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Mode Shift Behavior Study with Respect to Introduction of Metro Rail System in Indore City

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***Abstract*— With growing number of Vehicles and more importantly private vehicles at an alarming rate in almost all major and medium cities in India. No one can argue that the viable solution in present context can only be Rapid Transit system of public transport in the form of Metro, Bus transit System, Mono rails, Metro etc. It is targeted towards contributing significantly in sustainable mobility by shifting a large number of commuters from their current transport mode of choice – in most cases private cars. The travel behavior of a commuter is necessary to be analyzed before planning and operation of any such transit system. Before planning and implementation out of various types of model, the discrete choice model analysis of mode shift is necessary to formulated and studied. Which mode to choose from number of available modes and on what parameters under a given set of circumstances is studied through the mode shift behavior analysis. This study is aimed at developed a binomial logistic regression model based on the stated preference questionnaire response with regards to mode shift choice of commuters of Line 3 of Indore (M.P, India) metro which is under construction. Charts & Graphs related to reason of shift; current mode share etc. are also prepared. The equation is formulated which establishes the relation between the probability of shift and the independent variables.**

Index Terms*— SPSS, Mode Shift, Binary Logistics Regression, Mathematical modelling*.

I. INTRODUCTION

The transportation planning is a four-step process which includes the trip generation, followed by trip distribution then the modal split and finally trip assignment. Level of trip making is explained by trip distribution while the relative frequency with which the trips are made are explained by trip distribution. The modal split is concerned with assigning and choosing a suitable to make a particular trip. Increase in time per distance and increase in cost per distance cause the commuters to switch to car and two-wheelers from public transport. the individual characteristics of the traveler (like the trip purpose and the socioeconomic background) can affect the demand for such a transport mode. Mode choice study is necessary to develop any efficient transport network and for economic and efficient operation and management of Transit system to solve the ever-increasing problem of congestion and delays. Since the fast-developing cities are introducing metro transit services now, and the cities are not planned, developed and designed keeping in mind this new introduction, the early land use planning has not reserved space for any such system. Which leads to large difficulties in build transfer facilities for the dedicated metro corridor and the available space for normal movement is also suffered. This can create an additional disadvantage rather than providing the solution for reduction of congestion. The need of the study are as follows: -

- The study will help us understand the mode shift behavior based on mathematical models and user-based opinion.
- The parameters which are assessed to be important are carefully dealt with while operation, maintenance and expansion of the Transit System to increase efficiency.
- The study on its successful completion will provide us with the current mode share of the city based on our sample size and establish relation between shift probability and independent variables.

Relevant Literature Review

The modal split modelling analysis is carried out with the well-suited Logit and Probit Models. Both of them have certain advantages over the other. The Mode choice analysis is generally carried out in two ways, Travel Demand Modelling and the other is a Discrete choice modelling. The Discrete choice modelling can be of Aggregate or of disaggregate type with the shared general concept of maximizing the utility. The difference lies in the extent of data recorded in formulating these models. The binomial logistics regression model so formulated provide the probability of certain choice made by the responder with regards to the parameters associated with the system. The Binomial model developed is targeted towards identifying the influence of various parameters on the mode chose by the commuter, and whether they switch from Bus to Metro or from PMVs to Metro and on what criteria. For decades, the revealed and the stated preference surveys are used to obtain the responses and carrying out with regards to value goods which are non-marketable. The questionnaire included the question which could collect data regarding socio-economic and Travel characteristics of commuters.

Some relevant works in mode choice modelling

O.A Khan (2007) conducted the research for modelling passenger mode choice behavior with the help of stated preference survey data. For development of a standard method for conducting such surveys sampling techniques, choice of study area, use of demographic characteristics are mentioned. The Author developed a mathematical model to forecast the travel mode choice behavior in the multi modal environment of Redland Shire.

R. Ashalatha1 et al. (2013) carried out a multinomial logistic regression modelling to study about the behavior of mode choice of people in Thiruvananthapuram city. The study has successfully identified that with age the preference towards car

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increases and the preference towards the bikes decrease as we compare it with the public transport.

