Mode Choice Behaviour Analysis Using MNL Regression: A Case Study in Uppal

Pavan Kalyan Kolluri [1], Dr. D. Rajashekar Reddy [2].
[1]*M.E Scholar, Department of Civil Engineering, University College of Engineering, Hyderabad*
[2]*Professor, Department of Civil Engineering, University College of Engineering, Hyderabad.*

Abstract: **Trip behavior of commuters in metropolitan cities like Hyderabad is a critical issue, which is always a heterogenous part in planning, understanding of the mode of choice. Due to lack of indecorous unborn soothsaying plans in Hyderabad, the trip distribution and traffic are impacted. This present study is concentrated on mode choice of Hyderabad commuters choosing the public transport over private transport. The aim is to prognosticate mode choice model for work trips and institutional trips based on questionnaire data. Sample was collected through questionnaire by conducting face to face interview, with commuters and by advanced technics. The analysis is performed using the multinomial logit model (MNL), which is based on a utility function. The utility function contains exertion characteristics, trip characteristics including trip cost, trip time, the distance between activity place, and the individual characteristics to calculate the maximum utility of the mode choice. These parameters have to be substantially considered when evolving urban traffic models and trip plans. The advantage of using the multinominal logit models and utility function is the ability to identify the relationship among the trip behavior of an individual and the mode choice. With the results, it's possible to estimate the influence of the various variables on mode choice and identify the best mode based on the utility function. The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software. The estimation of utility function coefficients was calculated through regression by SPSS software. Model variables were estimated using T- statistics at the confidence position of 95% and the variables which T- value are larger than critical t- value (1.96) was eliminated from model and null hypothesis was rejected. Feting these factors and their variations will help Hyderabad city planners in developing effective transportation policies to enhance urban mobility.**

Keywords—utility function, mode choice modeling, Multi nominal logit model, SPSS software

I. INTRODUCTION

The behavior of commuters in choosing their mode of transport is crucial for transportation planning. Commuters select from various options based on specific reasons, with numerous factors influencing their choice. Analyzing these decisions is vital for addressing several issues, such as predicting demand for new transport modes, reducing traffic congestion, allocating resources effectively, evaluating travel efficiency, and gaining insights into commuter behavior. Mode choice analysis is the third step in the classical four-step transportation planning process, following trip generation and trip distribution. This analysis involves understanding which transport mode is chosen under particular conditions. of Commuters evaluate the disadvantages competing modes compared to their preferred choice and select the one with the least disutility. Mode choice models are essential for understanding travel demand, especially as private transport gains popularity in developing countries like India due to the poor performance of public transportation. This study aims to identify the factors influencing mode selection in Uppal, a sub urban city in Telangana, India.

II. RESEARCH STUDIES:

[1] Compared logit-based and weibit-based models, highlighting the fixed variance issue in logit models and how weibit models overcome this by allowing more flexible utility variance. [2] Focused on Park & Ride (P&R) facility usage in Warsaw, using MNL models to analyze factors like gender, income, travel, and transfer time, with implications for urban transport planning. [3] Mode choice in Ramadi, Iraq, was analyzed using multiple linear regression, showing that car ownership, age, and trip cost significantly influence mode choice, explaining 82.9% of the variance. [4] Studied transport mode choices of Lebanese students, finding cost as the key factor, and emphasized the importance of improving Lebanon's public transport for northern Beirut areas. [5] Examined commuting in Nanjing, China, finding that bike use dominates shorter distances, while cars dominate longer commutes. The study used NL models and a combined SP-RP approach to analyze travel modes and preferences. [6] Highlighted the

importance of travel mode choice models that estimate changes in modal shares, emphasizing determinants like personal characteristics (age, gender, occupation) and service characteristics (travel time, cost). [7] Reviewed mode choice modeling, stressing the importance of disaggregate models (e.g., Logit, Probit), which better capture individual characteristics and behavioural factors in decision making. [8] Analyzed commuter behavior in Thiruvananthapuram, India, showing that as age and travel cost increase, people switch from public transport to cars and two-wheelers. [9] Studied tourists' mode choice in Nha Trang, finding that shorter travel times, lower costs, and higher service quality drive demand for certain travel modes, particularly among higher-income tourists.

MNL Regression Model

The Multinomial Logit (MNL) model framework has gained widespread adoption in both urban and intercity mode choice modeling, primarily due to its straightforward mathematical structure, simplicity in estimation and interpretation, and flexibility in adding or removing choice alternatives. These models have proven effective in calculating various mode shares when commuters have more than two travel options available. Logistic regression is utilized to forecast the presence or absence of a characteristic or outcome based on a set of predictor variables. MNL regression extends this concept by enabling the classification of subjects using multiple predictor variables, making it more versatile than binary logistic regression as the dependent variable is not limited to two categories.

