From the study it has been observed that the modal share of 2-wheeler is 70 %, bus is about 23 % and car is about 7% of the total trips. It means mode choice of road user mainly depends on the income level of the individual. Low income group users are preferred to use 2- wheeler and it influences highly on cars and buses. Only high income group users are preferred to use cars and female road users are used buses in safety point of you.

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