Vineet Chauhan et al. (2016) has carried out a study on the mode choice behavior of people of Delhi towards Public transport so that such kind of public transport could be developed which could incentivize the use of public transport. A questionnaire survey is carried out to collect information regarding the travel and personal characteristics. To analyze and predict whether the existing metro users have switched from buses or they have shifted from their private vehicles like car and bikes i.e. PMVs a binomial logistic regression model is formulated. The binomial logistic regression modelling is conducted to foresee in the case whether the existing metro users have moved from bus or are new addition to the public transport framework of the city.

Yuanqing Wang et al. (2016) through this paper the researchers by using of a logistic regression modeling to examine mode shift behavior study after conducting the stated preference survey auto, taxi, bus, electric bicycle, and bicycle users after the introduction of metro service. Females who are auto and taxi users are more likely to use metro than their male counterparts. Longer trips for electric bicycle and taxi travelers have preference towards the newly introduced metro. A 13-min reduction in in-vehicle time & $4.00 decrease in movement cost for metro administration will pull in almost 80% of auto commuters to opt for metro.

Aditya V Sohoni et al. (2016) conducted study which is an attempt to understand the key parameters which are considered primarily important by the local commuters who are responsible for the mode shift. The obtained results of this study are used to estimate the daily ridership of the proposed route of the metro system and it is also used in suggesting improvements in design parameters of existing transport planning. NLOGIT 4.0 which is an econometric software was used to conduct the Combined RP-SP Modelling by using the Sequential Estimation Method is carried out so as to obtain the utility equation coefficients of the Mumbai metro.

Jerry Soman et al. conducted research to predict the travel pattern, and identify the major and minor factors to choose a particular mode and to develop a model for the same are some main objectives of this study. The study concluded that the level of education, distance, travel time, comfort, gender, travel cost are certain parameters which influence the mode choice behavior of commuters.

The modal share study is amongst the primary techniques of traffic engineering. Thus, ample amount of studies have been conducted in the past to carry out mode shift analysis of the commuters in a particular city when and where any new transport system is introduced. By reviewing the above-mentioned works and other similar works mentioned in the references it is found that the metro cities in all developing and developed countries experiences the traffic inefficiency and overstressed networks at some point of time. Since both the urban population and the vehicular growth is rising at an exponential rate the city planners come up with idea of introduction of metro in the city. Since the fast-developing cities are introducing metro transit services now, and the cities are not planned, developed and designed keeping in mind this new introduction, the early land use planning has not reserved space for any such system. Which leads to large difficulties in build transfer facilities for the dedicated metro corridor and the available space for normal movement is also suffered. This can create an additional disadvantage rather than providing the solution for reduction of congestion.

A lot more similar studies are done in this field concerned with a specific city under consideration. We have studied these papers for understanding the basics of our works, and have incorporated relevant ideas for this study.

II. STUDY AREA

Indore city being a metro city of the state, is governed by Municipal Corporation which comes under Indore Metropolitan Region. As per Census of India, population of Indore city in 2011 was 1,964,086; of which male and female are 10,20,057 and 9,44,029 respectively. In addition to this the population of Indore Urban/metropolitan was 21,70,295. There is a large chunk of people who come to Indore in search of their livelihood. These people are estimated to be 1,00,000 who are not from Indore city but reside there for livelihood. From 2001 to 2011 rate of growth is 32.7%, of which in urban areas the rate is 40.1% and rate of 15.3% in rural areas. In most of the developing and developed nations as soon as the population of the city surpasses the 1-1.5 million the arrangements for introduction of MRTS are started and with growing population, the steps of implementing and expanding the network is carried out.

A proper modal split study is necessary to analyze the demands of the consumer which are then implemented into the transit system to deliver the objectives which are of providing the metro. As per the DPR prepared by the *Rohit Associates Architects and Engineers Pvt. Ltd* the Indore metro rail system will be adopting the steel-wheel- technology while using the standard gauge of 1435mm. There are 4 lines and stabilizing lines on line 1 and line 3, total of 89 stations. Out of the projected 85 stations 8 are to be constructed underground, 6 will be at grade and 75 would be on elevated corridors.

The Indore metro rail system will be adopting the steel-wheel- technology while using the standard gauge of 1435mm. In the initial phase the Line 3 of the Indore metro is under construction and its operation is projected to be started from late 2023. The focus areas for conducting survey would be, the probable stations which are to be constructed in the first phase of metro construction.

