Travel Mode Choice Modeling of Karachi Commuters

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Abstract:

This paper presents development of discrete choice utility model for modal choice behavior using revealed preference data, collected from Karachi, Pakistan. The selected model is applied to estimate the modal share of existing modes and to evaluate different policies in the context of gaining more riders for bus to improve the traffic condition. Various MNL and NL models with different nesting structures are developed using incremental approach. It is found that modal share of bus is 41 percent. It is concluded that most suitable policy to improve the bus rider ship is to reduce the total travel time, by providing express bus service and bus lanes.

Keywords: Travel Modes, Multinomial Logit Model, Nested Logit Model, Revealed Preference Data, Utility Maximization,

Abbreviations:

MNL: Multinomial Logit

NL: Nested Logit

Hielow 1.0: Hierarchical Logit for Windows (Discrete choice modeling software)

1. Introduction

In the last few decades, rapid population growth and physical expansion of all the world largest cities had resulted in the sharp increase in the demand for transportation facilities. Because of the increase in the traffic, many cities like Bangkok, Dhaka, Manila, New Delhi, and Karachi are facing serious problems of traffic congestion, high rate of accident, and environmental degradation.

Karachi is the largest city and one of the major commercial centers of Pakistan, having estimated population of 13 million at an annual growth rate of 3.52 percent compared with the national growth of 2.1 percent annually. There are many modes of transport available in Karachi such as private cars, motorcycles, paratransits, coaches and buses. Karachi has 17,145 intra city buses; all owned and operated by the private operators. Apart from this Karachi also have 39,907 taxis, 29,275 rickshaws, 478,644 cars and 390,154 motorcycles registered up till June 2000, (Excise Department, 2001). Despite of heavy traffic on the roads of Karachi, fewer efforts have been made to understand the behavior of commuters in selecting mode for their travel.

According to the Regional Transport Authority (RTA, 2000), 72 percent of all commuters using buses travel by Karachi's 8,773 minibuses. These mini buses (Coaches and Small buses) provide a cheap mode of transport and their fare ranges between 5 to 10 rupees[1] where as larger buses are expensive to purchase and difficult to operate. Public transportation system has a very important role in the urban transportation system of Karachi as the majority of the common people are heavily dependent on the public transportation. Compared with the private cars, public transport is more favorable on financial,

[1] One US dollar is equivalent to 60 Pakistani Rupees (State Bank of Pakistan, Exchange rate for November 2006)

social, economic and environmental grounds. In order to understand the travel mode preference of the people it is necessary to model the mode choice behavior and to estimate market share of each mode for shaping effective policies. This paper presents development of discrete utility models under the framework of MNL and NL models and through comparison of the various models, most suitable model is selected to estimate the mode share. This model is then used for analysis of variables that are subjected to produce significant change in the current transport policy settings in the milieu of commuter behavior of Karachi, Pakistan.

2. Mode Choice Modeling

The shift has been occurred in the mode choice modeling from aggregate to disaggregate technique, as it was found that directly modeling the decision process of individual had several significant advantages over aggregate modeling (FTA 2000). Disaggregate technique explains why an individual makes a particular choice given his/her circumstances and is better able to reflect changes in choice behavior due to changes in individual characteristics and attributes of alternatives (Ben-Akiva and Lerman 1985). The notion of utility maximization provides premises to develop individual choice models; theory of utility maximization assumes that an individual will choose the alternative that appears to maximize his or her utility when the choice is being made (Meyer and Miller 2001). Due to the involvement of the randomness in the individual decision-making phenomena, one could only estimate the *probability* that a given alternative from a choice set will provide the maximum utility to the individual and hence be chosen. With the assumption of independent and identical

distribution of this randomness through Gumbel type I distribution, family of logit models are easily estimated under the framework of utility maximization (Ortuzar and willumsen 1994).

Forinash et al. (1993) applied nested logit modeling approach to analyze the business travel in Ontario-Quebec corridor of Canada. A set of nested logit structures allowing the differential sensitivity to changes in service quality of rail was estimated. It was found that the nested logit structures with bus-train or car-train nests were providing superior results than MNL models. Car, train, air and bus formed the choice set. It was concluded that the consideration of bus and car in one nest gave better results than the consideration of these two modes as separate ones. This proved the usefulness of application of NL structures in travel behavior analysis.

Polydodoropoulou and Ben-Akiva (2001) applied the combination of SP and RP in the Nested Logit Model. The model consists of access and main mode choice developed for the Tel-Aviv Metropolitan area. The upper level represents the main mode choice including bus and mass transit in the public transport nest, while car driver and car passenger in the private transport nest. The lower level of the nested logit model represents the access choice to the bus or mass transit alternatives. The model is developed to illustrate a methodology to estimate a NL model using both RP and SP data. The model was also used to conduct sensitivity analysis and estimation of value of time for different users.