Given the numerous competing transportation modes in Uppal, including buses, cars, motorized two-wheelers, motorized three-wheelers, and intermediate public transport, the MNL model was selected to examine commuters' mode choice behavior. Most of these options are transit modes, with the exceptions being three-wheelers and intermediate public transit. The latter is restricted to specific areas within the city, while three-wheelers are typically used for very short trips. The research aimed to identify the various factors influencing mode selection in the city. Consequently, all relevant socioeconomic and trip characteristic variables were incorporated into the model, with coefficients estimated using the maximum likelihood criterion.

Description of the Study Area

Uppal is a suburban city in Eastern Hyderabad Telangana, India. As per Census 2011, [10] Uppal has a total population of 384,835 as per the census 2011. Out of which 195,649 are male while 189,186 are female. In 2011 there were a total of 94,044 families residing in Uppal. The Average Sex Ratio is 967. The size of the area is about 8.01 square kilometres. Population Density 11205 people per km. As per Census 2011, all of the population of Uppal Mandal lives in rural areas. The average literacy rate is 83.5% and the sex ratio of Uppal Mandal is 967. The total literacy rate of Uppal Mandal is 83.54%. The male literacy rate is 78.57% and the female literacy rate is 70.07% in Uppal Mandal.

In Uppal Mandal out of total population, 147,712 were engaged in work activities. 84% of workers describe their work as Main Work (Employment or Earning more than 6 Months) while 16% were involved in Marginal activity providing livelihood for less than 6 months. Of 147,712 workers engaged in Main Work, 1,526 were cultivators (owner or co-owner) while 2,087 were Agricultural labourer.

III. METHODOLOGY

The objective of this research is to examine the commuter mode choice patterns in Hyderabad. The study aims to determine the key factors influencing the selection of specific transportation modes in the city, including those that encourage or discourage the use of public and private transport. The research focuses exclusively on work-related and institutional trips. To assess the travel patterns across all available modes in Hyderabad, the study employs a revealed preference survey methodology, which is designed to investigate travel behavior in real-world situations.

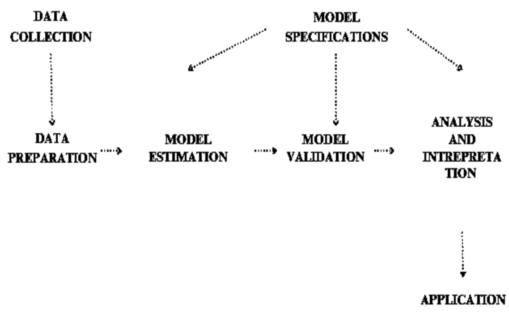

Fig 1. Flow chart

MNL modeling was adopted in the study because of its capability in estimating the mode shares where more than two choices of modes of travel are available for a commuter. The questionnaire covered areas of socioeconomic and trip information of commuters.

The following data were elicited from respondents:

- Socioeconomic characteristics of each individual (age, gender, education, vehicle ownership, and monthly income).
- Trip-related variable (distance, cost, travel time) represented by conveyance mode,

Sampling Procedure

Sufficient care was taken to ensure that the sample is of optimum size. The sample size depends on the population of the city under study. The research work is strictly stick to work trips and educational trips of Uppal a sub divisional area of Hyderabad city. Census of [10]. Assuming the population to be normally distributed, empirical formulas taken from [11] [shown in Eqs. (1) and (2)] were used to determine the sample size. Assuming the population to be normally distributed, empirical formulas given by Cochran [shown in Eqs. (1) and (2)] were used to determine the sample size.

1. $n^o = \frac{Z^2pq}{e^2}$ Eqs (2)
2. $n = \frac{n0}{[\ 1+\frac{(n0-1)}{N}]}$ Eqs (3)

whereas,

n_0 = sample size for infinite population, n = sample size for finite population, Z = statistical parameter corresponding to confidence level (Z is 1.96 for 95% confidence interval), N = population size, e = desired margin of error (adopted as 5%), p = hypothesized true proportion for population (adopted as 0.5 to account for the worst case) and q = 1- p

Thus, for the case above, a sample size of at least 385 people would be necessary. In this study sample size of 547 is considered. Coding of data will be done to facilitate easy handling of information and the pattern followed. The coded data were inputted to Statistical Package for Social Sciences (release 15.0.0 for Windows, SPSS; SPSS 2006) for analysis.

Design of Questionnaire

A pilot questionnaire survey was first conducted. The questionnaire focused on the socioeconomic status and travel habits of the individuals. Socioeconomic factors included age, gender, employment type, monthly earnings, and ownership of a vehicle. Aspects of travel covered the distance between home and workplace, chosen mode of transportation, rationale for selecting this mode, wait times, time spent in transit, and travel expenses. Additionally, it gauged commuters' satisfaction with their current mode of transport, their openness to change, and their motivations for considering a switch, as gathered from the survey responses. It also contained questions that enabled ranking of mode attributes in general and ranking of performance of the existing TGRTC and metro service in the city. Efficiency level of existing TGRTC and metro services were ranked based on factors such as comfort, time of travel, cost of travel, safety, ease of boarding, frequency/availability, travel in peak hours, reliability, travel in difficult weather. A pilot survey was conducted and 547 samples were obtained. Based on the response, preferences, and the suggestions of the commuters, the variables were shortlisted and the questionnaire was further refined. A comprehensive survey was conducted among commuters using this improved questionnaire.