Table 1. Details of Metro Route as proposed in DPR

S. No	Line No.	Description	Length (Kms)
1	Line 1	Aurobindo hospital – Indore By pass	18.42
2	Line 1B	Aurobindo Hospital – Regional Park	13.57
3	Line 2	Dewas Naka- Mhow	28.91
4	Line 3	Ring Road (Bengali Sqaure- Palasia- Vijay Nagar- Radisson Square-Bengali Sqaure)	31.46
5	Line 3s	Nanod- Rajwada- Bengali- Indore By pass	15.12
6	Line 4	MR 11 -Nanda Nagar- Indore By pass	16.9
	Total		**124.5**

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III. METHODLOGY & ANALYSIS

Initially the stated preference questionnaire was designed which included the entries to collect data regarding socio-economic and Travel characteristics of commuters. The questions were prepared keeping in mind the selected part of Survey Area, which included the proposed stations for Metro Line 3 which is under construction. The questionnaire was prepared in the digital form as well to attract the online responses to the Survey. Thus, the language and the technical aspects were carefully mentioned for self-understanding of the user. Socio Economic parameters such as Age, Gender, Income group, vehicle ownership was used to model the likelihood of switching to metro along with travel parameters such as Purpose of trip, mode of commute, Discomfort Faced & the possible reason to switch to metro etc. were also necessary to examine the likelihood of the commuter to switch to metro. A pilot survey was also carried out in online as well as offline mode to assess the efficiency of the questionnaire designed.

Data Collection

The pilot survey brought out many shortcomings in the survey design both with respect to obtaining responses and influence of particular parameters in modelling. The problem of non-response by the commuters were faced. The general respondents are not familiar with google forms so there were some bogus and wrong responses. The problem of non-response by the commuters were faced largely due to unprecedented occurrence of Pandemic COVID 19 wrong responses and physically carrying out the survey was not possible due to lockdown imposed and social distancing guidelines after unprecedented occurrence of Pandemic COVID 19. Since we have assumed that our population is normally distributed, empirical formulas which were given by Lemeshow and Levy (2008) are used to determine our sample size

$$No = \frac{Z^2 pq}{e^2} \qquad \{1\}$$

Where,
N0 = is the sample size from infinite population,
e = desired error (here we have adopted as 5%),
Z = statistical parameter corresponding to confidence level (Z is 1.96 for 95% confidence interval),
N =Total population size of study area i.e. Indore

p = hypothesized true proportion of population (adopted as 0.5 to account for the worst-case scenario) &

n = sample size

$$q = 1 - p \qquad \{2\}$$

$$n = \frac{No}{\left[1+\frac{No-1}{N}\right]} \qquad \{3\}$$

From the above equation, it can be obtained that the **345** no. of survey samples must be obtained to get good proportion of population covered. We obtained 395 samples to be on the safer side, of which 255 are from online mode.

Preliminary Data Analysis

For preliminary analysis of data with respect to study of current share of transport, probable percentage shift as per stated response and other comparison are drawn using the Microsoft excel software along with preparation of charts etc. for better understanding.

The Age effects

The oldest group preferred Cars as PMV more as compared to all other classes. With age the tendency towards using PMVs is increasing.

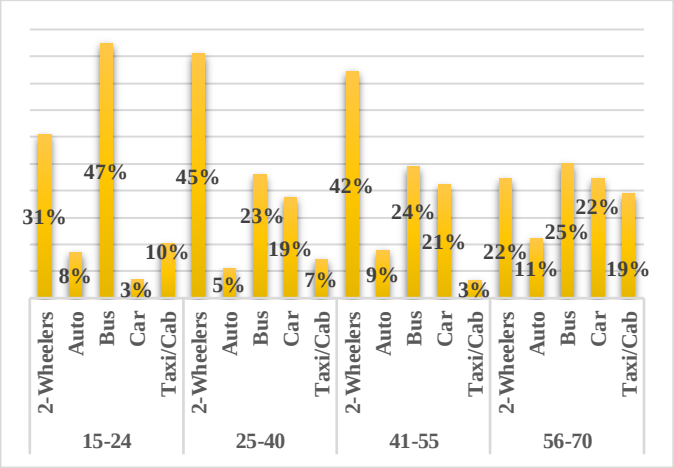

Fig. 1. Age group–based classification of mode preference

The Gender effects

The females are more inclined towards using the metro as compared to their male counterparts.

