Nested-Logit Mode-Choice Model for Office Workers: A Case Study in Dhaka City

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Abstract

This study was an attempt to construct a demand model for transport modes using nested logit model which can contribute by extending two or more choice models for the people of Dhaka City. LIMDEP, transport application software, was used to estimate the mode choice model. Office workers of Dhaka City were selected for the study, because most of the head offices as well as branch offices of the public and private organizations are located in Dhaka City and these offices are a major pull factor for rural-urban migration. The workers of these offices make up a large part of the traffic and are expected to continue their contribution to traffic demand into the future.

Data were collected from both secondary and primary sources. About 250 office workers of three private organizations were surveyed randomly by using a pre-tested questionnaire. Office workers chose only five different modes such as public bus, private auto, auto rickshaw, rickshaw and walk as their primary as well as available alternative modes. Socio economic data included age, gender, educational qualification, status of job, household size, and household income. Travel and mode choice data included household car ownership, trip origin, trip destination, frequency of trips, distance from home to office in km, most frequently chosen mode and alternative modes. It also included in-vehicle travel time, out-vehicle travel time including access time, waiting time and egress time together, cost of travel in Tk., and level of service including accessibility, convenience, privacy, safety and comfort of primary and different alternative modes.

The outcomes of the generic analysis indicate that about 52 percent office workers choose public bus as their primary mode. About 86.30% and 81.82% office workers reach their chosen mode on foot and by rickshaw within 10 minutes respectively. Higher income groups choose mainly private auto or auto rickshaw as their primary mode. It is found from the study that mode choice was also influenced by gender and females were more inclined to choose a comfortable mode. The study tried to indicate a sensible nested logit mode choice model for the office workers, but it could not choose any of the model results as a final nested logit model due to wrong sign of different variables and poor statistical significance. One of the most surprising and interesting findings is that there was no rational interrelationship between distance, in-vehicle travel time and cost in Dhaka city. Finally, the results obtained in the specific context led to some recommendations for future users of these powerful modelling tools.

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Abbreviation and Acronyms

CBD	Central Business District
FIML	Full Information Maximum Likelihood
IIA	Independence of Irrelevant Alternative
IID	Independent and Identical Distribution
LIML	Limited Information Maximum Likelihood
LOS	Level of Service
MNL	Multinomial Logit
NL	Nested Logit
NMT	Non-Motorized Transport
STP	Strategic Transport Plan

Chapter 1

Introduction

1 Introduction

1.1 Background of the Study

Demand forecasting is an essential element in the analysis of transportation system (Ben-Akiva and Lerman, 1985). A major innovation in the analysis of transportation demand is the development of disaggregate travel demand model based on discrete choice methods. Disaggregate travel demand model involves micro level data (typically collected by surveys of individual households) without first aggregating it to a zonal level.

Discrete choice models have played an important role in transportation modelling for the last few decades (Abdel-Aty and Abdelwahab, 2001). They provide a detailed representation of the complex aspects of transportation demand, based on strong theoretical justifications. Moreover, several packages and tools are available to help practionners using these models for real applications, making discrete choice models more and more popular (Bierlaire, 1997).

Many mode choice models are based on the Multinomial Logit (MNL) Model or some variation of the logit function. MNL use in mode choice requires caution due to its Independence of Irrelevant Alternative (IIA) property that assumes the cross elasticities between all pairs of alternatives to be identical. As in many cases of choice situations such an assumption does not hold, further variation of logit formulation is needed. The nested logit model is an extension of multinomial logit model designed to capture correlations among alternatives (Ben-Akiva and Lerman, 1985) and the nested logit structure is defined as a hierarchical choice structure that determines the joint choice.

Both nested logit and multinomial logit model can be represented as a tree structure that represents all the alternatives. The multinomial logit model treats all the alternatives equally, whereas the nested logit model deals alternative groups separately. The grouping of alternatives indicates the degree of sensitivity (i.e. cross elasticity) among alternatives. Alternatives in the common nest show the same degree of increased sensitivity compared to the alternatives outside the nest. The nested logit model is a widely used form of the discrete choice model and has been extensively presented and described in the literature (e.g. Ben-Akiva and Lerman, 1985; Lerman, 1984; Train, 1986; Ortuzar and Willumsen, 1994).

There is very little emphasis on modelling mode-choice in a developing country like Bangladesh. In Dhaka City, the capital of Bangladesh, the traffic and transportation conditions have seriously deteriorated and in many respects have already reached a crisis level. The city already faces serious traffic congestion and various deficiencies related to transport modes. In the context of the present scenario, mode choice modelling should receive emphasis in transport sector to forecast demand for different transport modes.

In this regard, this study was an attempt to construct a demand model for transport modes using nested logit model which can explain the potential modal split between different modes available for the people of Dhaka City as well as can contribute by extending two or more choice models for the people.

On the other hand, the transportation literature suggests that different user groups have different characteristics with respect to commuting patterns as well as with respect to their propensity to switch between travel options. Considering the above situation, one user group namely office workers of Dhaka City, has been selected for study of their modal choice. Most of the head offices as well as branch offices of the public and private organizations are located in Dhaka City (Uddin, M.H. *et al.*, 2004) and these offices are a major pull factor for rural-urban migration. As a result, the workers of these offices make up a large part of the traffic and are expected to continue their contribution to traffic demand into the future.

This study was an attempt to develop a mode choice model using the nested logit model formulation for the office workers for a given dataset with known parameters such as age, gender, educational qualification, status of job, household size, household income, household car ownership, distance from home to office, weekly frequency of trips, time of the trip, in vehicle travel time, out vehicle travel time (which includes access time, waiting time and egress time), cost and level of service. The calibrations of the mode choice models are performed using the program LIMDEP, a transport application software. This program allows the user to calibrate either multinomial or nested logit models.

The model has been formulated for eleven modes consisting of motorized transport such as public bus, micro bus, private auto, auto rickshaw, taxi, human hauler, motor cycle etc. and non motorized transport such as rickshaw, bicycle, van, walk, which are the main modes prevailing in Dhaka City.

1.2 Objectives of the Study

The specific objectives of the study can be summarized as follows:

- To investigate the nature and extent of the factors that contributes to regular transportation mode choice of the office workers.
- To develop a nested logit mode choice model for office workers of Dhaka City.
- To recommend some measures to facilitate the mode choice options for the office workers.

1.3 Scope of the Study

By this study, the nature and magnitude of various factors that play a role in choosing a regular transportation mode by the office workers have to be estimated using LIMDEP. If it is indeed the case that office workers have different travel patterns, and perhaps more importantly, different propensities to shift commuting patterns and modes, knowing and understanding this will be important in the development of future travel demand management in increasingly congested cities. As such, and for the purposes of traffic demand management, it is worthwhile to understand the factors that affect travel demand.

Although the study would be based on office workers it will be helpful to inform other future research on mode choice modelling in respect of Dhaka City. Again the models developed within the framework of this effort would be the basis for such universal model.

1.4 Limitations of the Study

Any research needs long-term observation on the subject. On the other hand, if the study could consider all the office workers employed in different public and private organizations of the Dhaka City it would have been more helpful to understand the actual scenario. But due to time and resource constraints, the study has considered a limited sample of 250 office workers of three private organizations. In addition, very few studies have been done in mode choice modelling in our country. For that reason, the study had very little precedence to draw from and instead, relied on studies conducted in the context of different situations abroad.

Another important limitation of this study is that it can not develop a sensible nested logit mode choice model for the office workers. It may be happened due to irrational interrelationship between in vehicle travel time, out-vehicle travel time, cost and distance. These variables did not show the expected result based on the sign. In our country, travel time in any mode does not conform to the distance the mode traverses and the travel cost. On the other hand, the sample size was very small to describe the situation properly that add to the problem for developing a comprehensive mode choice model.

1.5 Organizations of the Study

This thesis consists of seven chapters. The first chapter provides an introduction to the study. It also describes the objectives, scopes, limitations and organizations of the study. Chapter two describes the concept of discrete choice model including multinomial logit and nested logit models. This chapter also includes a review of literature/research conducted on the transport mode choice modelling. Chapter three describes the detailed methodology of the study. It also contains a detail discussion on data preparation stages for generic analysis and calibration of nested logit mode choice model. Chapter four provides a brief description of the study area. Chapter five contains generic analysis of socio-economic and travel characteristics of office workers. Chapter six describes the estimation and calibration of the nested logit models for the office workers. This chapter does not present all the models that have been estimated during the analysis, but it does present some significant models with the final model that has been selected. Finally, Chapter seven states its implication for the transportation planners, represents recommendations for future research in this field and provides a conclusion.

Chapter 2

Literature Review and Theoretical Framework

2. Literature Review and Theoretical Framework

There is very little emphasis on modelling mode-choice in a developing country like Bangladesh. In Dhaka City, the capital of Bangladesh, the traffic and transportation conditions have seriously deteriorated and in many respects have already reached a crisis level. In the context of the present scenario, mode choice modelling should receive emphasis in transport sector to forecast demand for different transport modes. Considering the situation, the study was an attempt to develop the model choice models for a selected group i.e. office workers in Dhaka City.

In this regard, an extensive literature survey and review on transportation issues in Dhaka City, discrete choice analysis, disaggregate behaviour models including multinomial logit and nested logit models were conducted for concept development and some of these are discussed in this chapter.

2.1 Major Transportation Issues in Dhaka City

Bangladesh has experienced a high rate of urbanization (26% in year 2000) in the last quarter of a century which is unparalleled in its history. Nearly half of the all rural-urban migrants are coming to Dhaka, the capital city with the highest level of facilities and employment opportunities (Tariq, 1997).

With an increasing rate of population growth of about 7% per year (Karim, 1992), Dhaka is expected to become one of the largest and most populous cities by early this century. Over the last 10 years, the population of Dhaka City has more than doubled (STP, 2005). The growing demand of the citizens for civic facilities, utilities and amenities are exceeding the available supply and infrastructure facilities present. Transportation is one of the badly affected sectors in this respect. Present transportation facilities of Dhaka City are unable to accommodate the excess traffic and the growing traffic demand in the near future. The transportation condition of Dhaka in fact has in many parts already reached a crisis level, especially poor public transit provision and automobile dependency has led to inefficient utilization of the available road space resulting in frequent traffic congestion and delay which is further aggravated by unplanned traffic circulation system

The city already faces serious traffic congestion and various deficiencies related to transport modes. These are reducing functional efficiency of the city and are being considered as major impediments for economic growth and development causing frustration and prompting popular demands to find urgent solutions to the problems. From a present population of around 17 million in the greater Dhaka area, it is anticipated that the population in 20 years will reach 36 millions (STP, 2005). In this context, mode choice modelling should receive emphasis in transport sector to forecast demand for different transport modes.

2.1.1 Transport Modes in Dhaka City

In Dhaka City, there is a large combination of different transportation modes of both motorized and non-motorized transport (NMT) and both these fast and slow transport vehicles operate together on almost all of the roads. The major motorized transport vehicles are bus, mini bus, car, taxi, jeep, truck, pick-up, auto rickshaw, auto-tempo and *mishuk*, while rickshaw, van, bicycle, walk constitute the non-motorized ones.

Dhaka is one of the least motorized cities in the region with approximately 32 motorized vehicles per 1000 residents. Only 14% trips are made by automobiles and about 60% people travel by buses (STP, 2005). How these proportions will change over the coming years is a matter of speculation. Non-motorized transport and para-transit play an important role in the transportation system of the city. The use of rickshaws has a long history and they began operating in the late 1940s. At present rickshaw is one of the primary travel modes of the city. Although the maximum number of rickshaw licenses is set by the Dhaka City Corporation at just under 80000, the number actually operating is estimated at between 400,000 and 600,000 (STP, 2005). Generally the slow moving rickshaw is suitable for short distance trips. They can effectively operate on almost all roads of the city except some major roads. However, due to the absence of traffic planning, management and enforcement rules, uncontrolled dominance of rickshaws causes severe traffic problems on all major roads.

Auto rickshaws, tempos, and rickshaws are fast increasing as substitutes of buses although they are expensive and cost higher than bus service. As a result, a large section of the people has poor access to transport services. A large number of trips in Dhaka take place by walking. This is due to the fact that the majority of the people in the City are not able to pay for transportation.

There are very few detailed studies concerning transport demand and mode choice of individuals for proper planning and management of traffic for urban areas of Bangladesh. Therefore, it has become increasingly important to allocate the individuals in their appropriate mode to solve the present state of the problem.

2.2 Discrete Choice Analysis

Demand forecasting is an essential element in the analysis of transportation systems. It is concerned with the behaviour of consumers of transportation services and facilities. A major innovation in the analysis of transportation demand was the development of disaggregate travel demand models based on discrete choice analysis methods. The research field of transportation demand forecasting has started to focus on disaggregate travel behaviour and micro-simulation models. Development of disaggregate behaviour model was prompted by increasing awareness that traditional multi stage engineering models are inaccurate.