Su (1995) employed three modeling approaches to determine the utility functions for the alternative modes and to estimate the future rider ship of the MRT in Taipei. RP, SP and Market Segmentation methods were used. Eight logit models were found to be acceptable and after comparison most suitable was

selected based upon its low predicted deviation, no collinear effect between variables and satisfaction with all statistic test. The selected model estimated that total share of public transportation will increase from 36.2 percent in 1994 to 41.9 percent after MRT is operated and then would gradually decrease to 37.1 percent in 1999. It was also found that reduction in 10 percent of in vehicle travel time of MRT will increase the 6 percent share to the MRT.

3. Data Collection Methodology

Modeling of travel mode choice behavior of Karachi commuters requires individual level data set. For this purpose questionnaire is designed to conduct survey in order to fulfill the obligations of the discrete choice utility based models.

3.1 Design of Questionnaire

Questionnaire was mostly designed to collect RP data, information about the socioeconomic characteristics such as age, sex, occupation, household size, individual income, family income, number of cars available, number of motorcycle available, object of travel, mode available and mode used by the traveler was incorporated in Part- A. The service attributes of various existing modes such as access time, waiting time, in vehicle travel time, egress time, total travel time and total travel cost was included in Part-B of the survey questionnaire.

3.2 Survey

The 11 towns of Karachi city, with a population of 5,587,989 were considered as population of interest. Simple random sampling technique was employed with a sample size of 900 individuals. The number of samples selected from each town

was based on population of the town as shown in table 1. Direct interview method was adopted to enquire about questions in the questionnaire; Data was mainly collected from two points i.e. Homes and Shops. About 8.0 percent of the samples were kept for external validation. Therefore the total available survey samples were 775 out of which 537 samples were obtained from homes and 237 survey samples from shops by interviewing shop owners. Total sample population consisted of 66% of males and 34% of females with the occupation of government employ, private employ, businessmen, students and housewife.

3.3 Observed Modal Choice from Data

The table 2 shows the observed modal choice directly obtained from the data. It reveals that, public transportation has the share of 70.6% where as private transportation has 25.4 %. Bus is the dominating mode with the share of 46.2%. Very few commuters use paratransit (Taxi/Rickshaw) for their frequent trips, due to high cost of this mode in comparison with other travel modes.

4. Modeling Methodology

For modeling the existing market share of different modes, RP method has been used under the framework of utility based discrete choice modeling. Different structures of MNL and NL models are calibrated by a computer software package, HieLoW 1.0, which uses maximum likelihood method. The general framework of model development is shown in figure 1 and the steps involved in model development are illustrated in the following paragraphs.

4.1 Model Structures

Models with different nesting structures as shown in figure 2 are developed and estimated. The results of statistical tests of each model are compared with

others, in order to obtain the most appropriate model i.e. which represents the most accurate travel behavior. Following structures are devised for the development of logit models.

- **Type A:** The MNL structure has been devised as base model.
- **Type B:** The car and motorcycle are grouped in the private mode nest. It is based on the assumption that private modes, share the same unobserved components of utility. In other words, if the level of service of one private mode is improved, it will attract other private mode more than other modes (FTA 2000).
- **Type C:** The paratransit, coach and bus are grouped in the public mode nest. These groups are expected to be more sensitive to each other than private mode. For example, if the level of service of one public transport mode is improved, it will attract other public modes more than other modes.
- **Type D:** The car, motorcycle and paratransit are grouped in the same nest of "Up to destination" by assuming that these mode provide the service up to the destination of commuters.
- **Type E:** Three-level nesting is devised in which, the coach and bus are grouped in the nest of "inconvenient modes". This "inconvenient modes" and paratrnsit are grouped in public nest. It is assumed that paratarnsit has higher preference in public modes.
- **Type F:** Referred to type E, three level nesting structure is devised, in which car and motorcycle are grouped in private nest while, paratransit and "private" are grouped in "comfortable mode".

- **Type G:** Two-level nesting structure is devised, in which car and motorcycle were grouped in private, while paratransit, coach and bus are grouped in public mode.
- **Type H:** Two-level nesting structure is used with car and partransit grouped together in “expensive” nest. It is assumed that both are expensive than all other modes.

4.2 Specification of Utility Function

The utility function is combination of the different variables such as characteristics of travel mode and respondent’s socio economic characteristics. Considering the results of data analysis, different independent variables are randomly selected and analyzed based on the statistical test and fit ratio of the model. The following variables are selected in the study:

- **Traveler related variables**

Family income of traveler

Number of car ownership in household

Number of motorcycle ownership in household

Age

Sex

- **Mode related variables**

Total cost

Total travel time private

Total Travel Time Public

Incremental approach has been used to develop the model, for which all above-mentioned independent variables are used. First the utility function is developed with the essential variables like total travel cost and total travel time of each

mode. From this basic specification incremental changes are proposed by observing the statistical testing. The incremental changes adopted in the study are as follows:

1. *Adding few variables to the specifications:* The independent variable "individual income" is used in the utility function of car, coach and bus in the RP data. As the individual income increases or decreases, the probability of selecting car as travel mode also increases or decreases respectively. While the effect of individual income on selecting bus and coach as travel mode is found vice versa of car.
2. *Testing interactions between variables*: The result of "total travel cost" divided by "family income" is used because the low family income travelers will be more sensitive to travel cost than higher income. Such specification implies that the importance of cost in mode choice decision diminishes inversely with increasing monthly family income of the traveler. Total Travel cost divided by family income is treated as generic variable.
3. *Total travel cost*: The total travel cost variable is treated as specific. In the refinement process total travel cost is also used as generic variable i.e. total cost of private and total cost of public.
4. *Travel time private:* The travel time private is treated as generic i.e. Car and motorcycle are assigned the same travel time private coefficient.
5. *Travel time public*: The travel time public is treated as generic i.e. Paratransit, coach and bus are assigned the same travel time public coefficient. In the refinement process travel time is also used as specific variable.

6. *Modal Constant***:** The modal constants or alternative specific constants are defined relative to bus. It implies the difference in the utility of private car, motorcycle, paratransit and coach from that of bus when "all else is equal" (FTA 2000).
7. *Family income*: Family income is considered as alternative specific socioeconomic variable. This variable is specific to car users and bus users in RP data as this causes significant affect on selecting car and bus. As the family income increases or decreases the probability of selecting car and bus also increases or decreases respectively.
8. *Number of car and motorcycle ownership*: The numbers of car and motorcycle ownership are also alternative specific socioeconomic variables. The car ownership and motorcycle ownership have higher influence on the usage of car and motorcycle respectively.
9. *Sex:* Sex (gender) is another alternative specific socioeconomic variable, which is specific to coach and paratransit**.** 1 and 0 represents male and female respectively. It is observed that, if the sex is male the probability of selecting coach is higher, while in case of female, probability of selecting paratransit is high.
10. *Age*: Age is also alternative specific socio economic variable, which is specific to bus and paratransit only. As the age increased the probability of using bus is decreased where as the probability of selecting paratransit as travel mode is increased.

4.3 Model Calibration

HieLoW 1.0 is used for estimating the coefficients of the utility functions. The *t*- statistics of all explanatory variables used in utility function is

obtained along with rho- square, log likelihood with zero coefficients and likelihood at convergence for the whole models. Sign test, t-test, chi-squared test and likely hood ratio index (LRI) are used to determine whether the model is good or not.

5. Model Calibration Results

The results of the models are first tested in the same structure and than with other structures in order to obtain the best model. The revealed preference method is based on the existing experience of the modal choice. As the main objective of the study is the determination of existing modal share. In order to achieve that, MNL and NL model using RP data are estimated to determine the existing modal share of car, motorcycle, paratransit, coach and bus.

5.1 MNL Model

Several MNL models are developed using incremental approach within Type A structure and in these A-1, A-2, A-3 and A-11 satisfies the statistical tests. Although the OVTT time for private vehicles and age of motorcycles users have low t-statistic, but still these variables are retained in the model because these variables are believed as an important variable (Meyer and Miller 2001). From type-A MNL models “A-11” is used to test with other significant models and defined as unrestricted model because it includes higher variables than other models. The remaining models are defined as the restricted models. The results of the test is shown in table 3, from this it is revealed that A-11 is the most appropriate MNL model.

5.2 NL Models

Different nesting structures are modeled using Hielow 1.0, and in the each structure several models are developed using incremental approach. From these structures, Type C and Type H models satisfies the statistical test. This implies that these structure models have acceptable logsum parameter value, (which should lie between 1 and 0) (FTA 2000), all the other nesting structures have logsum parameter value greater than 1 and hence collapse to MNL model. It was observed that only model C-1, C-4, C-6, C-8 and H-1, H-2, H-3, H-4, H-5, H-6, H-7 and H-8 obtained the acceptable value of logsum parameter as this parameter value in these models is significantly different from one.

Although the OVTT time for private vehicles and age of motorcycles and car users have low t-statistic, but still these variables are retained in the model because these variables are believed as important variables. Out of C series models, modal C-7 is used to test with others and defined as unrestricted model because it includes the number of variables greater than other models. The remaining C-series models are defined as restricted models. The results of the test are shown in table 4. This table shows the estimation results of the likelihood ratio test with the null hypothesis that Model C-1, C-4, C-6 or C-8 is better than Model C-7. The null hypothesis can be rejected at more than 99.9% confidence level (or less than 0.001 level of significant) with chi-squared distribution. The rho square of Model C-7 is found higher than all. Due to this, Model C-7 is preferred in type-C NL logit model structure.

Table 5 shows the estimation results of the likelihood ratio test with the null hypothesis that Model H-1, H-2, H-3, H-4, H-5, H-6 or H-8 is better than Model H-7. The null hypothesis can be rejected at more than 99.9% confidence level (or

less than 0.001 level of significant) with chi-squared distribution. The rho square of Model H-7 is found higher than all. Due to this Model H-7 is preferred for type-H NL logit model structure.