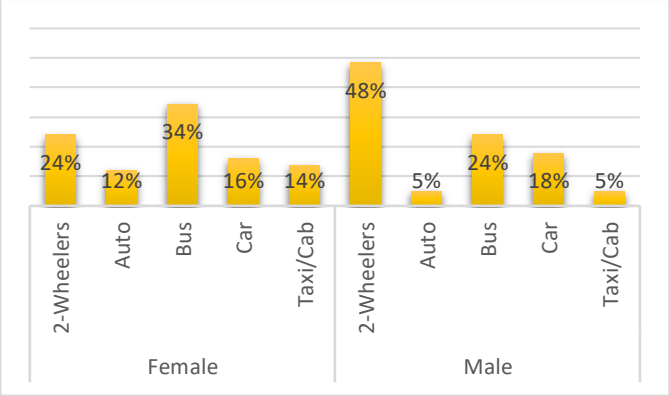

Fig. 2. Gender based classification of mode preference

The Income effects

With increase in income, there is an obvious shift from public transport and 2 wheelers to personal cars.

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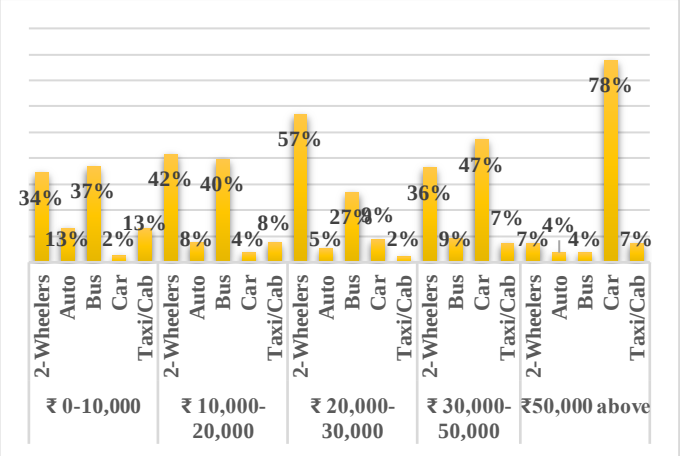

Fig. 3. Income based classification of mode preference

The Reason of Shift

As per the stated preference survey responses obtained, the single most important reason to shift to metro would be that it would be cheaper to travel from metro than the Taxi/Cab. Similar to Taxi/Cab commuters the single most important reason for Auto users to shift would be that the newly introduced transport system will turn out to be cheaper than the current one. For Bus users, "There is no direct bus service", & the current bus service is not punctual are the two main reasons for switching to metro. For 2-Wheeler users the single most important reason which is associated with 25% of such commuters is that "There is lot of traffic and congestion on road". Last but foremost, the main reasons to shift to metro from cars are • that "It will take less time to travel the same distance from metro" & "There is lot of traffic and congestion on roads".

Binomial Logistic Regression Analysis

The various independent variables are Gender, Age Category, Income Category, Purpose of the Trip, Vehicle Owned, Current Mode Being Used, occupation and the level of Discomfort faced in the current mode. Since our dependent variable can only take two values i.e. whether Yes or No, we chose to run the Binomial Logistic Regression analysis. While using the Binomial logistic regression, one of two categories of our dependent variable is kept as reference category variable. The coefficients of all our independent variables are estimated based on this by a method known as the maximum likelihood method. For each category of our categorical variable the odds ratio is determined based on the reference category. The role of odds ratio is to make us understand that how much variation is brought in the odds of being the dependent variable is changed by 1-unit variation in the values of our independent variables. The dependent variable which is "Will they shift to metro" has been encoded in SPSS as below.

Table 2. Dependent variable coding

Original Value	Internal Value
No	0
Yes	1

In SPSS, initially dependent & the independent variable is defined. The categories of the categorical variables are also accordingly defined as per the stated preference survey conducted. The data of responses are entered in the software as per the codes assigned. The data is carefully checked and any redundant, bogus and incomplete entries are removed. Thereafter the BLR test is run for the data. We have carried out analysis both stepwise & Enter mode. Also, for formulating the generalized equation for the probability of shift we conducted the test considering all the variables except Gender as continuous variables. The equation can be prepared for respective category of the categorical variables. The equation so obtained would be valid for that particular category & a different equation for other category, which is unwanted in our case.