Variables Used in the Study

Socioeconomic variables such as gender, age, education, monthly income, and vehicle ownership are believed to be important factors in mode choice. Transport System Variables such as travel cost, travel time and distance data were extracted from the data collected. The categories used for this study are shown in Table 1

Table 1. variables were considered

Considered	Categories	N	Marginal Percentage	Pattern
Mode Chosen	BUS	220	40.2%	1
	BIKE	148	27.1%	2
	CAR	50	9.1%	3
	METRO	129	23.6%	4
Gender	MALE	363	66.4%	1
	FEMALE	184	33.6%	2
Age Group	21-30	258	47.2%	1
	31-40	197	36.0%	2
	41-50	46	8.4%	3
	ABOVE 50	46	8.4%	4
Education	PRIMARY	23	4.2%	1
	SECONDARY	44	8.0%	2

	INTER	99	18.1%	3
	GRADUATION	344	62.9%	4
	ABOVE GRADUATION	37	6.8%	5
Vehicle Owner Ship	OWNS VECHICLE	257	47.0%	1
	OWNS CAR	51	9.3%	2
	OWNS 2-WHEELER	212	38.8%	3
	OWNS BOTH CAR AND BIKE	27	4.9%	4
Monthly Income	LESS THAN 10000	188	34.4%	1
	10000-20000	77	14.1%	2
	20000-30000	138	25.2%	3
	30000-40000	99	18.1%	4
	ABOVE 5000	45	8.2%	5
Distance	0-5	37	6.8%	1
	6-10	116	21.2%	2
	11-20	221	40.4%	3
	20-50	173	31.6%	4
Cost of the Journey	10-30	65	11.9%	1
	30-50	214	39.1%	2
	50-100	172	31.4%	3
	ABOVE 100	96	17.6%	4
Travel Time	0-10	16	2.9%	1
	10-20	198	36.2%	2
	20-40	286	52.3%	3
	4	47	8.6%	4
Valid		547	100.0%	
Total		547		

Preliminary data analysis

A preliminary analysis of the coded data was performed to yield an overview of the mode choice behavior of commuters in the city of Uppal. Various cross-classification charts were prepared with respect to age, gender, income, distance etc. The various analysis conducted are explained in the following sections.

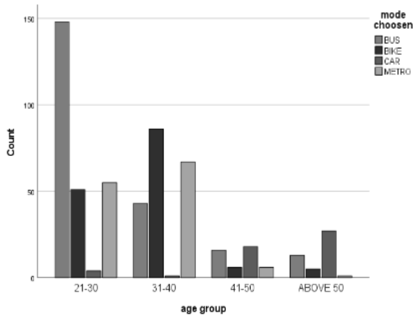

Fig 1. Age group–based classification of mode preference.

The effect of age of commuters on the choice of mode is shown in Fig. 1. It can be observed that higher age groups preferred metro mode. Among the personalized vehicles, car was preferred by higher age group, whereas two- wheelers and bus were more preferred by lower to middle age group

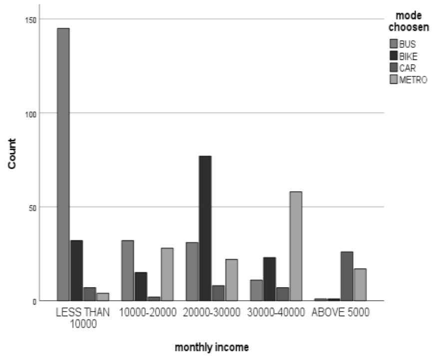

Fig. 2. Gender-based classification of mode preference

Fig. 2 shows monthly income-based classification of mode preference. As evidenced in Fig. 2, lower- and middle-income groups preferred public transport system. With the increase in income, percentage of people preferring buses decreases. For high-income groups, car is the main mode of travel. Two-wheeler usages are highest among the middle-income groups

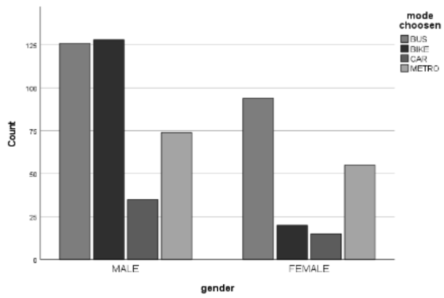

Fig. 3. Gender-based classification of mode preference

Gender was also found to have an influence on the choice of mode as can be observed from Fig. 3. Car as mode of travel is mostly preferred by males than females. Similar trend was observed in the case of two-wheelers as well. Of the various modes of travel within the city, females preferred public transport system (buses) more than any other mode, whereas males preferred two-wheelers.