5.3 Comparison of MNL and NL models

The comparison between MNL and NL model is done by adopting the likelihood ratio test with null hypothesis that NL model is better than MNL model. The result is shown in table 6. This table show, null hypothesis that model C-7 or H-7 is better than A-11 is rejected at 99.758% and 99.9% confidence level. Hence MNL modal A-11 is preferred to NL models i.e. C-7 and H-7.

5.4 Prediction test for Model A-11

Although the model illustrates a reasonable goodness of fit when measured by standard statistical tests, it should be evaluated to predict the observed choice behavior. This is so called the prediction success. A prediction success table is a cross classification between the observed and predicted alternatives (Arasan et al., 1996). The probability of choice of each alternative is estimated for each observation in the data set using the utility functions obtained from the calibration. The alternative with the highest probability is considered chosen alternative and is compared with the alternative actually chosen. The prediction success table by cross tabulating predicted and observed values is shown in table 7. It shows that predicted share of trips for motorcycle and bus are closely matched the observed share of these modes trips. The percent correctly predicted results of car, paratransit and coach are rather low satisfactory. So, MNL (A-11) model is selected as most suitable model obtained after the comparison with NL models and satisfactory passing the prediction test. The model (A-11) parameters along with different statistical test results are shown in table 8.

5.5 Model Validation

To obtain the efficiency of a model, the main consideration is targeted on its ability to predict the correct market share of the alternative modes. Since all models are based on the micro level, it is necessary to aggregate the choice probability of each individual. Therefore the sample enumeration method is adopted to aggregate the result of individual's modal spilt. In this study, both the internal and external validations have been done in order to check the prediction capability of the obtained model. For this, 8.0 percent samples from the initial data were reserved separately for external validation. The total number of samples used in external validation is 74. The results for internal and external validations for RP data model are found to be satisfactory and are shown in table 9. It can be seen from the table that, for internal validation the prediction for car, motorcycle and coach is overestimated, while bus and paratarnsit are underestimated. The paratransit has higher deviation than all other modes, which may be caused due to less number of observed samples that select paratransit as their travel mode as the total number of paratransit users is only 31 out of 775 samples. In external validation, motorcycle and coach are overestimated and car, paratransit and bus are underestimated. After the aggregating the results it is found that car has 13.2 percent, motorcycle has 18.3 percent, paratransit has 2.52 percent, coach has 25.4 percent and bus has 41 percent modal share in the existing situation.

6. Policy Sensitivity Analysis

In this section attention has been paid to the selection of the most effective policy, which can cause the diversion effect on shifting the rider ship

from other modes to bus. For this purpose incremental MNL model is used instead of direct calculation from the elasticity. The following equation is used to analyze the policy sensitivity analysis suggested by Ben-Akiva and Lerman (1985).

$$P_n'(i) = \frac{P_{n(i)} e^{\Delta V_{in}}}{\sum_{j \varepsilon C_n} P_n(j) e^{\Delta V_{jn}}} \qquad (1)$$

6.1 Reducing the Total Time of Bus

There are several measures to reduce the total travel time of bus such as increasing the frequency, introducing express bus service and providing the bus lanes on the main routes. The results of the policy sensitivity analysis are shown in table 10. The results in this table reveals that as the total travel time of the bus decreases by every 5.0 percent, modal share of bus will increase by 5.5 percent. In addition, it is also observed that paratransit users are less inclined to shift to bus, as very small share of commuters will transfer from that mode. However the major share will shift from coach. The reason for this may be that coach usually takes much time than other modes. The results also reveal that for RP data the percentage shift from coach to bus has highest proportion of about 78 percentages.

6.2 Reducing the Total Travel Cost of Bus

There are several measures to reduce the total travel cost of bus such as introducing monthly and weekly tickets, adjusting fare structure, offering concessions to frequent users. The results of the policy sensitivity analysis are shown in table 11. The results show that as the total travel cost of the bus

decreases by every 5.0 percent, modal share of bus will increase by 1.7 percent. However the major share will shift from coach. The reason for this may be that coach usually takes much time than other modes and it is used by low-income groups so total travel cost has higher influence on coach users especially low class people than any other mode. The results also reveal that for RP data the mode shifted from coach to bus has highest proportion of about 78.6 percentages.

The results revealed that the most effective policy to attract commuters to use bus is reducing the total travel time. It is therefore suggested to reduce the total travel time of bus by 10 percent in order to gain more 12.3 percent riders to the bus. As a result of this the modal share of the bus will rise to 46 percent which will improve the traffic condition of the Karachi city.

7. Conclusion

1. According to the calibration results for RP data, the MNL model can be applied rather than NL model in the study area. The results are compared by sign test, t-test, value of rho-square and log likelihood test. Only two nesting structures, type C and type H obtained the acceptable logsum parameter, μ. However, when compared with the MNL, these NL model are not satisfies the log likelihood test.
2. According to the results by selected RP model, the present modal share is 41.0 percent by bus, 25.4 percent by coach, 18.3 percent by motorcycle, 13.2 percent by car and 2.5 percent by paratransit. The modal share obtained from the MNL model found quite close to the observed modal share, hence it also satisfies the prediction test.