IV. RESULTS & OUTCOMES

Table 3. Variables included in the model (Stepwise)

		B	Wald	Sig.	Exp(B)
Step 1	Discomfort in current mode		65.87	.000	
	Discomfort in current mode(1)	-.704	1.196	.274	.495
	Discomfort in current mode(2)	-.348	.355	.551	.706
	Discomfort in current mode(3)	1.784	8.529	.003	5.952
	Discomfort in current mode(4)	2.449	7.082	.008	11.571
	Constant	.154	.077	.782	1.167
Step 2	Current_mode.		33.99	.000	
	Current_mode.(1)	-.181	.069	.792	.835
	Current_mode.(2)	.464	.602	.438	1.591
	Current_mode.(3)	-1.447	6.600	.010	.235
	Current_mode.(4)	-1.594	6.634	.010	.203
	Discomfort in current mode		70.605	.000	
	Discomfort in current mode(1)	-.918	1.675	.196	.399
	Discomfort in current mode(2)	-.511	.629	.428	.600

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	Discomfort in current mode(3)	1.977	8.841	.003	7.218
	Discomfort in current mode(4)	2.573	7.035	.008	13.103
	Constant	.989	1.481	.224	2.690
Step 3	Income		18.93	.001	
	Income (1)	-.737	2.467	.116	.478
	Income (2)	-1.276	10.72	.001	.279
	Income (3)	-.416	.714	.398	.660
	Income (4)	-2.264	10.94	.001	.104
	Current_mode.		24.30	.000	
	Current_mode.(1)	-.285	.145	.704	.752
	Current_mode.(2)	.365	.314	.575	1.440
	Current_mode.(3)	-1.435	5.379	.020	.238
	Current_mode.(4)	-1.175	2.597	.107	.309
	Discomfort in current mode		68.82	.000	
	Discomfort in current mode(1)	-.707	.881	.348	.493
	Discomfort in current mode(2)	-.122	.031	.860	.885
	Discomfort in current mode(3)	2.464	11.618	.001	11.748
	Discomfort in current mode(4)	3.067	8.975	.003	21.470
	Constant	1.296	2.214	.137	3.655

The table above is the output table showcasing the behavior of the variables considered when the test is run in the stepwise manner. Here the model is prepared in 3 steps, in the first step the "Discomfort" variable is added in the model for better prediction. Since for income variable the value of significance is < 0.05 hence the null hypothesis is rejected. Similarly, in the subsequent steps the "Current mode" variable and then the "Income" variable is added in the model for accurate prediction. No new variable is after that, because there was no appreciable improvement in the prediction of mode choice by adding any new variable in the model. Since these 3 variables are having significance value <0.05 thus they have significant relationship with the dependent variable. It is also evident that Discomfort category 1 & 2 have a negative correlation suggesting that the low and very low discomfort facing users will not be shifting to the metro. Whereas the higher categories show a positive a correlation.

Similarly, it can be seen that the income variable has a negative correlation with the shift, which indicates that with increase in incomed the tendency towards shift decreases, we have seen this trend from the initial analysis charts as well. The categories in the current mode are encoded as none, auto taxi, cab, Bus, Bike and Car which is increasing order from Public Transport to PMVs. The negative correlation indicates that the chances of shift decreases as one respondent moves up in that ladder with respect to the reference category. The Exp (B) which means the odds ratio with respect to the reference category. Thus, the respondent who experience "Very High" discomfort are 11.5 time more likely to switch as compared to respondents who are experiencing "Very Low" discomfort. Similar conclusions can be drawn from the table above.

Table 4. Variance explained by the model

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	365.330[a]	.215	.297
2	325.420[a]	.300	.414
3	304.579[b]	.340	.470

R square values has more impact in Ordinary Linear equation mathematical modelling, here in logistic regression modelling though the R square has no significant meaning. The scientists have worked upon coming up with a well-accepted technique. The predictors are able to explain the 34% of variance as per Cox & Snell R square and 47 % variance as per Nagelkerke R square. The values keep on increasing with addition of a variable at each step. Also -2 Log Likelihood value goes on decreasing with additional variable. this test indicates us about the contribution of each variable at every step in the model.