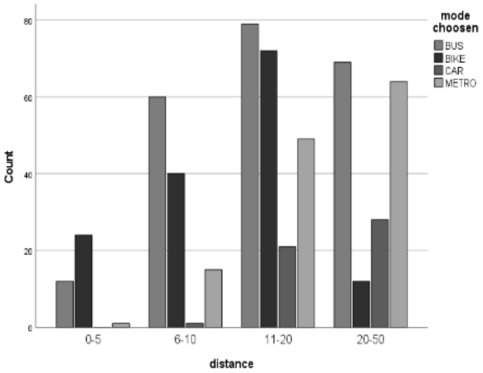

Fig. 4. Distance-based classification of mode preference

Mode preference based on distance is given in Fig. 4. It shows that bus and metro is preferred for longer distance trips. Bike is preferred for nearby trips. Whereas car is chosen for long journey trips.

IV. RESULTS AND DISCUSSIONS

Table 2. Model Fitting Information

Model	Model Fitting Criteria Likelihood Ratio Tests			
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1379.701			
Final	239.263	1140.438	72	.000

Table 2 presents a statistical comparison between the intercept-only model and the final model. The intercept-only model is a basic model that predicts the output variable using only an intercept, without any predictor variables. The final model, however, includes specified predictor variables and is developed through an iterative process aimed at maximizing the log likelihood of the observed outcomes in the output variable, as shown in Table 2. Incorporating predictor variables and optimizing the log likelihood of the observed data makes the final model superior to the intercept-only model. The contribution of each variable to the model is demonstrated by the likelihood ratio test. The statistical significance of the differences between the two models is confirmed by the chi-square statistic, which represents the difference in the -2 log-likelihoods of the null/intercept-only and final models. With a significance level below 0.05, we can infer that the final model significantly outperforms the null model.

Table 3. Likelihood Ratio tests table

Parameter	Likelihood Ratio Tests			
	-2 Log Likelihood	Chi-Square	Degree of freedom	Significance.
Intercept	239.263a	.000	0	.
gender	299.535	60.272	3	.000
age group	262.404b	23.141	9	.006
education	261.826	22.563	12	.032
vehicle owner ship	491.845	252.582	9	.000
monthly income	417.524	178.261	12	.000
distance	333.640	94.377	9	.000
cost of the journey	289.925	50.662	9	.000
travel time	269.712	30.449	9	.000

The likelihood ratio tests that show the contribution of each variable to the model are shown in Table 3. Table 2 shows that all variables have a significance level below 0. 05. Therefore, it can be concluded that all the variables used in the model have significant contribution toward predicting the mode choice behavior of commuters. Of these gender, vehicle ownership, monthly income, distance to travel, cost of travel and travel time are found to be the most significant ones.

Table 4. Pseudo R-Square

Cox and Snell	.876
Nagelkerke	.949
McFadden	.815

The pseudo R2 value of the final model according to Cox and Shell, Nagelkerke, and McFadden tests were 0.876, 0.949, 0.815, respectively. Pseudo R2 value indicates the proportion of variance of the response variable explained by the predictors and its maximum value is 1. Larger pseudo R2 statistics indicate that larger percentage of variation can be explained by the model. Thus, based on the pseudo R2 values it can be concluded that the model developed in the present study explains approximately 81–94% variation. Hence, the model may be deemed statistically significant.

Table 5 Classification

Observed	Predicted				
	BUS	BIKE	CAR	METRO	Percent Correct
BUS	204	3	2	11	92.7%
BIKE	3	145	0	0	98.0%

CAR	3	0	47	0	94.0%
METRO	10	5	0	114	88.4%
Overall Percentage	40.2%	28.0%	9.0%	22.9%	93.2%

The overall goodness of fit of the MNL model developed is Shown in table 5. It can be seen that for each case, the predicted response category is chosen by selecting the category with highest model predicted probability. Cell on the diagonal are correct prediction. Cells off the diagonals are incorrect prediction. It can be observed that out of 220 commuters were found to be used bus. The MNL predicted total number of bus commuter as 204 and wrongly predicted that 3 bus commuters used two Wheelers ,2 used car and 11 used metro. Therefore, the accuracy of prediction of busses 92.7%. Similar analysis on two-wheeler commuters gave a prediction accuracy of 92.4%, car as 75.6% and metro as 88.4%. The model has an overall accuracy of 93.2%

Interpretation of Parameter Estimates

Tables 6 ,7,8 and 9 give the parameter estimates that summarize the effect of each predictor for commuters' choice of car relative to bus and car relative to two-wheeler, respectively. B values are the estimated MNL regression coefficients for the models. Parameters with negative coefficients decrease the likelihood of that response category with respect to the reference category. Exp (B) Value are odds ratios for the various categories of the predictors /dependent variable.