3. In terms of gaining more bus riders the performance of bus service measures as increasing frequency, decreasing the waiting time, providing bus lanes and express bus service should be introduced to decrease the total travel time of bus. It is also found that in case of the improvement of the bus service, major share would be diverting from the coach. Policy to reduce the 10 percent total travel time of the bus will increase the modal share of bus to 46 percent i.e. the bus riders will increase by 12.3 percent.

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Table 1: Populations and Number of Samples Selected From Each Town

S.No	Name of town	Town Population	Number of samples	% Share in total samples
1	New Karachi	684,183	110	12.24
2	North Nazimabad	496,194	80	8.87
3	Gulberg	453,490	73	8.11
4	Liaquatabad	449,091	72	8.04
5	Jamshed	733,821	118	13.13
6	Saddar	616,151	100	11.02
7	Lyari	607,992	98	10.88
8	SITE	467,992	75	8.37
9	Baldia	406,165	66	7.26
10	Keamari	383,778	62	6.86
11	Gadap	289,564	47	5.18
	Total	**5,587,989**	**900**	**100**

Table 2: Observed Mode Choice Distribution

	CAR	MC	P.T	COACH	BUS	TOTAL
Frequency	100	128	31	158	358	775
Percentage (%)	12.9	16.5	4.0	20.4	46.2	100

Table 3: Likelihood Ratio Test between Model A-11 and Models A-1, A-2 and A-3

Variables	Model A-1	Model A-2	Model A-3
Log-likelihood of Unrestricted Model (Model A-11)	-591.36	-591.4	-591.4
Log-likelihood of Restricted Model	-616.91	-603.115	-628.02
Likelihood Ratio Test Statistic ($-2[L^{restricted} - L^{unrestricted}]$)	51.1	23.43	73.24
Number of Restrictions (Number of different variables)	5	1	3
Level of Significance for rejecting Restricted Model	< 0.001	< 0.001	< 0.001

Table 4: Likelihood Ratio Test between Model C-7 and Models C-1, C-4, C-6 and C-8

Variables	Model C-1	Model C-4	Model C-6	Model C-8
Log-likelihood of Unrestricted Model (Model C-7)	-592.8	-592. 8	-592.8	-592.8
Log-likelihood of Restricted Model	-649.2	-620.4	-604.7	-631.8
Likelihood Ratio Test Statistic ($-2[L^{restricted} - L^{unrestricted}]$)	112.9	55.2	23.7	77.9
Number of Restrictions (Number of different variables)	5	2	1	3
Level of Significance for rejecting Restricted Model	< 0.001	<0.001	<0.001	<0.001

Table 5: Likelihood Ratio Test between Model H-7 and Models H-1, H-2, H-3,H-4, H-5, H-6 and H-8

Variables	Model H-1	Model H-2	Model H-3	Model H-4	Model H-5	Model H-6	Model H-8
Log-likelihood of Unrestricted Model (Model H-7)	-594.9	-594.9	-594.9	-594.9	-594.9	-594.9	-594.9
Log-likelihood of Restricted Model	-626.2	-603.9	-626.3	-619.1	-615.6	-596.3	-605.8
Likelihood Ratio Test Statistic ($-2[L^{restricted} - L^{unrestricted}]$)	62.5	18	62.7	48.4	-41.4	2.8	21.8
Number of Restrictions (Number of different variables)	5	1	3	0	2	1	5
Level of Significance for rejecting Restricted Model	< 0.001	<0.001	< 0.001	N.A	< 0.001	<0.001	<0.001

Table 6: Likelihood Ratio Test between MNL Model and NL Model

Variables	Model C-7	Model H-7
Log-likelihood of Unrestricted Model (Model A-11)	-591.36	-591.4
Log-likelihood of Restricted Model	-592.782	-594.92
Likelihood Ratio Test Statistic ($-2[L^{restricted} - L^{unrestricted}]$)	2.844	7.12
Number of Restrictions (Number of different variables)	2	1
Level of Significance for rejecting Restricted Model	< 0.242	< 0.001

Table 7: Prediction Success for the Model

Observed Choice	Predicted Choice					
	Car	Motorcycle	Para Transit	Coach	Bus	(observed trips)
Car	78	13	0	1	8	100 (12.90%)
Motorcycle	4	121	0	2	1	128 (16.52%)
Para Transit	1	0	21	1	8	31 (4.00)
Coach	10	11	2	122	13	158 (20.38%)
Bus	19	22	3	13	301	358 (46.19%)
(Predicted trips)	112	167	26	139	331	775 (100%)
Predicted Share (%)	14.45	21.55	3.35	17.93	42.71	100
(%) Percent Correctly predicted	78.0	94.53	67.74	77.22	84.08	82.96