2.2.1 The Background of Discrete Choice Analysis

The basic problem confronted by discrete choice analysis is the modelling of choice from a set of mutually exclusive and collectively exhaustive alternatives. Generally, discrete choice analysis uses the principle of utility maximization. Briefly, a decision maker is modelled as selecting the alternative with the highest utility among those available at the time a choice is made. An operational model consists of parameterized utility functions in terms of observable independent variables and unknown parameters, and their values are estimated from a sample of observed choices made by decision makers when confronted with a choice situation. Since it is impossible to include all the chosen alternatives by all individuals, the methods include the concept of random utility, an idea that first appeared in psychology

(Thurston, 1927). The origin of probabilistic choice models are in mathematical psychology (see Thurston, 1927; Luce, 1959; Marschak, 1960; Luce and Suppes, 1965; Bock and Jones, 1968; Tversky, 1972). But discrete or qualitative response models have also been used for many years in biometric applications (see Berkson, 1944; Finney, 1971; Cox, 1970).

2.2.2 Transportation Applications of Discrete Choice Analysis

The early transportation applications of discrete choice models were made for the binary choice of travel mode (e.g. Warner, 1962; Lisco, 1967; Quarmby, 1967; Lave, 1969; Stopher, 1969; Gronau, 1970; de Donnea, 1971; McGillivary, 1972; Talvitie, 1972; Wigner, 1973; Watson, 1974). Some of these studies focus on the estimation of a "value of time", the trade off between travel time and travel cost implied by a travel demand model. Other researchers emphasized the development of policy-sensitive models for predictions of the market shares of alternative modes (e.g. Stopher and Lisco, 1970).

Further progress in transportation applications following these early studies was accompanied by improved discrete choice modelling methods. The research during the early 1970s was oriented toward mode choice models with more than two alternatives and applications to the travel related choices such as trip destination, trip frequency, car ownership, residential location and housing (Rassan *et al.*, 1971; Ben-Akiva, 1973; 1974; Brand and Manheim, 1973; McFadden, 1974; Domencich and McFadden, 1975; Richards and Ben-Akiva, 1975 and Lerman and Ben-Akiva, 1975).

The choice of mode for travel to work has been invetigated extensively by many researchers (e.g. Atherton and Ben-Akiva 1975; Ben-Akiva and Richards 1975; Parody 1976; Train 1976; Daly and Zachary 1979).

2.2.3 Factors Influencing the Modal Choice

Bruton (1975) argued that three main factors are responsible for the choice of mode for personal trips. These are first, characteristics of the journey that includes journey length and purposes; second, characteristics of the traveller which includes income and car ownership: and third, characteristics of the transport system which includes relative travel time, relative travel cost, relative level of service, and accessibility indices.

According to Paquette et al. (1982) cited in Hoque (1997) the factors influencing of mode choice have been classified into three groups. These are:

i. type of trip, which includes purpose, time, length, and orientation with respect to Central Business District (CBD)
ii. a trip-maker's characteristic, which includes income, occupation, auto ownership, worker per household, distance from CBD and
iii. relative level of services (LOSs) which includes travel time, travel cost, and accessibility.

Case and Latchford (1981) further pointed out two cultural or social aspects as the influencing factors on choice of mode in countries of South East Asia.

i. The first is the status aspect. For example, Philippinos prefer to travel by bus or jeepney even though they might be able to travel by motor-cycle, however, to be a tricycle passenger is adjusted to be of high status.
ii. The second aspect relates to the fear of criminal assault. Passenger, therefore, are unwilling to share the vehicle with strangers.

McFadden (1979) had studied the factors influencing the choice of mode and tabulated them in decreasing order of importance. These are:

i. variables with critical explanatory power are travel cost, on-vehicle time, walk time, transfer wait time, transit initial headway, number of persons in household who can drive, determinants of alternative availability (e.g., ability to drive, auto required at work), and wage.

ii. variables with important explanatory power are numbers of transfers, respondent's relation to household head, employment density at work location, suburban or urban, and family composition.

iii. variables with ambiguous explanatory power are household income, residential population density, CBD location with respect to residence, number of workers in household, age of household head, reliability of transportation mode, perception of comfort, safety, and convenience and

iv. variables with low explanatory power are CBD work location, sex of respondent, age of respondent, work status of household head, general attitudes toward privacy, delay, and safety.

2.2.4 Travel Choice and Behaviour Pattern

Brand (1976) highlighted seven different issues around which the research of travel behaviour may be structured. The behavioural assumptions those need to study are related to perception, valuation and structure of choice, and possible conditioned or learned behaviour resulting from the stimuli that give rise to the travel decision for various household and individual traveller.

The seven issues are:

1. What attributes of the travel choice influence the amount of travel?
2. Are the attributes influencing the travel such as modes used to produce transportation perceived together with the travel choice or independently of travel choice?
3. Are perceived values of attributes that influence travel related to "objectively measured" values and if so how?
4. What is the structure or set of the travel choice from which the traveller actually choose?
5. Do attributes influencing travel choice vary in their effect from a travel choice to another?

6. Can travel be considered as the manifestation of a set of conditioned behaviour that involves learning and changes of behaviour overtime?

7. What are the basic behavioural units those affect the finding of question no: 1 to 6?

Brand (1976) also explained the state of interaction of travel behaviour, travel model and observed data.

Travel Modelling Diagram:

1. Travel behaviour and human opportunities ⟹ 2. Observed choice: Individual travel choice and aggregate travel pattern

2. Observed choice ⟹ 3. Alternative models replicate travel choices.

3. Alternative models replicate travel choices ⟹ 4. The rules of behaviour implicit in travel models

Figure 2.1 Travel Modelling Diagram

Source: (Brand, 1976)

Kanafani (1983) expressed that though choice is a complex process and very little has been known about it, simplifications have been made to permit the analysis of travel choice using manageable quantitative models. In addition to that, empirical evidences are still rare since the probabilities of controlled experimentation are very limited.

Choice process can be deterministic and reproducible i.e. the potential driver is repeatedly faced with the same set of alternatives and the choice will consistently be the same. It also assumes that there is a consistent and stable decision rule always followed by the trip maker and this is similar to individual preference behaviour in the micro-economics theory.

Stochastic models, a far superior model for predicting travel bahaviour than the former one, do not assume the consistency of the decision rule and rather incorporate the randomness or stochastic fluctuation in the choice processes though the sources of the randomness are still unknown.

Among others, Ben-Akiva and Lerman (1985) noted down the qualities of behaviour in three ways.

i. descriptive - it postulates how human being behave rather than how they should behave,
ii. abstract - it can be formalized in being behaved at particular circumstances and
iii. operational – it can be expressed in the form of models with parameters and variables that can be measured.

But unfortunately at present no unique universally accepted theory can satisfy all those conditions. They viewed choice as an outcome of a five-step sequential decision making process:

i. definition of choice problem
ii. generation of alternatives,
iii. evaluation of attributes of the alternatives
iv. choice,
v. implementation

Thus a specific theory of choice is a collection of procedures that define the following elements; decision maker, alternatives, attributes of alternatives, and decision rules.

However there can be some other factors influencing the decision rules such as

i. habit,
ii. intuition,
iii. imitation of a leader,
iv. assumption of some form of conventional behaviour

As the number of possible modes increased it became necessary to know the effects of different pricing policies or operational characteristics on their ability to attract passengers. This has led researchers to probe into the choice process followed by trip makers both individually and in an aggregated manner.

Bruton (1975) defined Modal Split as the proportion of people availing different modes of travel. In the choice hierarchy, the choice of mode comes just before the 'choice of route'. There are primarily two ways to perform the modal split analysis. The ways are:

i. aggregate (viz. Modal Split Curve or Function Method and Generalized Cost Model Method) and
ii. disaggregate

Tye Sherman *et al.* (1982) in their research on Disaggregate Travel Demand Model (DTDM) have mentioned the following advantages of the Disaggregate Model over the Aggregate Model. These are as follows:

i. economy of data collection - since the details introduction about the individual is incorporated into response of each respondent in a disaggregate approach , the sample size required for disaggregate method is far less than aggregate approach of modal split analysis.

ii. policy sensibility - improved ability to predict the effect of policy changes since the disaggregate approach deals with the details of an individuals attributes and probes into the behaviour pattern, it is easier to evaluate the impact of policies on different groups or market segments.

iii. flexibility - to meet different problems, needs and response time, it is not an absolute location model. Rather, it can take the advantage of the previous studies for both long-range analysts of issues.

iv. transferability - potential for improved transferability of model estimation results from one geographic area to other because unlike aggregate method the model the behaviour of an individual of the population.

According to Kawamoto and Setti (1990), the disaggregate choice analysis approach can be categorized into three types based on the assumption that whether compensation can be made between the attributes that influence the trip makers decision.

i. Compensatory
ii. Non-compensatory and
iii. Semi-compensatory

i. **Compensatory**

These models assume that time and cost are compensatory attributes. The Logit and Probit are the two most well known compensatory models. In these models each mode has got some utilities associated which is again a function of variables that characterized socio-economic characteristics and the mode attributes (travel cost, comfort, safety etc.). The share of each mode is proportional to the associated utility of the mode.

ii. **Non-compensatory**

They assume that the choice is based on the attribute-to-attribute comparison of available alternatives. It does not recognize the compensatory property among the attributes. The examples are Lexicographic, Conjunctive, and Disjunctive models.

iii. **Semi-compensatory**

This model strikes a balance between the former two types of models. It is based on the assumption that the trip-makers perceive and distinguish between two distinct categories of utilities viz.

a. intrinsic utility of a mode (comfort, safety and travel time) and
b. utility of money spent to use a given mode (dependent on the characteristics of the trip maker).

This model also assumes that the compensatority is allowed only the attributes of the same category.

2.2.5 Disaggregate Behavioural Model

To differentiate a behavioural model based on the individual observations from a behavioural model that use aggregate data, the former has been named as 'disaggregate behavioural model'. Rujigrok (1979) has provided an operational definition for this class of model as:

> a model that describes individual choice amongst a finite number of discrete alternatives as a function of a number of variables defined and measured on the same individual level.

The terminology is, however, somewhat misleading due to use of the term disaggregate. It is considered as a relative concept. To remove confusion, generally, this class of models is now referred to as 'individual choice models' (Spear, 1977).

The first work on individual choice modelling is credited to Warner (1962). He developed binary mode choice models for three sets of distinct binary choice situation: 1. between car and bus 2. between car and train and 3. between bus and train. For each choice set the split was considered between work and non-work trips to CBD. His major concern was to examine the influence on mode choice exerted by three economic variables time, cost and income. Other variables included in the analysis were trip distance, age and sex of the trip maker. Warner used a linear discriminant model to obtain initial estimates for a binary choice Logit model, which he then estimated with non linear regression techniques.

Lisco (1967) was concerned with journey to work from a Chicago suburb to the central area. His main objective was to put a value on commuters travel time. Like Warner he also used a binary choice model but employed Probit analysis rather than Logit analysis. The variables used in the model were time and cost differences of modes, income, age, sex and family structure.

In the same year, 1967, Quarmby used discriminant analysis and calibrated a linear model with the values representing the overall utilities of various factors. His work was undertaken in Leeds with the specific intention of trying to estimate the significance of different factors that influence mode choice. For that purpose he considered the various components of travel time (walking time, waiting time, in-vehicle time) separately, because they could be evaluated by the trip makers. He tested three forms of time and cost variable (ratios, log ratios and difference) and concluded that best results were obtained by using the difference form of the time and cost variables. His model predicted existing modal split with a high degree of accuracy.

Stopher (1969) carried out a survey on academic and administrative staff at University College, London, to discover the most important factors that are considered by people in choosing their mode of travel to work. Four factors were found to be most important time, cost, comfort and convenience. As there are difficulties involved in the quantification of comfort and convenience, he considered only time and cost for his analysis.

Rassam *et al.* (1971) calibrated a multinomial logit model for the first time – to analyze the choice behaviour among multiple transportation alternatives. There application dealt with the choice of four access modes to an airport. They calibrated their models using both maximum likelihood techniques and by constrained least squares regressions.
The modelling procedure developed in 1979 by Hensher was based on the probabilistic choice but the applicability was confined within two modes only.

Disaggregate models are also aggregate since the population is aggregated according to the parameter which indicate their socio-economic characteristics. Sometimes this method is also referred to as behavioural models, since this approach is based on two behavioural factors- the economics of consumer behaviour and the psychology of choice behaviour (Stopher and Meyburg, 1975)

In 1984, while applying the multinomial Logit model in the city called Kaoshiung in the South of Taiwan, Lin assumed the utility function to be a linear one (Bhattacharjee, 1994).

2.2.6 Functional Forms of Individual Mode Choice Models

The various mathematical functions of different models namely Logit, Probit, Dogit, Generalized Extreme-Value and Nested Logit have been developed in individual choice modelling. The models being considered in this study are Logit Model and Nested Logit Model.