The odd ratio of a coefficient indicates how the risk of the outcome falling in the reference group, changes with the variable in question. The odd ratio value of each category of the predictors is computed with reference to the category of the same predictor, chosen by default in the present study, the last category of predatory chosen other referenced by default.

The MNL model estimates for a unit increase in each variable affecting commuters' choice of bike relative to bus, when the other variables in the model are held constant, are discussed in the following sections (as given in Table 6,7,8,9).

A. Bike in Relation to Bus

Gender: Males are 153.9 times more likely to choose bikes than females

Age group: Bike preference peaks for ages 31–40 (144.14 times more likely to choose bikes) and is lower for ages 21–30 (43.62 times) and 41–50 (15.72 times).

Education: Those with primary and secondary education are less likely to choose bikes (0.9 and 0.27 times, respectively), while individuals with intermediate (3.92 times) and graduation-level education (5.48 times) are more likely to opt for bikes.

Table 6. Analysis of MNL Regression model of Bike in relation to Bus.

Mode chosen		B	Exp(B)
BIKE	Intercept	-22.349	
	[gender=1]	9.642	153.994
	[gender=2]	0b	.
	[age group=1]	5.078	43.6240
	[age group=2]	7.273	144.1454
	[age group=3]	3.663	15.72730
	[age group=4]	0b	.
	[education=1]	-0.707	.90
	[education=2]	0.9615	2.70
	[education=3]	1.231	3.92
	[education=4]	1.602	5.48
	[education=5]	0b	.
	[vehicle owner ship=1]	1.204	3.702
	[vehicle owner ship=2]	1.131	3.287
	[vehicle owner ship=3]	8.417	453.973
	[vehicle owner ship=4]	0b	.
	[monthly income =1]	7.663	217.838
	[monthly income =2]	11.297	805.372
	[monthly income =3]	3.304	27.217
	[monthly income =4]	1.543	4.679
	[monthly income =5]	0b	.
	[distance=1]	20.016	498.950
	[distance=2]	12.063	172.519
	[distance=3]	3.208	24.737
	[distance=4]	0b	.
	[cost of the journey=1]	-3.003	.020
	[cost of the journey=2]	-1.053	.349
	[cost of the journey=3]	2.845	17.201
	[cost of the journey=4]	0b	.
	[travel time=1]	-2.805	.606
	[travel time=2]	3.727	5.96
	[travel time=3]	-5.828	.030
	[travel time=4]	0b	.

Vehicle Ownership: Two-wheeler owners are more likely to choose bikes, while those who own only cars show a lower preference. This could be due to the better maneuverability and suitability of bikes in congested traffic and for last-mile connectivity.

Income: Bike preference varies with income. Low-income groups (less than □10,000) are 217.8 times more likely to choose bikes, while those with incomes of □10,000–□20,000 are 805.3 times more likely. As income rises further, the likelihood decreases (27.21 times for □20,000–□30,000 and 2.76 times for □30,000–□40,000).

Distance: Shorter distances favor bike use, with 0–5 km trips being 498.9 times more likely to involve bikes, 6–10 km at 172.51 times, and 11–20 km at 24.73 times. As distance increases, commuters tend to switch from bikes to buses.

Cost of journey: Higher journey costs reduce the preference for bikes. Trips costing □10–□30 are 0.020 times more likely to involve bikes, while costs of □30–□50 and □50–□100 have 0.349 and 17.20 times the likelihood, respectively.

Travel Time: Bike use decreases with longer travel times. Short trips (0–10 min) favor bikes (0.6 times more likely), while mid-range trips (10–30 min) increase bike use (5.96 times), but long trips (30–60 min) favor buses (0.30 times).

B. Car in Relation to Bus

Gender: Males are 5.09 times more likely than females to switch from bus to car.

Age Group: The multinomial logistic regression reveals that younger commuters show a lower preference for cars. Individuals aged 21–30 have a 0.75 times chance of choosing cars over buses. Those aged 31–40 have a 0.29 times chance, while individuals aged 41–50 have a higher likelihood of 6.26 times.

Education: Educational attainment significantly impacts vehicle choice. Those with primary education have a 1.66 times chance of choosing cars over buses, while individuals with secondary education show a 1.24 times chance. Those with intermediate education exhibit a preference of 2.37 times, and graduates have a 1.93 times likelihood.

Vehicle Ownership: Vehicle ownership plays a crucial role in mode choice. Respondents with no bike ownership have a 0.32 times chance of choosing cars over buses. In contrast, individuals who own only a two-wheeler have a 16.09 times greater likelihood of choosing cars over buses, while those with only cars show a 0.49 times chance.