Table 8: Parameters of the A-11 MNL Model

Variables	Model A-11
TC/FI	-372.8 (5.813)
Travel Time	
Total Time (Private)	-0.054 (-4.468)
Total Time (Public)	-0.033 (-5.129)
Modal Constant	
Car	-1.508 (-1.564)
Motorcycle	-2.504 (-2.092)
Para transit	-6.258 (-5.098)
Coach	-1.583 (-5.267)
Owner Ship	
No. of car ownership	4.218 (7.971)
No. of motorcycle ownership	5.327 (8.763)
Income	
Income car	0.00009 (3.61)
Income coach	-0.00005 (-2.47)
Age	
Age Bus	-0.0143 (-1.69)
Age Paratransit	0.0645 (3.362)
Sex Parataransit	-1.607 (-3.44)
House Hold Size (Public)	0.5732 (3.614)
Logsum Parameter	-
Final log likelihood	-591.339
Log Likelihood with zero Coefficients	-1076.95
Rho- Square	0.45
Rho-bar square	0.43

Table 9: Internal and External Validation Results for RP model Data

	Car	Motor Cycle	Para-Transit	Coach	Bus	Total
RP Data Model (Internal Validation Results)						
Observed No. of Trips (%)	100 (12.90)	128 (16.52)	31 (4.00)	158 (20.39)	358 (46.19)	775 (100.00)
Predicted No. of Trips (%)	101.52 (13.2)	143.43 (18.3)	19.38 (2.52)	198.25 (25.4)	312.00 (41.00)	775 (100.00)
Deviation	-1.52	-12.04	36.29	-25.31	12.849	
RP Data Model (External Validation Results)						
	Car	Motor Cycle	Para-Transit	Coach	Bus	Total
Observed No. of Trips (%)	18 (24.32)	11 (14.86)	7 (9.46)	15 (20.27)	23 (31.08)	74 100
Predicted No. of Trips (%)	14.23 (19.23)	11.64 (15.73)	3.92 (5.3)	19.13 (25.85)	25.40 (34.32)	74.00 (100.00)
Deviation	20.94	-5.818	43.97	-27.52	-10.45	

Figure in the brackets ( ) represents the modal share

Table 10: Impact on Modal Split by Reducing Travel Time of Bus

% Decrease in $T.T_{Bus}$	**Car (%)**	**MC (%)**	**P.T (%)**	**Coach (%)**	**Bus (%)**	**Bus (+%)**	**% Shift from other competitive modes**			
0	13.2	18.5	2.5	25.4	41.0		Car	M.C	P.T	Coach
5	12.9	18.2	2.4	23.7	43.0	5.4	13.6	4.5	4.5	77.3
10	12.7	17.9	2.3	21.5	46.0	12.3	10.0	8.0	4.0	78.0
15	12.5	17.6	2.2	20.0	48.0	17.5	9.8	9.8	4.2	76.1
20	12.2	17.4	2.1	18.5	50.0	22.7	10.8	9.7	4.3	75.0
25	11.9	17.1	2.0	17.1	52.0	27.8	11.5	10.6	4.4	73.5
30	11.6	16.7	1.9	15.9	54.0	33.0	11.9	11.9	4.4	70.9

$T.T_{Bus}$ represents Total travel time in Bus

Table 11: Impact on Modal Split by Reducing Total Travel Cost of Bus

% decrease in $T.C_{Bus}$	Car (%)	MC (%)	P.T (%)	Coach (%)	Bus (%)	Bus (+%)	% Shift from other competitive modes			
0	13.2	18.3	2.5	25.5	41.0		Car	M.C	P.T	Coach
5	13.2	18.2	2.4	25.0	41.6	1.7	0.0	14.3	14.3	71.4
10	13.2	18.2	2.3	24.9	41.8	2.7	0.0	9.0	18.2	72.7
15	13.2	18.2	2.3	24.7	42.0	3.4	0.0	7.1	14.3	78.6
20	13.1	18.2	2.3	24.5	42.2	3.9	6.2	6.2	12.5	75.0
25	13.1	18.1	2.3	24.3	42.5	4.4	11.1	11.1	11.1	72.5
30	13.1	18.1	2.3	24.2	42.7	4.9	10.0	10.0	10.0	75.0