2.2.6.1 Logit Model

With its origin in the field of biometrics, the logit model has been the most popular individual choice model to date. It has been widely used in recent years for the analysis of travel demand, especially when this has involved more than two alternatives. Initially it was developed for use in a binary choice situation. Later, Theil (1969), showed how the binary choice model could be extended to multiple choice problems. For obvious reasons, only the Multinomial Logit Model (MNL) is being considered here. In deriving the functional form of the MNL, it has been assumed that random taste variation within the population of interest does not exist and that the effect of unobservable/unmeasurable attributes of individuals and alternatives are uncorrelated across individuals or alternatives. These assumptions amount to what has been described as independent and identical distribution (IID) of the error terms, whose mean value is zero. Specifying the random component of the utility function in this way, McFadden (1974) derived the simple MNL model from the theory of utility maximisation:

$$P_n(i) = \frac{e^{U_{in}}}{\sum_{n} e^{U_{jn}}} \qquad (2.1)$$

Where,

$P_n(i)$ = Probability of choosing alternative i by an individual, out of a choice set with n alternatives

U_{in} = Utility index of specific mode, i

U_{jn} = Utility index of alternative choice modes

In recent years, many empirical studies using the above functional form have appeared (for example, Rassam, *et al.*, 1971; Watson, 1974; Domencich and McFadden, 1975; Richards and Ben-Akiva, 1975; Adler and Ben-Akiva, 1976; and Ahsan, 1982). After Warner, the work of Rassam *et al.* (1971) is considered as leading to the most interesting and original probabilistic models of mode choice.

The logit transformation of the utility function avoids the problem of unbounded predictions. In comparison to other transformations, to be discussed later, the logit formulation is conceptually more acceptable and easier to interpret. Its relative computational efficiency and simplicity have helped it to become the most widely used individual choice model. However, it should also be borne in mind that many of the other models are of very recent development and so, naturally, some more time will be required for them to find wider use in practical applications.

Although it has proved to be the most widely used model of individual mode-choice, clarification of its structural/theoretical properties has revealed several weaknesses of the MNL. The assumptions of the MNL model relating to absence of random taste variation and uncorrelated error terms across alternatives and individuals, have been criticized as being over restrictive. Among others, McFadden (1974) has shown how these assumptions may lead to the violation of Luce's Axiom of Independence of Irrelevant Alternatives (IIA) by the MNL. The IIA property states that the relative odds of choosing one alternative over another is unaffected by the presence or absence of any additional alternative(s) in the choice set. This property, however, is not unique to the MNL model, but is embodied in any share model, e.g., gravity model. Spear (1977) has shown how easy it is to construct examples in which the IIA property yields false results. Sobel, in his example, considered the infamous problem of the red bus versus the blue bus. He considered a market shared by car and red bus in the ratio of 2:1. Then blue buses with everything identical to the red buses were introduced to the bus line. One would expect that the new market shares to be twothirds for car and one sixth for each of the bus modes red and blue. However, because of the IIA property, the MNL model will predict the cars new market share to be only twice that of the red bus, not four times as large. In addition to this problem there is also a potential major problem of biased estimation when the distinctiveness of the alternatives cannot be ensured.

Due to presence of the IIA property, the validity of the model in many travel demand applications has been questioned, particularly in complex choice situations where different degrees of similarity exist among alternatives. In the very recent literature, it has been suggested that the IIA property is not necessarily a negative feature of the MNL model (McFadden, 1979; Stopher, *et al.*, 1981). It is in fact useful for the prediction of demand for a new alternative. The MNL model implicitly assumes that the alternatives within the choice set are substitutes, and if the choice model is correctly specified, the IIA property is indeed a positive feature in that it leads to a simple model structure. The problem arises when either the alternatives are not clear substitutes or the choice model is incorrectly specified or combinations of both these situations exist. As these situations may arise in most empirical applications of mode-choice modelling, efforts have been made to develop model structures free of the IIA property, both within the logit framework and in entirely new structures.

The other assumption regarding the distribution of the error terms (that they are independently and identically distributed (IID)) may also be violated easily. If the variance of an unobserved attribute that affects choice is different across alternatives, then the random error terms will not be identically distributed. For individual mode choice models, the unobserved attributes of comfort and convenience may be taken as examples that influence a choice but vary greatly among the alternatives. So, the error terms will not be identically distributed. Empirical investigations suggest that the magnitude of error due to violation of IID is generally low (Horowitz, 1981). However, extreme departures can have serious effects on model estimation. Two potential remedies have been suggested to circumvent the violation of IID assumption. One is within the framework of MNL. This involves the inclusion of additional attributes in the model, in an effort to achieve an explicit representation of the variables that allow the error terms to be non-IID. The other approach to dealing with non-IID errors is to use a model which is not based on the IID assumption - an obvious solution.

2.2.6.2 Nested Logit Model

The nested model was introduced by Domencich and McFadden (1975). However, it was originally applied by Ben-Akiva (1974), and Ben-Akiva and Lerman (1974) but with a relaxation of constraints. Ben-Akiva (1974) derived nested logit model as an extension of the multinomial logit model designed to capture correlation among alternatives. The nested logit model is a widely used form of the discrete choice model and has been extensively presented and described in the literature (e.g., Ben-Akiva and Lerman, 1985; Lerman, 1984; Train, 1986; Ortuzar and Willumsen, 1994).

The nested logit model is currently the preferred extension to the simple multinomial logit model. The appeal of the nested logit model is its ability to accommodate differential degrees of interdependence (i.e. similarity) between subsets of alternatives in a choice set. This ability of the nested logit model reduces some of the limitations of the multinomial logit model, specially the Independence from Irrelevant Alternatives (IIA) limitation.

Watson (1974) has shown how a multimodal choice may be thought of in terms of a hierarchy of binary choices. In fact this hierarchy of binary choices is the concept underlying the nested logit model. Both multinomial logit model (MNL) and nested logit model can be represented as a tree structure that represents all the alternatives. The multinomial logit model treats all the alternatives equally, whereas the nested logit model deals alternative groups separately. Alternatives in the common nest show the same degree of increased sensitivity compared to the alternatives outside the nest. The difference between a simple MNL model and nested MNL model can be illustrated with the help of the following two diagrams. Figure 2.2 illustrates the model given by equation (2.1). Three modes have been imagined.

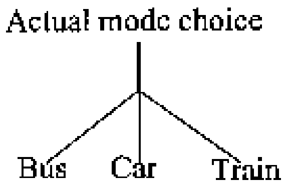


Figure 2.2 Simple MNL Model

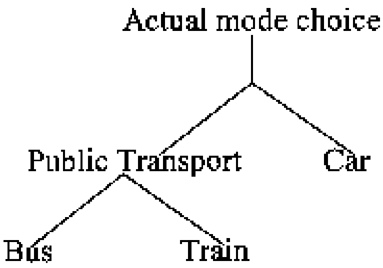


Figure 2.3 Nested MNL Model

To build a simple MNL model, it is conceptualized that each alternative is independently evaluated by an individual according to their respective utility function. It is assumed that individuals select the mode of greatest value of utility.

However, since the utilities cannot be completely observed (or measured), an error term is added to the deterministic part of the function. Given suitable assumptions about the distribution of these terms mentioned elsewhere, the MNL model is derived. There may be cases, where the alternatives are not completely independent. In this situation it is possible to postulate that a particular nested structure of choices applies. Alternatively, the validity of all such possible nested structures, as well as the simple (simultaneous) structure, may be tested. Figure 2.3 illustrates one of the possible (but most likely) nested structures in the same situation. Individuals are assumed to choose one of the alternatives at the lowest level of the tree. Thus, they also choose a limb. No assumption of equal choice set sizes is made at any point.
The mathematical form for a two- level nested logit model is as follows:

By the laws of probability, the unconditional probability of the observed choice made by an individual is:

$$P_n = P_{n/m} P_m \qquad (2.2)$$

where,

P_n = the unconditional probability of choice n

Pn|m = the conditional probability of choosing alterative n given that person has selected the choice-set m

Pm = the probability of selecting the choice-set m

The lower level choice in a nested logit model is a multinomial logit choice and can be expressed as

$$P_{(n/m)} = \frac{e^{\beta' x_n / m}}{\sum_{n_m} e^{\beta' x_j / m}} = \frac{e^{\beta' x_j / m}}{e^{I_m}} \tag{2.3}$$

The upper level choice probability is then expressed as

$$P_{(m)} = \frac{e^{\gamma' z_m + \tau_m I_m}}{\sum_{m} e^{\gamma' z_m + \tau_m I_m}} \tag{2.4}$$

where,

$\mathbf{x}_{n|m}$ = attributes of the choices

$\mathbf{z}_m$ = attributes of the choice sets

I_m = the inclusive value (log sum) of choice-set m, $I_m = \log \sum_{n_m} e^{\beta' x_j / m}$

β and γ = vectors of coefficients to be estimated

τ_m = the coefficient of the inclusive value of choice-set m.

a. Inclusive Value Parameter

The parameter τ is referred to as the inclusive value parameter. The value of this parameter should lie between zero and one (Gangrade *et al.*, 2002). When the parameter equals unity, the structure collapses to a multinomial logit model without a nested structure. The levels are separated and present independent and separate choice situations if the value of the parameter is equal to zero. If τ <0, an increase in the utility of an alternative in the nest (which should increase the probability of the nest being chosen), actually diminishes the probability of selecting the nest. In virtually all choice modelling situations, this is implausible. If τ >1, an increase in the utility of an alternative in the nest not only increases its selection probability but also the selection probability of the rest of the alternatives in the nest. That is, improvements in one alternative could increase not only the probability of that alternative being chosen, but some other alternatives would also gain a bigger share (Ortuzar and Willumsen 1994). While this may be plausible under certain limited conditions, it is generally not applicable to a wide variety of choice modelling situations. Therefore, the nesting structure that provides inclusive value parameter estimates between zero and one is generally adopted as long as the structure offers a plausible behavioural framework and interpretation.

b. Maximum Likelihood Estimation

For the nested logit models, there are two ways to estimate the parameters of the nested logit model using LIMDEP. These are:

- Limited information maximum likelihood (LIML) and
- Full information maximum likelihood (FIML)

A limited information maximum likelihood (LIML), sequential (multi-step) maximum likelihood approach can be done as follows: estimate β by treating the choice within branches as simple multinomial logit model, compute the inclusive values for all branches in the model, then estimate the parameters by treating the choice among branches as a simple multinomial logit models. Since this approach is a multi-step estimator, the estimate of the asymptotic covariance matrix of the estimates at the second step must be corrected.

The other approach of estimating a nested logit model is the full information maximum likelihood (FIML). In this approach, the entire model is estimated in a single phase. In general, the FIML estimation is more efficient than multi-step estimation. Until relatively recently, software for joint, full-information maximum likelihood estimation of all the parameters simultaneously was not available. This case is no longer true; several computer programs are available for FIML estimation of nested logit models. The LIMDEP software has the capability of estimating nested logit models using the FIML approach. Therefore, the models presented in this study were all calibrated using the FIML estimation approach.

2.2.6.3 Goodness-of-Fit Criteria

In this section, discussion will be made of suitable tests of significance or goodness-of-fit measures of nested logit model. Liou and Talvitie (1974) have suggested three ways of evaluating the performance of such a model. Firstly, the statistical significance of each parameter in the model and the model as a whole should be determined. Secondly, the reasonableness of the magnitude of the parameters of the model variables should be examined. And thirdly, the cross-validation of the model should be checked.

The second and third criteria will be considered first. There is no objective criterion for judging the reasonableness of the magnitude of the parameters of the model variables. It much depends on the variable concerned. Judgment is somewhat subjective. The sign of the paramater is also important. Fairly accurate prediction can be made about the signs and the parameters should have their expected signs. One of the major advantages of individual choice models is the prospect of their transferability. A true choice model should be transferable. But due to the presence of some idiosyncratic features of data, a model calibrated using one set of data may not have a good fit with another set of data. So, to ensure reliability of prediction, the model should be cross validated with different sets of data.

Different goodness-of-fit statistics have been proposed in the literature for evaluating the statistical significance of a calibrated random-utility mode-choice model (for example, Stopher, 1975; McFadden, 1979; Tardiff, 1976). These statistics unfortunately are not as well known, nor as well defined as goodness-of-fit measures for a technique like regression analysis. Nevertheless, they do provide a standard by which alternative model formulations may be compared.

The suggested early test statistics were *t*-statistics for the parameters and a chi-square statistic for assessing the entire model (Liou and Talvite, 1974; Stopher, 1975). These measures were found to be inadequate as a general method for assessing individual choice models. Particularly, difficulties were faced for comparison among models of different specifications. In recent years, several new measures have been put forward. At present the most widely used general good-of-fit measures are the log-likelihood function, the likelihood ratio and McFadden's prediction success index. Besides these, there are some others: the -2 log λ test (for comparing models of different specification), and multiple correlation coefficient.

The value of the likelihood function (L) is given by:

$$L = \prod_{ij} P_{ij}^{N_{ij}} \qquad (2.5)$$

where,

P_{ij} = the probability that person j would choose alternative i and

N_{ij} = 1 if i is chosen, otherwise 0.

P_{ij} is found from the model.

The logarithm of L is usually denoted L*. Setting all the parameters to zero, the corresponding L* is denoted as L*(0). It represents a state in which all alternatives are equally likely. L*(0) is a large negative number because of the way in which it is defined. L* calculated with the parameters of the utility function set to their maximum likelihood estimated values is denoted L*(β). L*(β) is a smaller negative number and a value of 0 would indicate a perfect model.