Monthly Income: Preference for cars relative to buses is inversely related to income. Individuals in the lowest income bracket (less than □10,000) have a 0.09 times chance of choosing cars over buses. This likelihood decreases further for those earning between □10,000 and □20,000 (0.038 times) and for those earning □20,000 to □30,000 (0.571 times), before slightly increasing to 0.808 times for the □30,000 to □40,000 range. This pattern aligns with previous observations regarding bike and bus choices, indicating that lower-income individuals are less likely to opt for cars.

Table 7. Analysis of MNL Regression model of car in relation to bus

Mode chosen	Predictor variables and their categories	B	Exp(B)
CAR	Intercept	2.622	
	[gender=1]	1.629	5.099
	[gender=2]	0b	.
	[age group=1]	-.287	.750
	[age group=2]	-3.544	.029
	[age group=3]	1.834	6.260
	[age group=4]	0b	.
	[education=1]	.511	1.667
	[education=2]	.217	1.243
	[education=3]	.659	1.933
	[education=4]	.866	2.378
	[education=5]	0b	.
	[vehicle owner ship=1]	-3.444	.032
	[vehicle owner ship=2]	2.778	16.091
	[vehicle owner ship=3]	-3.017	.049
	[vehicle owner ship=4]	0b	.
	[monthly income =1]	-2.310	.099
	[monthly income =2]	-3.271	.038
	[monthly income =3]	-.561	.571
	[monthly income =4]	-.436	.808
	[monthly income =5]	0b	.
	[distance=1]	-8.247	.001
	[distance=2]	1.466	4.332
	[distance=3]	-.448	.639
	[distance=4]	0b	.
	[cost of the journey=1]	-2.364	.1939
	[cost of the journey=2]	-2.148	.8841
	[cost of the journey=3]	1.180	1.3113
	[cost of the journey=4]	0b	.
	[travel time=1]	-4.978	.07
	[travel time=2]	1.310	3.706
	[travel time=3]	-1.451	.234
	[travel time=4]	0b	.

Distance (km): The analysis shows that the likelihood of switching from buses to cars decreases with travel distance. Short-distance commuters (0–5 km) have a 0.001.

time's chance of choosing cars over buses, whereas the preference for cars increases significantly for longer distances, with commuters traveling 6–10 km having a 4.332 times greater likelihood and those traveling 11–20 km having a 0.639 times greater likelihood of choosing cars

Cost of the Journey: The regression model suggests that as journey costs rise, the chance of choosing cars over buses increases slightly, though margins are not significant.

Travel Time: Travel time influences mode choice, with preferences shifting from car to buses as travel time increases. For travel times of (0–10) min, the chance of choosing car is 0.07 times, increasing to 3.706 times for (20–30) min but dropping to 0.234 times for (30–60) minutes. This decline may result from traffic congestion and adverse weather conditions.

C. Bike in Relation to Metro

Gender: Males are about 45.5 times more likely than females to switch from buses to two-wheelers.

Age Group: The multinomial logistic regression analysis indicates that younger commuters prefer two-wheelers over metro. Commuters aged 21–30 have 94.31 times the likelihood of choosing two-wheelers, while those aged 31–40 show a preference of 32.13 times, and those aged 41–50 have a significantly higher likelihood of 15.38 times. This suggests that preference for two-wheelers decreases with age.

Education: Educational background also plays a crucial role. Individuals with primary education have a 0.525 times chance of choosing two-wheelers over metro. Those with secondary education show a higher likelihood of 2.90 times, while those with intermediate education have a preference of 5.93 times, and graduates have a preference of 17.31 times.

Table 8. Analysis of MNL Regression model of bike in relation to metro

Mode chosen	Predictor variables and their categories	B	Exp(B)
Bike	Intercept	-25.428	
	[gender=1]	10.707	45.503
	[gender=2]	0b	.
	[age group=1]	6.8612	94.316
	[age group=2]	3.470	32.139
	[age group=3]	2.733	15.385
	[age group=4]	0b	.
	[education=1]	-.644	.525
	[education=2]	-.070	2.907
	[education=3]	.549	5.932
	[education=4]	7.814	17.31
	[education=5]	0b	.
	[vehicle owner ship=1]	-1.080	.5425
	[vehicle owner ship=2]	-.926	.7336
	[vehicle owner ship=3]	7.971	28.617
	[vehicle owner ship=4]	0b	.
	[monthly income =1]	16.295	1195.672
	[monthly income =2]	15.800	729.498
	[monthly income =3]	8.245	380.400
	[monthly income =4]	3.571	35.545
	[monthly income =5]	0b	.
	[distance=1]	22.947	92.41730
	[distance=2]	13.588	79.7909
	[distance=3]	3.824	45.777
	[distance=4]	0b	.
	[cost of the journey=1]	-6.565	.001
	[cost of the journey=2]	-.601	.549
	[cost of the journey=3]	2.146	8.547
	[cost of the journey=4]	0b	.
	[travel time=1]	2.908	5.055
	[travel time=2]	1.569	2.685
	[travel time=3]	-1.646	.0408
	[travel time=4]	0b	.