$T.C_{Bus}$ represents Total cost of travel in Bus

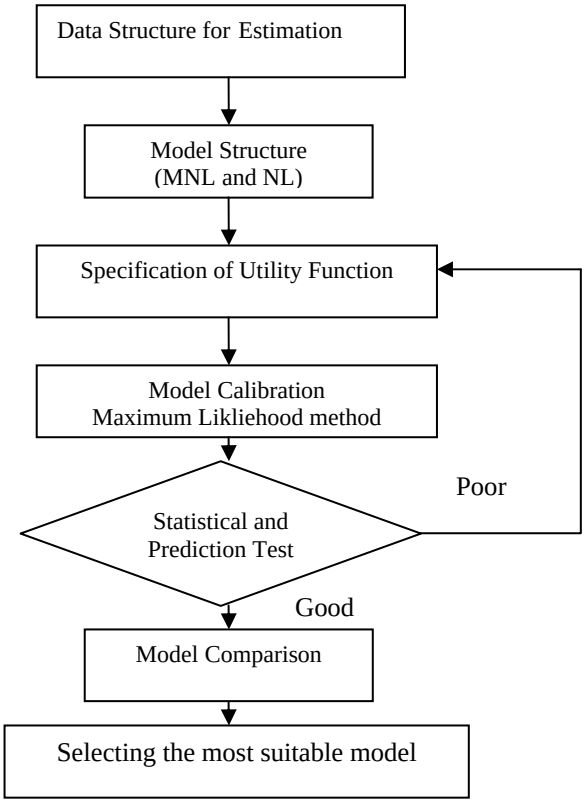
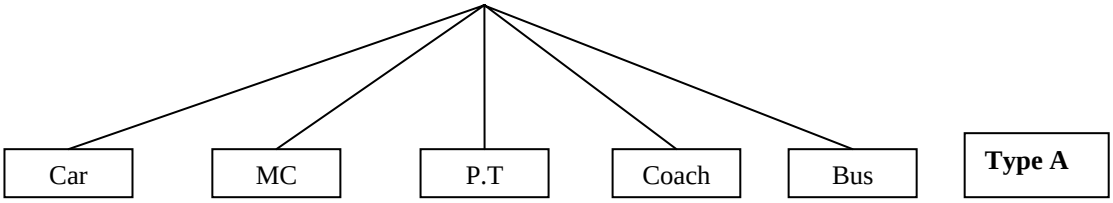
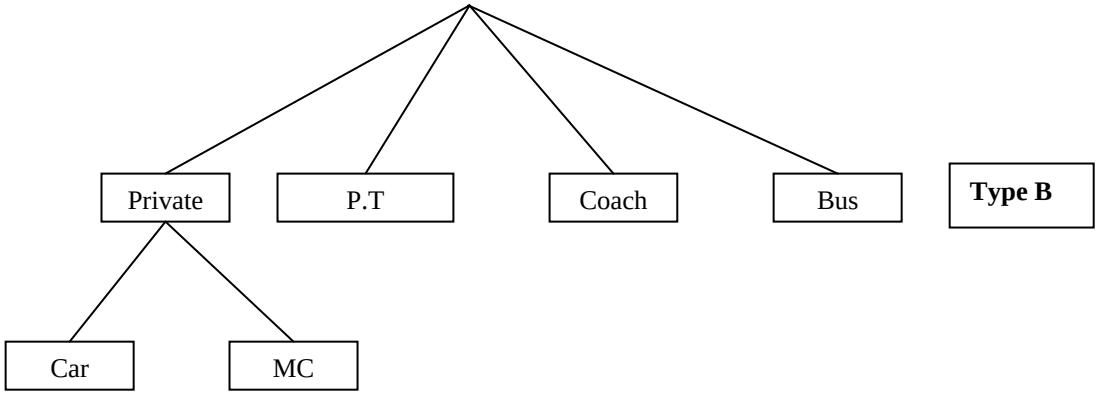
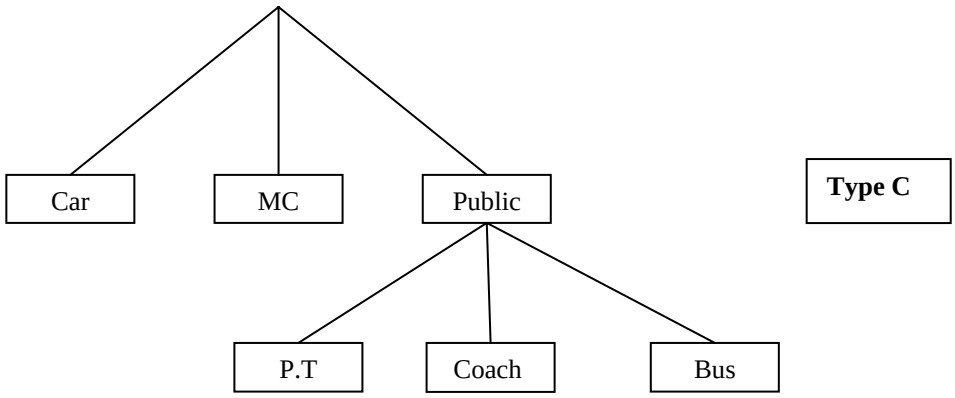