The likelihood ratio index (also called pseudo-R^2) has been developed and used to assess and compare models. It is defined as:

$$\rho^2 = 1 - L^*(\beta)/L^*(0) \qquad (2.6)$$

Where, ρ^2 is the likelihood ratio index (rho squared) and the other notations are the same as above. The values of ρ^2 however, cannot be judged in the same way of R^2 index. For a 'well fitted' model the value of ρ^2 tends to 0. McFadden (1979) suggests that values of 0.2 to 0.4 represent an excellent fit. He has also developed a classification test based upon assessing the number of individuals for whom the highest estimated probability coincides with their actual observed choice.

$-2\log\lambda$ test is defined as:

$$-2\log\lambda = -2L^*M - L^*M' \qquad (2.7)$$

Where,

L^*M = log likelihood for the model with M variables and

L^*M'= log likelihood for the model with M' variables, M' being a subset of M.

$-2\log\lambda$ is distributed like chi-square with M - M' degrees of freedom.

2.3 Studies Related to Mode Choice in Dhaka City

In Bangladesh few studies have been undertaken on the transport sector. Studies related to mode choice modelling in Dhaka City have been given very little emphasis. These studies are not adequate to provide a comprehensive picture of the mixed mode transport situation and traffic behaviour of vehicles. On the other hand, most of such studies focused basically on the physical, economical and social aspects of the different modes.

An attempt was made by Ara (1983) to find out the social and economic factors related with urban travel pattern and their relationship that influence the choice of particular transport modes. In particular, the author analyzed the travel behaviour of a number of households from some particular localities in Metropolitan Dhaka.

In this study, total family income appeared as a very important factor in determining its member to choose the appropriate transport modes for different trip purposes. It was found that in high-income group, private auto is the highest selected mode for different purposes. In the middle income group, rickshaw is the highest selected mode for different purposes. Members of low-income families make most of their trips on foot.

Variation in age and sex also produced variation in choice of mode. For example, the use of bus is mostly avoided by aged people and young children, considering safety and convenience. Females avoid bus use mostly because of less convenience, privacy, and comfort. Female work forces within upper and middle income families usually avoid bus transport because of its poor service quality. Working females without any private or official transport usually use rickshaws for work purposes. The transport ownership pattern in the family had an influence on their travel pattern. Families having private transport are less interested in using public transport like bus, minibus etc., which often lack comfort and convenience.

Hoque (1997) tried to find out the factors that play important role and their magnitude of influence in the modal choice. He also developed modal choice model for the non-motorized traffic especially for rickshaw. The author analyzed the factors like cost, safety, time saving ability, accessibility of the mode, and the comfort affecting the modal choice with Analytical Hierarchy Process (AHP) technique and also analyzed the behavioural pattern of the trip makers' and their attitudes towards choice of available modes. The author found that among five most important factors, cost was the strongest decisive factor in mode choice process. He also showed that the personal variables like age, sex, income, family size and vehicle ownership were well correlated and among all of these, income had been the most prominent factor influencing the weights of AHP. The author tried to develop different types of mode choice behaviour for the work trip in Dhaka City, specially the rickshaw and its competitors. He developed five different types models like rickshaw and auto rickshaw, rickshaw and bus, rickshaw and tempo, rickshaw and car and rickshaw and walk. Esrar (1992) developed home based trip generation models for Dhaka City. He also studied the inter-relationships of trip generating variables of the city.

Another attempt was made by Yasmin *et al.* (2006) who tried to examine the nature and extent of the factors that contribute to regular transportation mode choice of the public university students. In addition, the study was an attempt to develop mode choice models of multinomial logit type and used LIMDEP, an application software for calibration of the model.

To develop individual model choice model i.e. multinomial logit model, the authors considered some variables such as socio-economic variables like sex, age and type of the student, household income, household car ownership and travel attributes like distance from home to university, in vehicle travel time, out vehicle travel time which includes access time, waiting time and egress time, cost and level of service. The mode choice model used above variables to estimate the trip proportion of five selected major modes such as university bus, public bus, private automobile, auto rickshaw and rickshaw that they were the main modal variations chosen by the university students in Dhaka City. The final model included the major variables affecting the mode choice of the students. The shortcomings of final model were that it could not include cost variable which is very much important for choosing any mode and utility function for private auto could not describe the variables important for it.

Chapter 3

Methodology of the Study

3 Methodology of the Study

In order to obtain the objectives of the study, a series of procedures were adopted and the methodology followed in the study is described below:

3.1 Literature Survey and Review

The first stage of the study starts with an extensive literature survey and review.

3.2 Concept Development and Formulation of Objectives

Different relevant studies and the literature have been reviewed in this study to familiarize with the theories of disaggregate travel demand model, discrete choice models with the concept of nested logit model and their applicability in Dhaka City context. For literature review, the Library of the Department of Urban and Regional Planning, the Library of the Department of Civil Engineering of Bangladesh University of Engineering and Technology (BUET) and the Central Library of BUET have been visited. On the other hand, different journals and publications related to transportation and transport mode choice have been collected from the different web-sites. After development of the concept three objectives have been formulated for the study.

3.3 Selection of Study Area

The transportation literature suggests that different user groups have different characteristics with respect to commuting patterns as well as with respect to their propensity to switch between travel options. In this regard, one user group like office workers has been selected in the case study area. Because of the centralization of many head offices as well as branch offices of public and private organizations in Dhaka City, the number of office workers is increasing day by day. As a result, the workers of these offices make up a large part of the traffic and are expected to continue their contribution to traffic demand into the future.

In this regard, this study was an attempt to construct the mode choice model of office workers of private organizations. It did not consider individuals engaged in public organizations, because office transport service is available to most of them (Uddin, M.H. *et al*, 2004). As a result, office workers of private organizations are a better sample choice for understanding mode choice.

3.4 Data Collection

Data has been collected from both secondary and primary sources.

3.4.1 Secondary Data Collection

Secondary data in the form of documents was collected for the research from offices of three private organizations such as Sheltech (Pvt.) Ltd. (Sheltech), Engineering and Planning Consultants Ltd. (EPC) and Building for Future Ltd. (BFL).

3.4.2 Primary Data Collection

Primary data has been collected with a questionnaire survey of the office workers. Due to time and resource constraints, the study considered a sample size of office workers of private organizations. Based on standard deviation data from a previous study (Yasmin *et al.*, 2006) related to mode choice behaviour of public university students and following a standard statistical rule (McGrew and Monroe, 1993), it is found that 250 can be taken as an appropriate sample size for this study. The calculation for sample size is shown below:

$$\text{Sample size, } n = \left(\frac{Zs}{E}\right)^2 \qquad (3.1)$$

$$n = \left(\frac{1.64 * 5.18799046}{0.5379}\right)^2$$

$$n = 250$$

where,

n = Sample Size

Z = Level of Confidence

s = Standard Deviation

E = Standard Error

The employees of three private organizations such as Sheltech (Pvt.) Ltd., Engineering and Planning Consultants Ltd. (EPC) and Building for Future Ltd. (BFL) have been selected as sample frame. In these three organizations, 250 office workers have been surveyed randomly by using a pre-tested questionnaire. About 48 percent of respondents (24 percent from each organization) were from Sheltech (Pvt.) Ltd. and Engineering and Planning Consultants Ltd. (EPC) (see Table 3.1). The remaining 52 percent were from Building for Future Ltd.

Table 3.1 Summary of Primary Data Collection Sites

Organizations	Sample Size	Share in Total Sample (In percentage)
Sheltech (Pvt.) Ltd.	60	24
EPC	60	24
BFL	130	52
Total	250	100

Socio economic data included age, gender, educational qualification, status of job, household size, and household income. Travel and mode choice data included household car ownership, trip origin, trip destination, frequency of trips (weekly), distance from home to office in km, most frequently chosen mode and alternative modes. It also included in-vehicle travel time, out-vehicle travel time including access time, waiting time and egress time together), cost of travel in Tk., and level of service including accessibility, convenience, privacy, safety and comfort of primary and different alternative modes. In this study only one way trip (morning trip) from home to office was considered for travel and mode related data collection.

The transport system of Dhaka city is very diverse consisting of motorized transport such as public bus, micro bus, private auto, auto rickshaw, taxi, human hauler, motor cycle etc. and non motorized transport such as rickshaw, bicycle, van, walk etc. (Uddin, M.Z. *et al.*, 2004). Travel and mode choice data were collected for the study on eleven alternative transport modes such as:

- Public bus
- Micro bus
- Private auto
- Auto rickshaw
- Taxi
- Human hauler
- Motor cycle
- Rickshaw
- Bicycle
- Van
- Walk

After completion of questionnaire survey, data were edited, coded and computerized. From observation of the questionnaire it was found that the office workers choose only five different modes from above as their primary as well as available alternative modes. The chosen modes are

- Public bus
- Private auto
- Auto rickshaw
- Rickshaw and
- Walk.

For that reason, the remaining modes were excluded during data preparation. Then, the study developed the transport mode choice model for office workers on five different modes.

3.5 Data Preparation

This section describes the preparation of data from the travel survey as well as from the socio-economic survey databases. It addresses the major steps in acquiring, checking, and completing the data in order to prepare it to support mode choice modelling and the software used for this purpose. The study was an attempt to indicate a sensible modal choice of the office workers in Dhaka City under specific circumstances by calibration of nested logit model. The study also describes some generic analysis on the socio-economic and travel characteristics of the office workers of Dhaka city. In this regard, all collected data have to input and prepare in computer for

i. generic analysis and
ii. calibration of nested logit model

3.5.1 Data Preparation for Generic Analysis

Data were prepared for the descriptive analysis of socio-economic and travel characteristics of office workers of Dhaka City using SPSS 11.0. In this regard, the survey data include a database file, workerstravel.sav which contains socio-economic and mode specific data of 250 office workers. Data encoded for the generic analysis using SPSS 11.0 are shown in the Appendix B.

3.5.2 Data Preparation for FIML Estimation of Nested Logit Model

At first, data input was made using Microsoft Excel 4.0 for preparation of a comprehensive database for calibration of nested logit model. The estimation of model was thereafter completed using LIMDEP.

3.5.2.1 Data Set Up

The arrangement of the data set for estimation of the nested logit model is described in this section. The variables considered for the estimation of nested logit model by using LIMDEP are:

i. age of the office workers (in years)
ii. sex of the office workers
iii. educational qualification of the office workers
iv. status of the office workers
v. family size of the office workers
vi. household income of the office workers (in Tk./month)
vii. household car ownership

viii. distance from home to office (in Km.)
ix. in vehicle travel time (in mins)
x. out vehicle travel time (in mins)
xi. cost of travel (in Tk.)
xii. accessibility to the mode
xiii. convenience of the mode
xiv. privacy of the mode
xv. safety of the mode
xvi. comfort of the mode
xvii. the choice the office worker made
xviii. total number of available alternatives the office worker have
xix. the "number of the alternative" for which the row data is created

Numeric and descriptive types of data of above variables were collected by the questionnaire survey. But only numeric data are needed for calibration of logit model by using LIMDEP. As a result, data with qualitative values were coded with numerical values such as 1, 2, 3……….6. The assumption behind it is that increasing number (1, 2, 3…….6) means increasing utility.

The coding of nineteen different variables is shown below:

age = Age of the office workers in years

sex = Sex of the office workers, 1 = Male 0 = Female

eduqal = Educational qualification of the office workers

1 = Illiterate	2 = Class 1 to X
3 = S.S. C	4 = H.S.C
5 = Diploma	6 = Bachelor Degree
7 = Masters Degree	8 = PhD

status = Status of the office workers,

1 = Full time 0 = Part time

famsiz = Family size of the office workers

hhinc = Monthly household income in Tk.

hhcow= Household car ownership

1 = Private automobile 0 = None

dist = Distance from home to university in Km

ivtt = In vehicle travel time in mins

ovtt = Out vehicle travel time in mins (adding access time, waiting time and egress time together)

cost = Cost of travel in Tk.

access = Accessibility to the mode

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

convence = Convenience of the mode

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

privacy = Privacy of the mode

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

safety = Safety of the mode

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

comfort = Comfort of the mode

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

Y = The choice the office workers made (the value will be "0" or "1" depending upon the choice mode)

0 = When the mode is not choice mode

1 = When the mode is choice mode

NIJ = Total number of available alternatives the office workers have.

ALTIJ = The "number of the alternative" for which the row data is created. For this,

1 = Public bus

2= Private auto

3 = Auto rickshaw

4 = Rickshaw

5 = Walk

There is no requirement that the choice sets be the same across the individuals, but the nested logit model requires a definition of a universal choice set, so the command must contain the

; Choices = list of labels...

specification. The nested model structure does mandate one special consideration if some one is going to define utility functions for branches (ys), or limbs (zs). Since the datasets have one line of data for each alternative, the datasets must have more than one line of data for the variables in any branch or limb. In these cases, the values of `y' and `z' must be repeated for each alternative in the branch or limb.

As for example, some variables considered for the mode choice modelling are shown in tabular form (see table 5.1) which is prepared in Microsoft Excel 4.0. The data set of 250 office workers is shown in Appendix C.