Table 5. Model Prediction Report

Observed			Predicted: Will they Switch: No	Predicted: Will they Switch: Yes	% Correct
Step 1	Will they Switch	No	94	26	78.3
		Yes	71	159	69.1
	Overall Percentage				72.3
Step 2	Will they Switch	No	74	46	61.7
		Yes	26	204	88.7
	Overall Percentage				79.4
Step 3	Will they Switch	No	81	39	67.5
		Yes	29	201	87.4
	Overall Percentage				80.6

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The model so formulated using these 3 predictor variables is able to predict almost 81% for the cases correctly. In each step with the introduction of variable the percentage correct of the predicted cases increase which can be interpreted from the above table. This signifies that our model is well formulated and that the model is statistically significant one.

The output table below this paragraph is obtained by conducting the binomial logistic regression analysis without considering the predictors (except Gender) as the categorical. This led to reduced accuracy of the model and there are variations in coefficients values from what is obtained through stepwise method than the enter method. But since we have to see the relation of the probability of shift with all our predictors and develop a generalized equation for the complete study area. The table clearly explains that the variable such as Purpose, income, current mode and Discomfort have significant relationship with the mode shift and negates the null hypothesis. If the significance value of a certain parameter is >0.05 we can say that it confirms the null hypothesis, and that the model developed by such parameters is not good for prediction. It can be concluded from the below table that the female are 1.7 times more likely to shift to the newly introduced metro as compared to their male counterparts. Age, Purpose, Income and Current mode have negative correlation, whereas Gender, occupation, ownership and discomfort have the positive correlation. This trend could be understood more from the coding pattern each category of the variable. The odds ratio for current mode variable is less than 1, which means that the responders of the lower category are which are public transport users are more likely to shift to metro than the higher category PMV users i.e. Bike, Cars. Similar to what we have interpreted from the initial analysis, with increase in age the commuters show less willingness to shift to a new metro compared to the young commuters.

Table 6. Variables included in the model (Enter)

		B	S.E.	Wald	Sig.	Exp.B
Step 1	Gender (1)	.536	.286	3.515	.061	1.709
	Age	-.185	.175	1.118	.290	0.831
	Purpose	-.258	.119	4.722	.030	0.772
	Occupation	.081	.153	.281	.596	1.084
	Income	-.366	.157	5.406	.020	0.693
	ownership	.096	.190	.258	.612	1.101
	Current mode.	-.293	.157	3.490	.032	0.746
	Discomfort in current mode	1.229	.169	52.71	.000	3.418
	Constant	-.690	.744	.860	.354	0.502

V. CONCLUSIONS

In our study there is one dependent variable which is "Whether the person would shift to metro" and it is dichotomous in nature i.e. it could take two values whether "Yes or No". It is dependent on 8 independent variables as per our study, which includes Gender, Age, Purpose of trip, Income, Vehicle Ownership, Current Mode used, Occupation and Level of discomfort faced in the current mode. Based on this the logit equation is formulated as: -

$$\boldsymbol{Mode\ Shift\ (X) = log(\frac{P}{1-P})} = \boldsymbol{B_0 + B_1 * Gender + B_2 * Age + B_3 * Purpose + B_4 * Occupation + B_5 * Income + B_6 * Ownership + B_7 * Current\ Mode + B_8 * Discomfort}$$

As per the model our equation as developed is given below:

$$\boldsymbol{Mode\ shift\ (X) = \log(\frac{P}{1-P})} = \boldsymbol{-0.690 + 0.536 * Gender - 0.185 * Age - 0.258 * Purpose + 0.081 * Occupation - 0.366 * Income + 0.096 * Ownership - 0.293 * Current\ Mode + 1.229 * Discomfort}$$

Other Conclusions

- Charts are prepared, which provide necessary conclusions for our study. The charts were explained in the methodology section of this presentation.
- Since the developed model is able to predict only 81% of the results and there is still large scope of error which can occur. This may be due to 2 reasons
  - i) First, that the independent variables defined does not have a very strong relationship with the dependent Variable.
  - ii) Second, the responses as obtained are variable person to person and do not have common trend, thus it is difficult to obtain a model which could cover everyone and predict all cases.
- Reduction in fare cost is the single largest reason given by the taxi/cab and auto commuters.
- The entry and exit points of metro should be easily accessible so as to not cause extra trip for the commuters in other modes to access metro stations
- The facilities must be so provided in the currently under construction line and all future lines so as to woo as many private vehicle commuters as possible to help in curbing the pollution along with increasing the network efficiency.

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