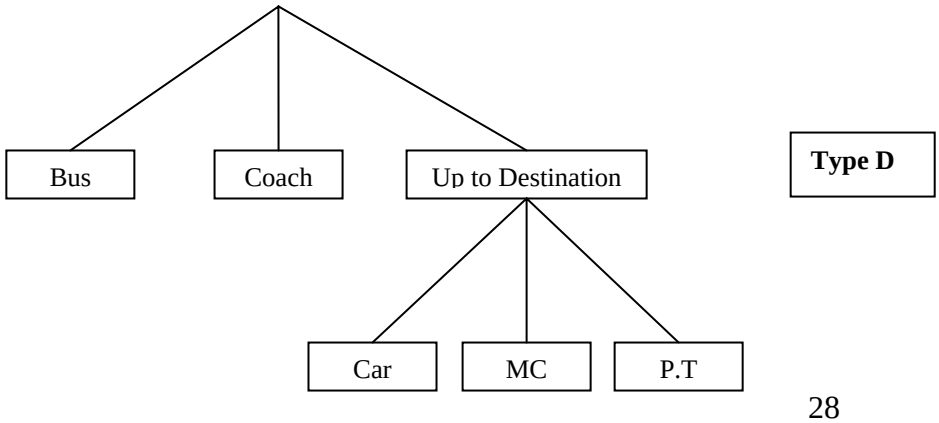
Figure 1: Framework for Model Development

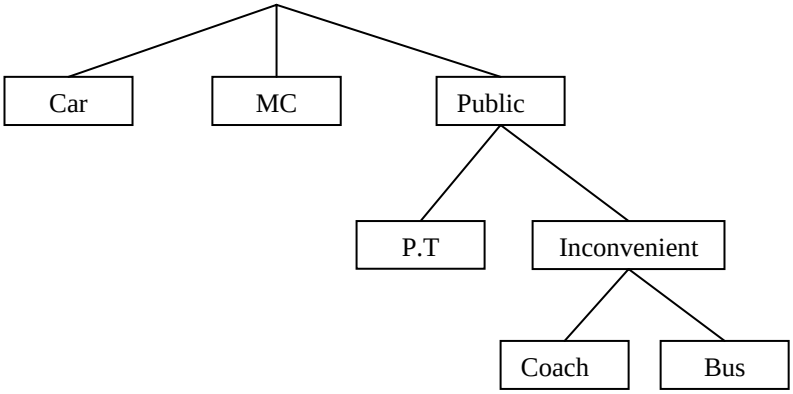
Figure 2: MNL and NL Structures











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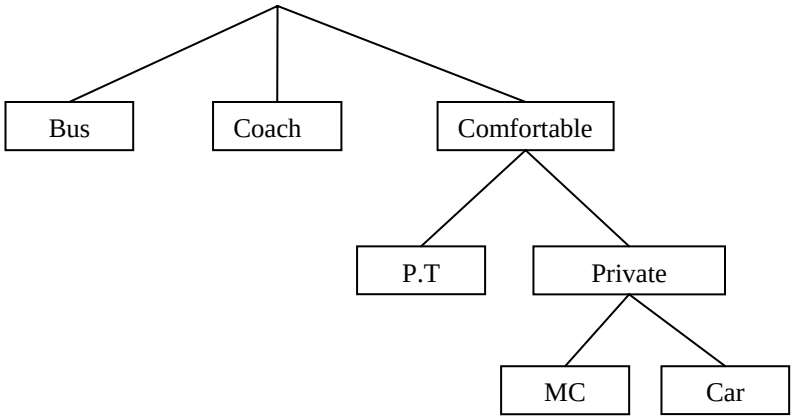

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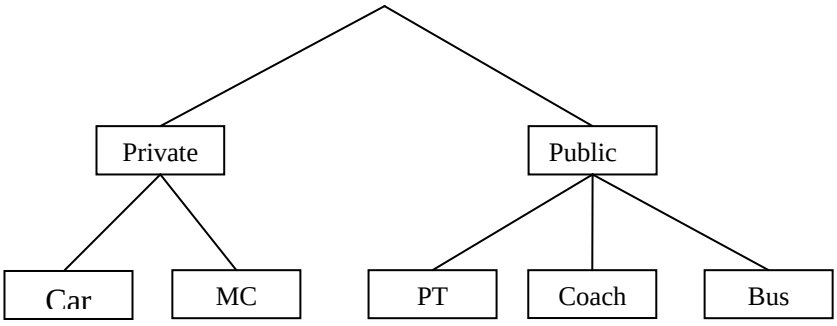

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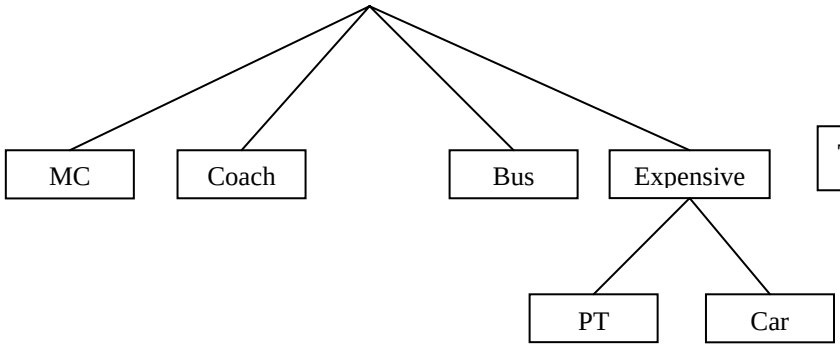

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