Table 5.1 Format of Data Entry for Calibration of Nested Logit Model

ID	age	sex	eduqal	hhinc	hhcow	dist	ivtt	ovtt	cost	Y	NIJ	ALTIJ
1	24	1	6	13000	0	3.00	20	2	20.00	1	1	4
2	30	1	6	30000	0	2.00	20	13	25.00	1	2	4
	30	1	6	30000	0	2.00	25	0	.00	0	2	5
3	24	1	6	13000	0	10.00	50	12	15.00	1	2	1
	24	1	6	13000	0	10.00	30	10	80.00	0	2	3
4	18	1	2	4000	0	2.00	15	0	.00	1	1	5
	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
250	20	1	2	4000	0	.25	5	0	.00	1	1	5

Source: Field Survey, 2008

As for example, the second employee has 2 alternatives available and he chooses the "Rickshaw" alternative as primary mode. In **NIJ column,** it has value of 2 in all rows for the second employee. and in the **Y** it has a value of "1" at value 4 (Rickshaw) in **ALTIJ** column.

For the third person, he has also 2 alternatives, so every rows have the value 2 in the **NIJ** column, and he chooses Public Bus as primary mode (have a value "1" in the column **Y** at 1 (Public Bus) in **ALTIJ** column.

Data input of two hundred and fifty office workers has been made using code in Microsoft excel 4.0 for preparation of a comprehensive database.

3.5.2.2 Data Import to LIMDEP

Data input of the above variables was done using Microsoft Excel 4.0 and import to LIMDEP 7.0. In the LIMDEP data sheet, there are nineteen variables, 250 samples / observations and 378 cases. Now, data is fully prepared for estimation and calibration process of mode choice of the office workers of Dhaka City.

3.5.2.3 Model Command for LIMDEP

After importing the data some model commands including hypothetical utility functions were written for the model estimation using LIMDEP. For FIML estimation of two level nested logit model the hypothetical utility functions include the equation for alternative choices as well as for branches. The equations for branches were specified exactly the same as those for alternatives. For example, in a two level model, the equation for branches might put the demographic characteristics, such as income or family size, at the top level. A complete model might appear as follows:

U(pub_bus)=A0+A1*HHINC+A2*IVTT+A3*OVTT+A4*COST
U(pri_auto)=B0+A1*HHINC +B1*IVTT+B2*OVTT+B3*COST
U(a_rick)=C0+A1*HHINC+ C1*IVTT+C2*OVTT+C3*COST
U(rick)=A1*HHINC + D1*IVTT+D2*COST
U(walk)=E0+E1*AGE +E2*SEX
U(public)=F0+AB*HHINC+BC*SEX
U(private)=G0+CD*HHINC
U(nmt)=DE*HHINC+EF*FAMSIZ

where,

U(pub_bus) = Utility index of public bus

U(pri_auto) = Utility index of private auto

U(a_rick) = Utility index of auto rickshaw

U(rick) = Utility index of rickshaw

U(walk) = Utility index of walk

U(public)= Utility index of public transport

U(auto)= Utility index of auto

U(nmt)= Utility index of non-motorized transport

A0 = Constant for public bus

A1 = Co-efficient of household income of the family (HHINC)

A2 = Co-efficient of in-vehicle travel time of public bus (IVTT)

A3 = Co-efficient of out-vehicle travel time of public bus (OVTT)

A4 = Co-efficient of cost of public bus (COST)

B0 = Constant for private auto

B1 = Co-efficient of in-vehicle travel time of private auto (IVTT)

B2 = Co-efficient of out-vehicle travel time of private auto (OVTT)

B3 = Co-efficient of cost of private auto (COST)

C0 = Constant for auto rickshaw

C1= Co-efficient of in-vehicle travel time of auto rickshaw (IVTT)

C2= Co-efficient of out-vehicle travel time of auto rickshaw (OVTT)

C3= Co-efficient of cost of auto rickshaw (COST)

D1 = Co-efficient of in-vehicle travel time of rickshaw (IVTT)

D2 = Co-efficient of cost of rickshaw (COST)

E0 = Constant for walk

E1 = Co-efficient of age of the respondent (AGE)

E2 = Co-efficient of sex of the respondent (SEX)

F0 = Constant for public transport

AB = Co-efficient of household income of the family (HHINC)

BC = Co-efficient of sex of the respondent (SEX)

G0 = Constant for private transport

CD = Co-efficient of household income of the family (HHINC)

DE = Co-efficient of household income of the family (HHINC)

EF = Co-efficient of sex of the respondent (SEX)

3.5.2.4 Utility Functions

Utility function is very important part of logit model estimation. There are some rules to define a utility function.

i. In the above example, there is A0, B0, C0 and E0 that represents the constant. There is no D0 in the utility function for Rickshaw, U (rick). Because there is an effect called "Independence of Irrelevant Alternative (IIA)". It is an important property of logit model. Because of this property there should be **"one constant less"** in the utility functions. It could be anywhere (i.e. for any mode), but same in all models.

ii. In the utility function A1, A2, A3, B1 ...D1, E1 etc represent the coefficients of the variables and the uppercase names represent the name of the variables. The next important thing is that different variables might affect different modes in case of choosing them. There are two kinds of variables: **Generic variable and alternative specific mode variable.**

   For example, 'household income (HHINC)' is a "generic variable" which might have effect on any alternative mode. So it can be included in all five utility functions. But because of "Independence of Irrelevant Alternative (IIA)" this variable should be specified for (n-1) mode.

   But 'in-vehicle travel time for private auto (IVTT)' has no effect for choosing a "Rickshaw" alternative. So in the utility function IVTT should be declared as a mode specific variable.

There are nineteen variables potentially available for the office workers' mode choice in the data set. Considering different variables (as generic or alternative mode specific variables) for different modes many model specifications were estimated using different utility functions.

3.6 Data Analysis

The study includes two types of analysis:

iii. generic analysis and

iv. calibration of mode choice model using nested logit model

3.6.1 Generic Analysis

The generic analysis of socio-economic and travel characteristics of office workers of Dhaka City has been presented using tables and figures prepared with the software Statistical Package for Social Science (SPSS) 11.0 and Microsoft Excel.

3.6.2 Calibration of Nested Logit Model

A full information maximum likelihood (FIML) approach has been followed to develop the nested logit model. The FIML estimation is the most efficient statistical approach, because the different nests are estimated simultaneously as opposed to sequentially in the limited information case (LIML). In this approach, the entire model is estimated in a single phase. Several computer programs are available for FIML estimation of nested logit models. The LIMDEP software has the capability of estimating nested logit models using the FIML approach. Therefore, the models presented in this study are all calibrated using the FIML estimation approach.

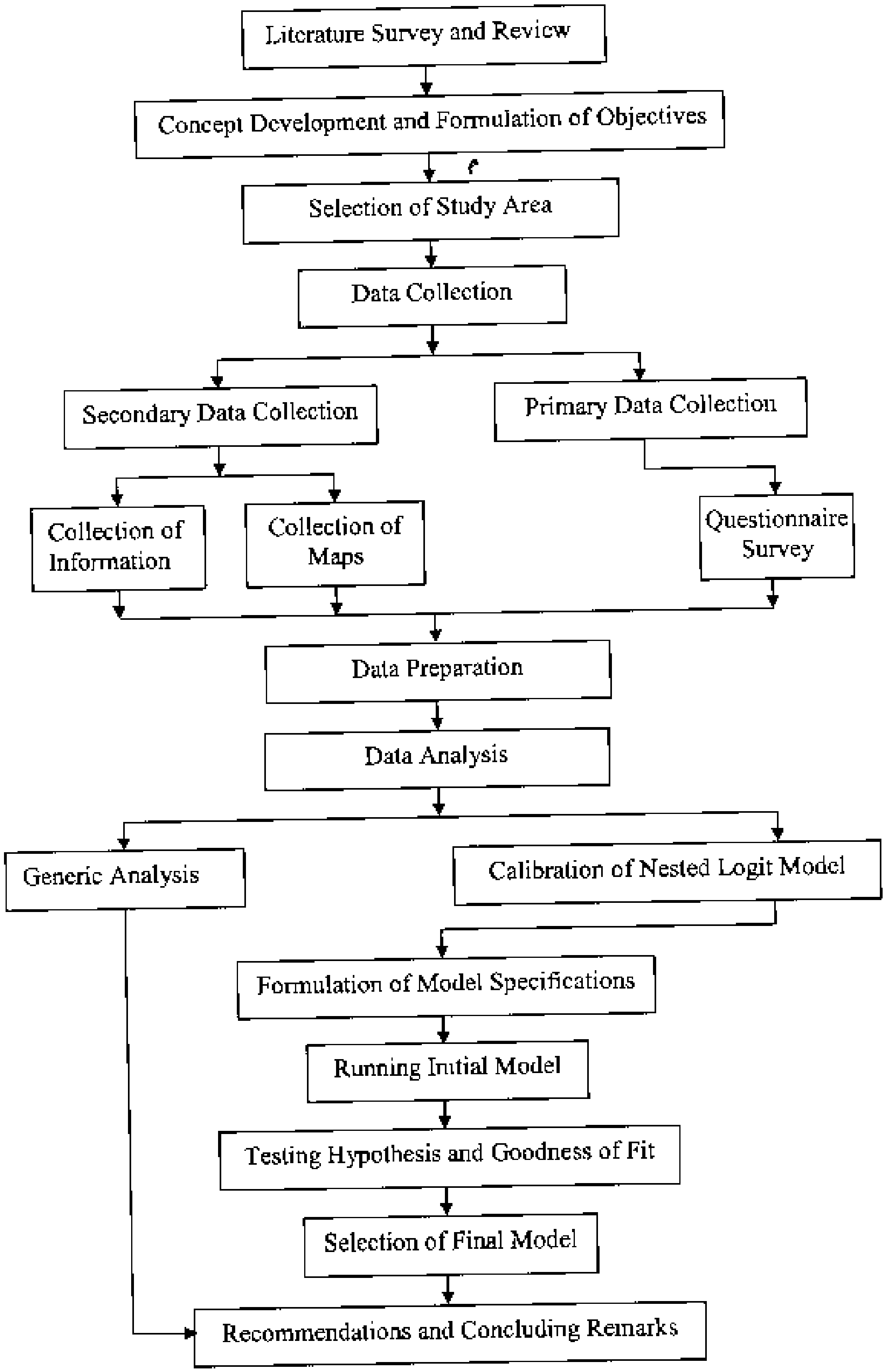
Several model specifications have been constructed considering the socio-economic variables and transport mode specific variables. Then, the models have been evaluated to reach final model by trial and error process i.e. by adding or deleting the variables from the specifications. After that, the models have been selected based on the expected sign, *t*-statistics (level of significance) and goodness of fit test. And finally nested logit model can contribute by extending two choice models for the office workers.

3.7 Recommendations and Concluding Remarks

Finally, the study formulates some recommendations and improvement measures related to mode choice facilitation of office workers.

3.8 Activity Flow Chart

Figure 3.1 Activity Flowchart of the Study



Chapter 4

Study Area Profile

4 Study Area Profile

Different public and private offices are a major pull factor for rural-urban migration in Dhaka City. The employees of these offices generate a lot of traffic in Dhaka City. In this regard, the study was an attempt to develop the transport mode choice model for office workers which would indicate the demand for different transport modes. The study excludes the office workers of public organizations because most of the public offices have their own transport for employees. Office workers of private organizations were selected as sample units to develop the transport mode choice model. Being concern to the limitation of time and resources, this study delimits its scope of investigation in the three private organizations such as Sheltech (Pvt.) Ltd , Engineering and Planning Consultants Ltd. (EPC) and Building for Future Ltd. (BFL) of Dhaka City.

4.1 Location of Three Private Organizations

The locations of the headquarters of the three private organizations are shown in Map 4.1.