Vehicle Ownership: Vehicle ownership significantly affects mode choice. Individuals with no vehicle ownership have a 0.54 times chance of choosing two-wheelers over metro. Respondents owning only a two-wheeler have a 0.73 times chance, while those with only a car exhibit a strong preference of 28.61 times for choosing two-wheelers over metro.

Monthly Income: Preference for two-wheelers relative to metro is higher among low-income groups (monthly income less than □10,000–20,000) and lower among high-income groups (monthly income over □30,000).

Distance (km): The analysis reveals that as travel distance increases, the preference for two-wheelers over metro decreases. Commuters traveling short distances (0–5 km) are 92.41 times more likely to choose two-wheelers, while those traveling 6–10 km show a likelihood of 79.7 times, and those in the 11-20 km range have a preference of 45.77 times. This indicates that two-wheelers are favoured for short trips due to their maneuverability and suitability for last-mile connectivity, while longer distances typically favor metro systems.

Cost of Journey: The MNL regression indicates that higher journey costs negatively impact the likelihood of choosing two-wheelers over metro. For a journey cost of □10–30, the chance of selecting two-wheelers is 0.14 times, for □30–50 it is 0.549 times, and for □50–100 it increases to 8.54 times.

Travel Time: Travel time also influences mode choice, with the analysis revealing that longer travel times reduce the preference for two-wheelers. For travel times of 0–10 minutes, the chance of choosing two-wheelers is 5.05 times, while for 10–30 minutes, it is 2.68 times, and it falls to 0.408 times for travel times of 30–60 minutes.

D. Car in Relation to Metro

Gender: The analysis shows that males are 14.7 times more likely to switch from buses to two-wheelers than females.

Age group: Age plays a significant role in transportation choices. Commuters aged 21–30 have (0.026 times) for choosing cars over metro, while those aged 31–40 show an even lower preference (0.001 times). In contrast, individuals aged 41–50 exhibit a slightly higher preference (0.380 times) for cars over metro. This trend indicates that middle-aged commuters are more inclined to prefer cars, whereas younger and older groups lean towards using metro systems.

Table 9. Analysis of MNL Regression model of car in relation to metro

Mode chosen	Predictor variables and their categories	B	Exp(B)
Car	Intercept	-.456	
	[gender=1]	2.694	14.798
	[gender=2]	0b	.
	[age group=1]	-3.632	0.026
	[age group=2]	-7.347	0.001
	[age group=3]	-.968	0.380
	[age group=4]	0b	.
	[education=1]	13.032	17.807
	[education=2]	3.189	0.255
	[education=3]	2.027	7.594
	[education=4]	1.811	6.114
	[education=5]	0b	.
	[vehicle owner ship=1]	-4.320	0.013
	[vehicle owner ship=2]	7.083	110.994
	[vehicle owner ship=3]	-3.463	0.031
	[vehicle owner ship=4]	0b	.
	[monthly income =1]	-.4086	0.665
	[monthly income =2]	1.233	3.430
	[monthly income =3]	4.380	79.861
	[monthly income =4]	6.322	556.657
	[monthly income =5]	0b	.
	[distance=1]	-5.316	0.005
	[distance=2]	2.991	19.899
	[distance=3]	.167	1.182
	[distance=4]	0b	.
	[cost of the journey=1]	-9.926	0.105
	[cost of the journey=2]	-5.695	0.392
	[cost of the journey=3]	-2.880	0.506
	[cost of the journey=4]	0b	.
	[travel time=1]	-5.080	0.006
	[travel time=2]	1.068	2.910
	[travel time=3]	-1.270	0.281
	[travel time=4]	0b	.

Education: Education level significantly influences the choice between cars and metro. Individuals with primary education are 17.807 times more likely to choose cars, while those with secondary education show a lower preference (0.255 times). Conversely, individuals with intermediate education (7.594 times) and those with a graduation degree (6.114 times) exhibit a higher likelihood of choosing cars over metro.

Vehicle Ownership: Vehicle ownership impacts mode choice as well. Those who own both a car and a two-wheeler are more likely to choose two-wheelers over metro, particularly in congested conditions where two-wheelers offer better manoeuvrability.

Income: Income level significantly affects transportation choices, with higher-income groups showing a greater preference for cars. Individuals in the low-income category (less than □10,000) are 0.665 times more likely to choose cars over buses. Those earning between □10,000 and □20,000 show a lower likelihood of 3.43 times, while those in the □20,000–□30,000 bracket exhibit 79.86 times the chance of choosing cars. For the highest income group (□30,000–□40,000), the preference decreases to 556.657 times for choosing cars over metro.

Distance: The analysis highlights that preference for cars diminishes as travel distance increases. For short distances (0–5 km), commuters are 0.05 times more likely to choose car over metro. This likelihood decreases to 19.89 times for distances between 6–10 km and 1.182 times for distances of 11–20 km. This trend indicates that distance between 6-10 km, commuters favor car, while longer distances typically favor metro systems due to better connectivity.