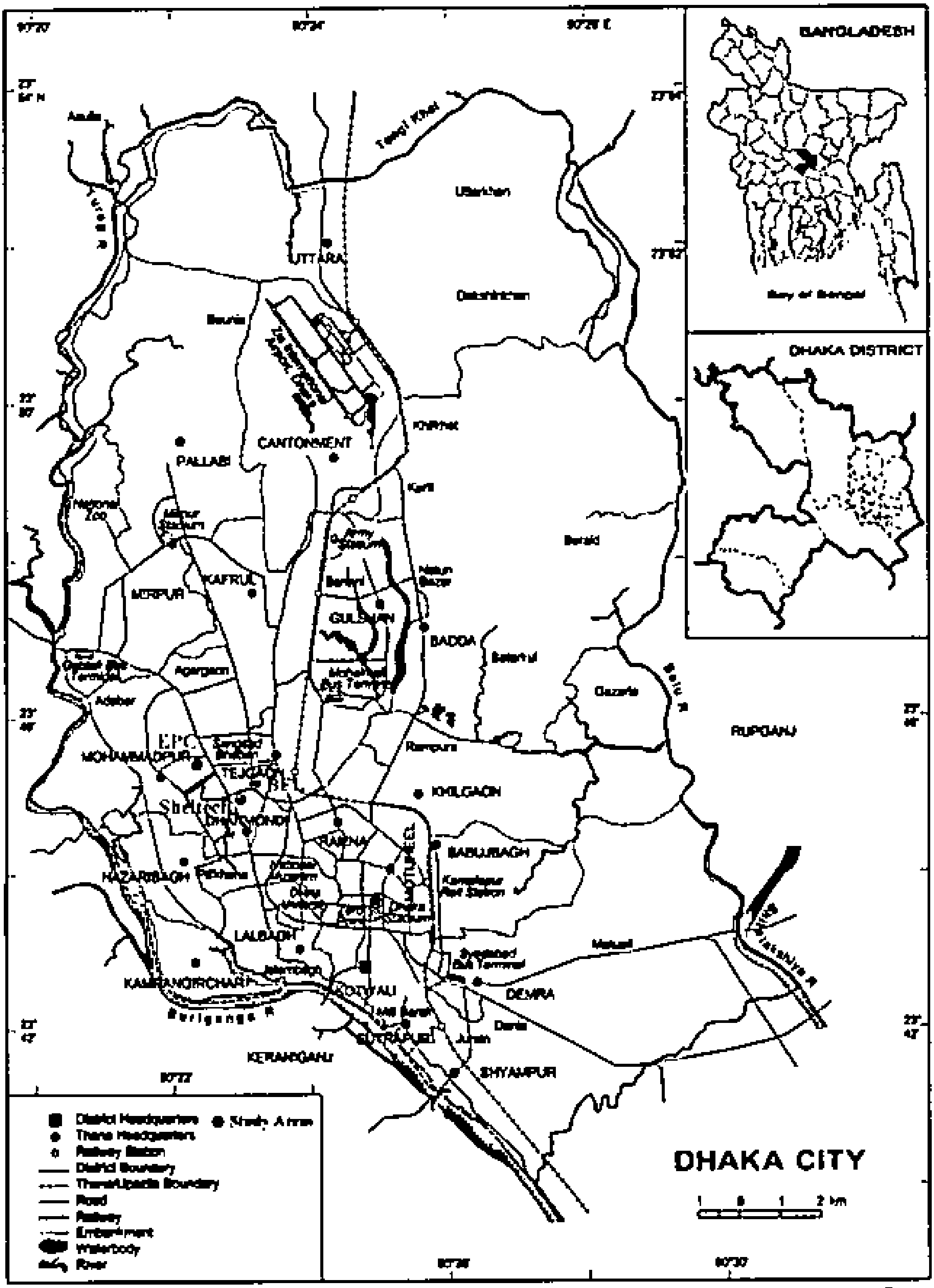
4.2 Overview of Sheltech (Pvt.) Ltd.

Sheltech (Pvt.) Ltd. (Sheltech) is a multi disciplinary firm engaged in various activities related to real estate development, consultancy, construction and other associated businesses. It was established in 1988 as a real estate firm (Sheltech, 2006). Since that time the firm has steadily consolidated its expertise in developing projects and has gained a high reputation in successfully completing its assignments. It is one of the pioneers of the housing industry in Bangladesh, and a founder member of Real Estate and Housing Association of Bangladesh (REHAB).

4.2.1 Major Fields of Activities

Sheltech offers all full range of services from project conception to completion including physical survey, project identification, feasibility study, planning, detailed engineering, bid documentation, construction supervision, project management, post evaluation etc. (Sheltech, 2006).

Map 4.1 Locaions of Three Private Organizations in Context of Dhaka City



Source: Banglapedia, 2008

Sheltech (Pvt.) Ltd. has developed a wide range of capabilities in the field of Design and Consultancy. Some of the sectors of work of Sheltech are outlined in Table 4.1.

Table 4.1 Major Field of Activities of Sheltech

Architecture:	**Environmental:**	**Waste Water:**
• Architectural Design • Landscape Design • Interior Design • Lighting • Acoustics	• Environmental Impact Assessment • Environmental Information System • Environmental Auditing and Accounting • Environmental Economics • Plan Development	• Process Technology • Sewer System • Pressure Pipelines • Pumping Stations • Recycling
Urban Planning:	**Physical Planning:**	**Infrastructure:**
• Surveying • Zoning • Urban Planning • Urban Development • Regional Planning	• Land and Studies • Socio Impact Assessment • Irrigation and Drainage • Land Development for Shelter Promotion	• Roads, Bridges and culvert Design • Drainage Systems and Pmmping stations • Traffic Control and Management • Transport and Traffic Studies • Transport Planning
Engineering Design:	**Solid Waste Management:**	**Management and Maintenance:**
• Foundation Design • Structural Design • Electrical Design • Sanitary and Plumbing Design • Airconditioning and Refrigeration	• Collection and Transportation • Waste Separation • Incineration and Composing • Recycling and Biogas • Manure	• Quality Control • Damage Analysis • Education and Training • Maintenance and Consultancy

Potable Water:

- Water Resources
- Purification
- Supply Systems
- Better and Improved water and Sanitation Program
- Arsenic Mitigation

Information Technology:

- Computerization Analysis
- Computerization Consultancy
- Education and Training
- 3D visualization

Economic Planning:

- Feasibility Analysis
- Operational System
- Financial Analysis
- Budgeting and Cost Monitoring
- Contract Documents

Source: (Sheltech, 2008)

4.2.2 Organization and Management

All technical and administration activities of the company are supervised and monitored by the Chairman, Mr. Kutubuddin Ahmed and the Managing Director, Dr. Toufiq M. Seraj (Sheltech, 2008).

4.2.3 Staff Resources

Currently the firm has over 300 professionals including Engineers, Architects and Planners and management staffs (Sheltech, 2008). Moreover, a skilled and well trained work force of about 3000 workers is currently employed at various projects of Sheltech (Pvt.) Ltd.

4.3 Overview of Engineering and Planning Consultants Ltd.

Engineering and Planning Consultants Ltd. (EPC) is a reputed Multidisciplinary Consultancy Organization, established in early 1979 with the aim at offering consultancy services for research studies, survey and development planning, feasibility studies, detailed design, implementation monitoring, benefit monitoring and evaluation and impact assessment of projects in the country and abroad (EPC, 2008). Accordingly, since inception, EPC has been providing services with the latest innovative method, technique and practices in the various sectors of national economy covering water resources, agriculture, forestry, fisheries, urban and rural development, physical planning, architecture and infrastructure, water supply and sanitation, roads and highways, environment, etc.

4.3.1 Major Fields of Development Activities

The major fields of development activities of EPC are shown below:

- Water Resources Development
- Water Supply and Sanitation
- Agriculture
- Fisheries
- Forestry
- Rural Development
- Urban Development and Physical Planning
- Municipal Development
- Sewerage and Waste Disposal
- Roads and Highways
- Bridges, Culverts
- River Basin Development
- Environment
- Socio-Economics
- Port Planning and Development
- Buildings and Structures

EPC offers all full range of services from survey and investigation, master planning, pre-feasibility and feasibility studies, financial and economic analysis, detailed design and specification, preparation of tender contract documents, supervision and quality control, training, project management, project benefit monitoring and impact evaluation.

4.3.2 Organization and Management

All technical and administration activities of the company are supervised and monitored by a group of directors, full-time professionals with long and outstanding career in the field of private sector consultancy. Each of the directors heads a particular branch of discipline and maintains a continuous and effective control on all activities throughout the duration of the project.

4.3.3 Staff Resources

The firm has a staff of approximately 133 professional and technical personnel. Most of the senior professionals have overseas experience or degrees (EPC, 2008). The multidisciplinary staff members of the firm are organized in different sections and professionals are encouraged to maintain close contacts with their universities or research institutes in order to keep pace with latest developments in their respective discipline. In addition, EPC maintains a retinue of highly qualified consultants from scientific and professional institutions.

4.4 Overview of Building for Future Ltd.

Building for Future Ltd. (BFL) is one of the prominent real estate developer companies of the country. It started its journey in 1994 with the aim to develop the construction technology to a world class standard (BFL, 2008).

BFL started computerization to systemize the organization into a corporate since 2000 and at present it is in a matured stage. The financial-management and accounting system is transparent and able to provide all sort of back up information needed for internal departments. The Engineering department is capable to meet any technical difficulties regarding construction with the engineers who are continuously checking the quality of the materials, techniques and skill of labour, time schedule for each job. They put all their information into the computerized data bank. The marketing and sales departments also record their activities to the main stream of information. This customized MIS enables the company to take appropriate decisions and to move faster.

4.4.1 Major Fields of Activities

The main activity is to build modern architectural structures with the infusion of latest technologies. The company also ensures sophisticated facilities and comfort keeping in mind the needs of the valued clients in order to make their living comfortable with environment friendly atmosphere.

4.3.3 Staff Resources

The firm has a staff of approximately 133 professional and technical personnel. Most of the senior professionals have overseas experience or degrees (EPC, 2008). The multidisciplinary staff members of the firm are organized in different sections and professionals are encouraged to maintain close contacts with their universities or research institutes in order to keep pace with latest developments in their respective discipline. In addition, EPC maintains a retinue of highly qualified consultants from scientific and professional institutions.

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4.4.2 Organization and Management

There are seven divisions such as human resource and administration, finance and accounts, engineering, marketing and product development, land procurement, legal and documentation and sales. The Chairman, Kazi Anisuddin Iqbal, is the key person for designing and supervising all the projects of BFL. The Managing Director, Tanveerul Haque Probal, has been administering the company.

4.4.3 Staff Resources

BFL has approximately 250 professional and technical staff. Moreover, a skilled and well trained work force of about 2000 workers is currently employed at various projects of BFL (BFL, 2008).

Chapter 5

Generic Analysis

5 Generic Analysis

A questionnaire survey was carried out on the office workers' socio-economic background and different travel attributes of their transport modes. Survey was carried out with a total of two hundred and fifty trip makers from different income classes of three private organizations in a random manner. Following sections of this chapter provide a generic analysis of the socio-economic and travel characteristics of the office workers based on the questionnaire survey.

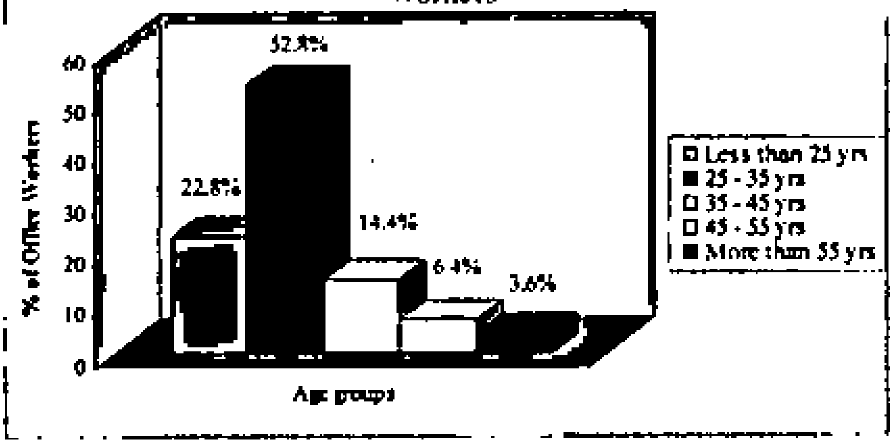
5.1 Socio-Economic Characteristics of Office Workers

This section describes the socio-economic background of the 250 office workers using Tables and Figures.

5.1.1 Age of the Office Workers

Figure 5.1 shows that most of the office workers (about 75.6%) were very young in age. It can be seen from Figure 5.1 that about 52.8 and 22.8 percent respondents were between 25 to 35 years and less than 25 years age group respectively. Only 3.6 percent respondents were more than 55 years old.

Figure 5.1 Age Group Distribution of the Office Workers



Source: Field Survey, 2008

5.1.2 Gender of the Office Workers

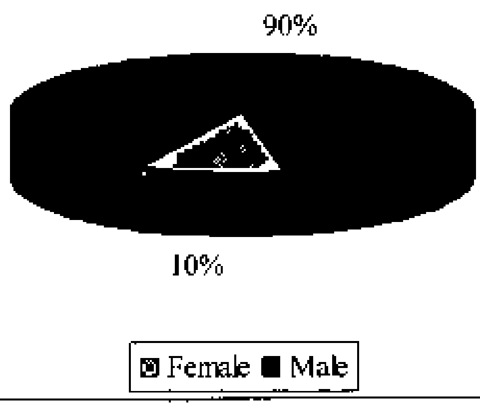
Though the questionnaire survey included all female workers employed in the three private organizations, the number of female office workers was significantly less than that of male workers. Figure 5.2 shows that out of 250 office workers only 10% were female where as 90% of the respondents were male. From the Table 5.1 it is also revealed that most of the female employees were also young like male.

Table 5.1 Age Group Distribution by Gender of the Office Workers

Age groups	Frequency of Office Workers	Gender of the Students			
		Female	In Percentage	Male	In Percentage
Less than 25 yrs	57	9	3.6	48	19.2
25 - 35 yrs	132	14	5.6	118	47.2
35 - 45 yrs	36	1	0.4	35	14
45 - 55 yrs	16	1	0.4	15	6
More than 55 yrs	9	-	-	9	3.6
Total	250	25	10	225	90

Source: Field Survey, 2008

Figure 5.2 Gender of the Office Workers



Source: Field Survey, 2008

5.1.3 Religion of the Office Workers

From Table 5.2, it is visualized that about 94% respondents were Muslim and the remaining 6% respondents were Hindu.

Table 5.2 Religion of the Office Workers

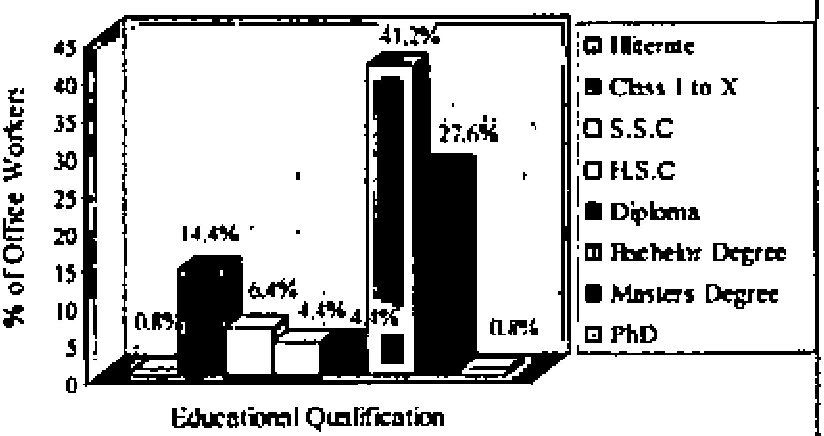
Religion	Frequency of Office Workers	In Percentage
Muslim	235	94
Hindu	15	6
Christian	-	-
Buddhist	-	-
Total	250	100

Source: Field Survey, 2005

5.1.4 Educational Qualification of the Office Workers

As Dhaka City has become a hub of commerce, business and education, the literacy rate in Dhaka is higher (about 68%) than other urban centres (Uddin, M.Z. *et al.*, 2004). Since this study also includes the office workers of three private organizations located in Dhaka City, the study shows the same scenario. From Figure 5.3, it is revealed that about 248 (98.2%) office workers were educated. Only 2 respondents (0.8%) were illiterate. On the other hand, about 41.2% and 27.6% respondents were obtained bachelor degree and masters degree respectively.

Figure 5.3 Educational Qualification of the Office Workers



Source: Field Survey, 2005

5.1.5 Job Status of the Office Workers

Among 250 respondents only 2 respondents (0.8%) are part time office workers (see Table 5.3).

Table 5.3 Job Status of the Office Workers

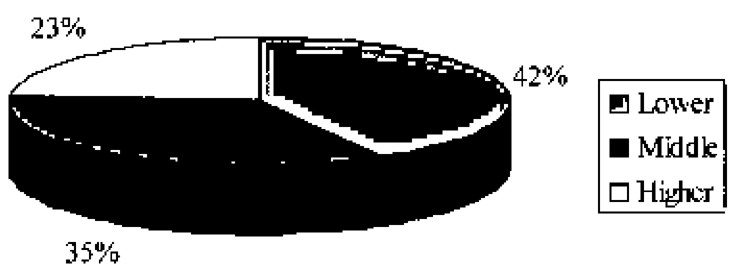
Job Status	Frequency of Office Workers	In Percentage
Part time	2	0.8
Full time	248	99.2
Total	250	100.0

Source: Field Survey, 2008

5.1.6 Monthly Income of the Office Workers

Income has been found to be the most influencing factor in one's travel decision. It was found that there were also significant variations in demand and travel behaviour, according to the income group. For that reason this study tried to include the office workers of all income groups i.e. lower income to higher income. The study considered three income groups such as lower (less than Tk. 10000), middle (Tk 10001 - 20000) and higher income group (more than Tk. 20000).

Figure 5.4 Income Group of the office Workers

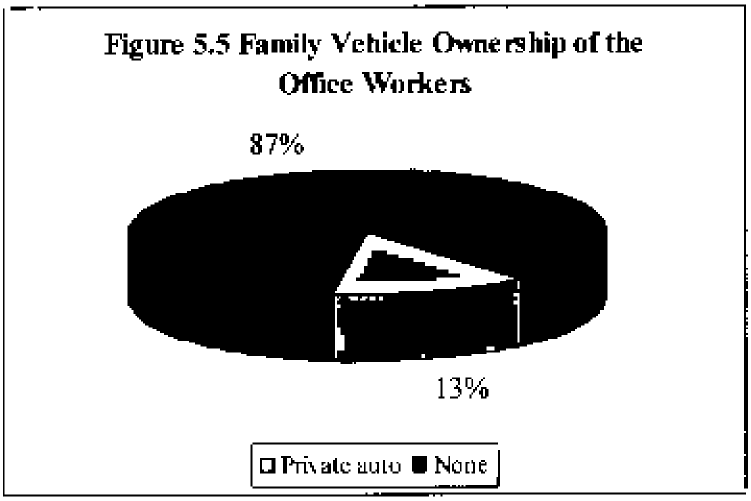


Source: Field Survey, 2008

Figure 5.4 shows that among the respondents the lower income group was the largest (42%). Middle income group was in second position (34.8%) and about 23.2% respondents were from higher income group.

5.1.7 Vehicle Ownership of the Office Workers

Vehicle ownership of the office workers determines their accessibility and hence, it is a significant factor in mode choice behavior. Out of 250 samples, only 33 office workers (13.2%) have their own private automobile (see Figure 5.5).



Source: Field Survey, 2008

5.2 Mode Preferences Based on Different Socio-Economic Conditions of Office Workers

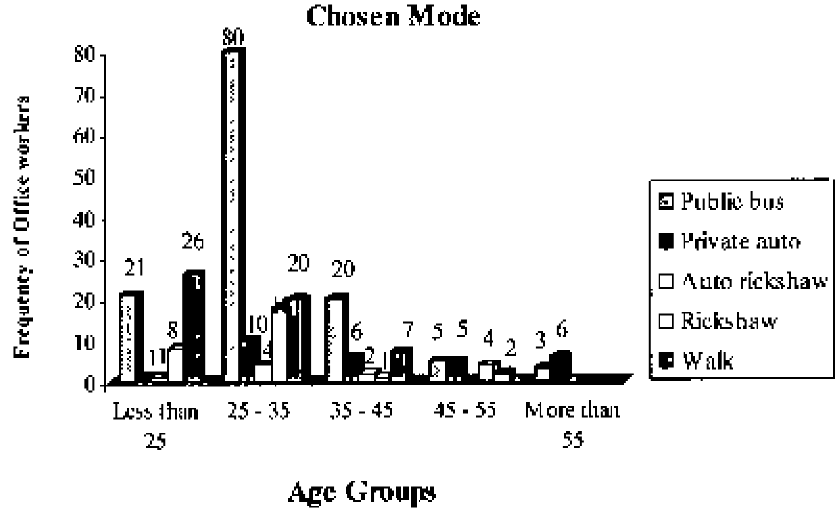
Different research has repeatedly found that travel choices are related to socio-economic characteristics. With a view to considering those factors in the analysis, the office workers were asked about their socio-economic conditions and their transport mode preferences. The following section discusses the results using Tables and Figures.

5.2.1 Office Workers Age Group by Most Frequently Chosen Mode

Though in general age is considered very important factor for transport mode selection, it was found from this study that the majority of the respondents of different age groups choose public bus as their primary transport mode (see Figure 5.6). There is no significant variation in choosing of primary mode by age. From Figure 5.6, it is seen that the respondents of young age choose public bus as their primary mode and the percentage of choosing walk as a primary mode is decreasing with the increasing of age.

Figure 5.6 shows that among 250 respondents most of the office workers (51.6%) were between 25 to 35 years of age. Among them, most of the respondents (80) choose public bus as their primary travel mode (see Table D5, Appendix D). The second highest primary travel mode for the same age group was walk. On the other hand, among 28 private auto owners, 10 respondents' were from this age group.

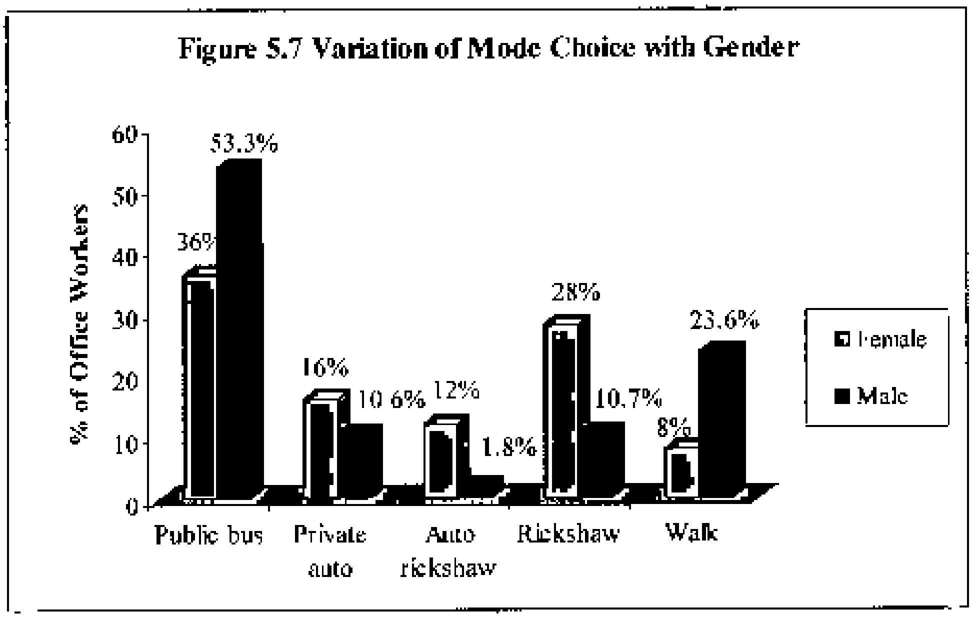
Figure 5.6 Age Group Distribution by Most Frequently Chosen Mode



Source: Field Survey, 2008

5.2.2 Gender of the Office Workers

It is evident that mode choice is highly influenced by gender and female are more inclined to choose a comfortable mode (Patterson *et al*. 2004). This study also comply with the previous study that females are always interested to choose the comfortable transport mode. From Figure 5.7, it is found that the female response towards choosing private auto, auto rickshaw and rickshaw was higher than the male workers. On the other hand, the female response to choose public bus and walk as primary mode was lower than the male workers.



Source: Field Survey, 2008

5.2.3 Educational Qualification by Most Frequently Chosen Mode

From the study it is found that the respondents whose educational qualifications were illiterate, Class I to Class X, Secondary School Certificate (S.S.C), Higher Secondary School Certificate (H.S.C.) and Diploma degree, had not any private auto and they did not choose the auto rickshaw as their primary mode.

Table 5.4 Relation between Educational Qualification and Most Frequently Chosen Mode

Educational Qualification of the Office Workers	Most frequently chosen mode					Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk	
Illiterate	-	-	-	-	2	2
Class I to X	11	-	-	1	24	36
S.S.C	6	-	-	1	9	16
H.S.C	4	-	-	1	6	11
Diploma	8	-	-	3	-	11
Bachelor Degree	63	11	4	14	11	103
Masters Degree	37	15	3	11	3	69
PhD	-	2	-	-	-	2
Total	129	28	7	31	55	250

Source: Field Survey, 2008

From Table 5.4 it is seen that most of the respondents of these groups choose walk as their primary mode. In addition, the second most frequently chosen primary mode is public bus for these groups. Most of the respondents who had bachelor and masters degree (63 and 37 respectively) choose public bus as their primary mode.

5.2.4 Job Status of the Office Workers

Among 250, only 2 respondents (0.8%) were part time office workers (see Table 5.5). Among them, one choose private auto as his primary mode and another choose rickshaw as his primary mode.

Table 5.5 Relation between Job Status and Most Frequently Chosen Mode

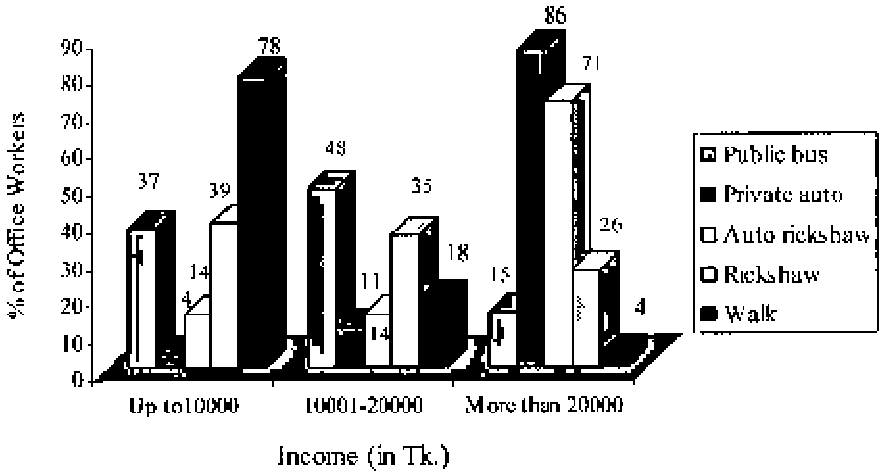
Job Status	Most frequently chosen mode					Total	% of Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk		
Part time	-	1	-	1	-	2	0.8
Full time	129	27	7	30	55	248	99.2
Total	129	28	7	31	55	250	100.0

Source: Field Survey, 2008

5.2.5 Monthly Income of the Office Workers

From the Figure 5.8, it is seen that the rate of choosing public bus, rickshaw and walk as the primary mode decreases with the increase of monthly income of the respondents. On the other hand, the rate of choosing private auto and auto rickshaw increases with the increase of monthly income of the respondents.