Cost of Journey: The cost of travel influences mode choice, although its impact appears limited. For journey costs between □10 and □30, the likelihood of choosing cars over metro is 0.14 times, increasing slightly to 0.39 times for costs between □30 and □50, and rising to 1.45 times for costs between □50 and □100. However, these values suggest that cost does not significantly affect the choice between metro and buses.

Travel Time: Travel time significantly affects mode choice. Shorter travel times favor car, with 0–10 minutes showing a preference of 0.06 times for car over metro. For travel times of 10–30 minutes, the preference is 2.91 times, and it falls to 0.281 times for travel times between 30–60 minutes. Traffic jams and parking availability for car may contribute to this trend, influencing commuters' decisions based on efficiency and convenience.

V. CONCLUSIONS

1. Bus, Metro in relation to bike and car.

Gender wise comparison revealed that Males prefer two-wheelers and cars more, while females show a stronger preference for buses or metro over both cars and two-wheelers., likely due to safety concerns, as women may find two-wheelers less safe and they feel uncomfortable driving car.

Age wise comparison revealed that younger commuters favor buses and two-wheelers, and middle age commuters preferred bikes over buses, with a decline in preference as age increases. while older age commuters increased the preference of bus and car. As age rises, preference for two-wheelers decreases and shifts toward bus and car. Where as in metro younger commuters are more likely to use two-wheelers and metro, while older individuals shift towards cars. As age increases, preference for two-wheelers declines in favor of cars and metro. The possible reason may be the safety and comfort. Multinomial logistic regression analysed that Bus usage is more common among commuters with lower educational qualifications, while those with higher education favor cars and two-wheelers.

As education levels increase, the preference for buses decreases. Higher education increases the likelihood of choosing a bike, car over a bus. Where as in metro analysis Those with higher education (secondary level and above) prefer metro over other modes, while those with lower education levels favor bikes and cars. The trend shows that as education increases, so does the preference for metro.

Vehicle Ownership: Individuals with both a car and a two-wheeler may opt for two-wheelers for short trips and cars for longer ones. Two-wheeler owners show less interest in buses, generally preferring two-wheelers for their convenience. while car-only owners prioritize cars over buses and two-wheelers. Car owners tend to prefer driving due to safety, comfort, and flexibility. while those without any vehicle have a much lower likelihood of choosing cars over buses. Where as in metro analysis Car owners prefer their cars for longer trips, while two-wheeler owners favor metro more than car owners, likely due to income differences. Commuters who own both cars and two-wheelers prefer two-wheelers for short trips and cars for longer ones. This suggests that those who own both a car and a two-wheeler are more likely to choose two-wheelers due to parking constraints and the maneuverability of two-wheelers. Income: Low-income commuters (earning less than □20,000 per month) show a higher preference for buses, while higher-income groups increasingly favor bus and cars. As income rises, bus preference decreases, and car usage becomes more prevalent. Where as in metro analysis Preference for metro decreases as income rises, although metro is more popular for longer travel distances, especially intercity trips. This trend parallels observations regarding choices between cars and buses, indicating that income significantly impacts transportation preferences.

Distance: As travel distance increases, commuters tend to prefer buses over bikes and cars. For short trips, two-wheelers are chosen for convenience, The variation is because for the last mile connectivity, they choose bike rather than bus. while cars are favoured for safety and comfort. However, buses are still preferred over cars and two-wheelers for longer intercity trips. Whereas in metro analysis, with increase in travel time, commuters were found to give less preference to car and two-wheelers relative to metro.

Cost of Journey: Higher travel costs lead commuters to favor buses over two-wheelers, but the cost difference between buses and metro has little impact on choice. Car users are less affected by cost considerations when choosing between cars and buses. The same trend is continued for the metro mode analysis.

Travel Time: Two-wheelers are the most popular among personalized modes but may lose appeal when travel time. As travel time, increases commuters shift toward bus and metro over two-wheeler and car. And other possible reasons are traffic jam and parking facilities provided at metro station, facilitating park and ride system

A comparison between two-wheeler users and car users with reference to their preference to bus and metro revealed that two-wheeler owners showed a greater preference to bus and metro compared with car users. This may be because users of two-wheelers generally fall under low/middle income category, and therefore their next natural choice will be either bus or metro. The commuters, who own both two-wheeler and car, gave least preference to bus, metro and gave higher preference to car. This is because in a developing country like India, given the poor state of public transport, and poor parking facilities for cars those owning car as well as two-wheelers prefer car owing to its safety and flexibility. The study also revealed that the bus commuters who own both car and two-wheeler preferred two-wheeler when faced with a situation that demands switching from bus. This shifting from bus is mainly due to the inefficient andnonreliability of bus transport.

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