Figure 5.8 Mode Choice Variation with Income



Source: Field Survey, 2008

5.2.6 Vehicle Ownership of the Office Workers

An interesting finding has been shown in the Table 5.6. It is believed that very high income persons, who have easy access to private auto, are more likely not to use other modes because of factors like privacy, safety etc. But, from this study it is found that three respondents had their own private auto, but they choose public bus as their primary mode and they used the private auto occasionally (see Table 5.6).

Table 5.6 Relation between Vehicle Ownership and Most Frequently Chosen Mode

Ownership	Most frequently chosen mode					Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk	
Private auto	3	28	-	2	-	33
None	126	-	7	29	55	217
Total	129	28	7	31	55	250

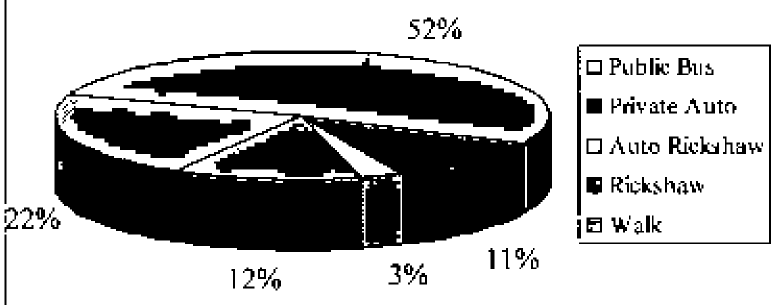
Source: Field Survey, 2008

5.3 Mode Preferences

5.3.1 Most Frequently Chosen Mode

Figure 5.9 shows that public bus (52%) was the most frequently chosen mode of the office workers. It is very interesting that walk (22%) has been chosen as their primary transport mode after the public bus. About 12% and 11% respondents choose rickshaw and private auto respectively as their primary mode shown in Figure 5.9. Only 3% office workers choose auto rickshaw as their most frequently chosen mode.

Figure 5.9 Most Frequently Chosen Mode of the Office Workers



5.3.2 Alternative Modes

The five modes in the study were Public Bus, Private Auto, Auto Rickshaw, Rickshaw and Walk. These modes were not only used as primary modes by the office workers but also they used these as their alternative modes. According to the percentage of office workers, the results have been ranked and are shown in Table 5.7.

Table 5.7 Alternative Modes of the Office Workers

Name of modes	Frequency	In Percentage	Rank
Public Bus	16	12.8	3
Private Auto	5	1.6	5
Auto Rickshaw	53	42.4	1
Rickshaw	48	38.4	2
Walk	6	4.8	4
Total Response	128	100	

Source: Field Survey, 2008

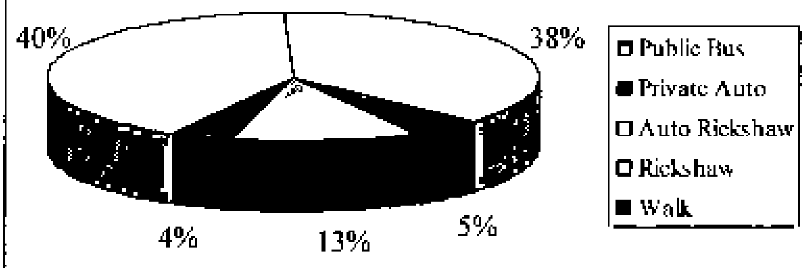


Figure 5.10 Alternative Modes of the Office Workers

On the basis of this ranking, auto rickshaw was mostly used as alternative mode and then rickshaw has the second preference. Public bus was in third position as an alternative mode.

5.3.3 Supporting Modes with Most Frequently Chosen Mode

Most of the office workers used supporting mode with their primary mode especially with public bus and auto rickshaw. Table 5.8 shows that 136 office workers use supporting mode with their primary mode. From Table 5.8, it is seen that the majority (58%) of the bus users reached the bus stop by walking. In addition, about 7 office workers use supporting mode with auto rickshaw, among them most of the office workers (86%) used walking as their supporting mode to reach to auto rickshaw. As a result, it is found from the study that walking was the most prominent mode as the supporting mode.

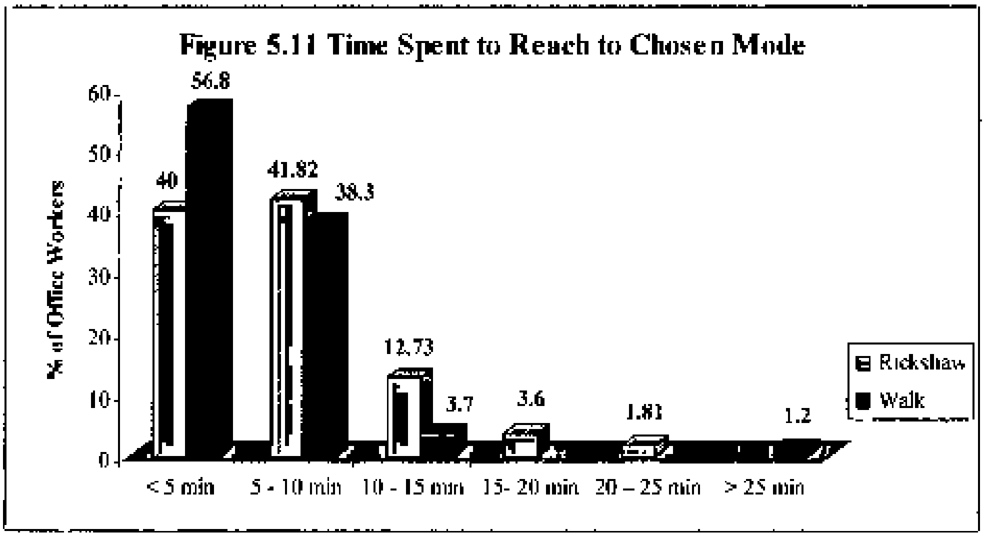
Table 5.8 Supporting Mode with Most Frequently Chosen Mode

Supporting Modes	Most frequently chosen mode				Total
	Public bus	%	Auto rickshaw	%	
Rickshaw	54	42	1	14	55
Walk	75	58	6	86	81
Total	129	100	7	100	136

Source: Field Survey, 2008

5.3.4 Time Spent to Reach to Most Frequently Chosen Mode

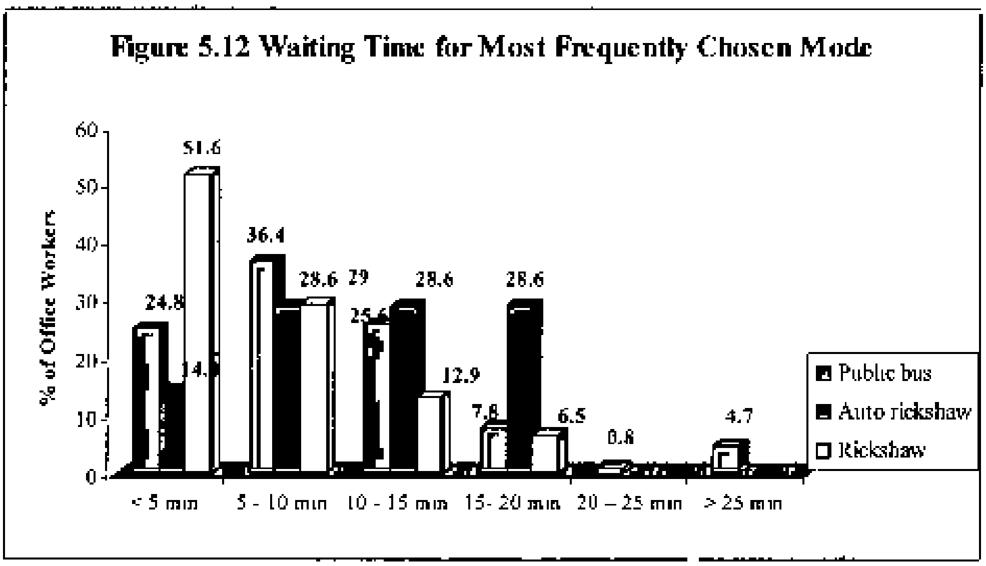
From Figure 5.11, it is found that majority of the respondents (40% and 41.82%) can reach their chosen mode by rickshaw within 10 minutes. Besides, most of the respondents (56.8% and 38.3%) can find their primary mode within a convenient walking distance which takes time up to 10 minutes.



Source: Field Survey, 2008

5.3.5 Waiting Time for Most Frequently Chosen Mode

From Figure 5.12, it is seen that office workers have to wait more time for public bus than auto rickshaw and rickshaw. People have to wait longer for their primary modes. Most of the office workers (36.4%) have to wait for a period of 5 - 10 minutes for public bus. From Figure 5.12 it is also seen that about 25.6% respondents have to wait for a period of 10-15 minutes for the bus. The office workers have to wait for auto rickshaw for up to 20 minutes and most of the respondents get a rickshaw within 5 minutes.



5.3.6 Level of Service of the Modes

Office workers were asked about their opinion regarding some of the travel attributes such as accessibility, convenience, privacy, safety and comfort for different chosen transport modes. They gave their opinion about these attributes of their chosen modes using a five digit scale which includes very poor, poor, moderate, good and very good. The results are shown in Table 5.9, Table 5.10, Table 5.11, Table 5.12 and Table 5.13.

5.3.6.1 Accessibility

From Table 5.9 it is visualized that the accessibility of the auto rickshaw is very poor in comparison with other modes. In addition, about 37.2% and 12.4% respondents thought that the accessibility of public bus is moderate and poor respectively. On the other hand, private auto owners have 100% accessibility to their auto. Most of the auto rickshaw users ranked their accessibility to that mode from very poor to moderate.

Table 5.9 Office Workers Opinion about Accessibility of Chosen and Available Modes

Category Level	Modes									
	Public bus		Private auto		Auto rickshaw		Rickshaw		Walk	
	F	%	F	%	F	%	F	%	F	%
Very Poor	18	12.4	-	-	11	18.3	3	3.8	-	-
Poor	52	35.9	-	-	20	33.3	17	21.5	14	23
Moderate	54	37.2	-	-	17	28.3	31	39.2	25	41
Good	20	13.8	-	-	10	16.7	25	31.6	18	29.5
Very Good	1	0.7	33	100	2	3.3	3	3.8	4	6.6
Total Response	145	100	33	100	60	100	79	100	61	100

Source: Field Survey, 2008 F= Frequency; %= Percentage

5.3.6.2 Convenience

Most of the respondents (40%) thought that the convenience of the public bus is moderate. About 72.7% private auto owners were highly satisfied with the convenience aspect. About 36.7% and 25% auto rickshaw ranked the convenience of the auto rickshaw as poor and very poor respectively. Though the convenient aspect for rickshaw should be in better position than all other modes as rickshaw is easily available, it provides door to door services and it is cheaper than traveling by all other modes but the study shows that office workers are not satisfied with this mode. From Table 5.10 shows that about 40.5% and 30.4% rickshaw users ranked the convenience of rickshaw as moderate and poor respectively.

Table 5.10 Office Workers Opinion about Convenience of Chosen and Available Modes

Category Level	Modes									
	Public bus		Private auto		Auto rickshaw		Rickshaw		Walk	
	F	%	F	%	F	%	F	%	F	%
Very Poor	11	7.6	-	-	15	25	5	6.3	-	-
Poor	49	33.8	-	-	22	36.7	24	30.4	-	-
Moderate	58	40.0	1	3	13	21.7	32	40.5	5	8.2
Good	23	15.9	8	24.2	7	11.7	17	21.5	20	32.8
Very Good	4	2.8	24	72.7	3	5	1	1.3	36	59.0
Total Response	145	100	33	100	60	100	79	100	61	100

Source: Field Survey, 2008 F= Frequency; %= Percentage

5.3.6.3 Privacy

Since bus is a public transport, there is no privacy. The study also shows the same scenario. Private auto were in the highest position in respect of privacy, because 100% users ranked privacy as very good for private auto (see Table 5.11). On the other hand, the office workers who use auto rickshaw as their most frequently chosen mode ranked privacy of auto rickshaw as moderate (26.7%), good (56.7%) and very good (16.7%).

Table 5.11 Office Workers Opinion about Privacy of Chosen and Available Modes

Category Level	Modes									
	Public bus		Private auto		Auto rickshaw		Rickshaw		Walk	
	F	%	F	%	F	%	F	%	F	%
Very Poor	21	14.5	-	-	-	-	-	-	-	-
Poor	62	42.8	-	-	-	-	7	8.9	1	1.6
Moderate	49	33.8	-	-	16	26.7	26	32.9	25	41.0
Good	10	6.9	-	-	34	56.7	37	46.8	29	47.5
Very Good	3	2.1	33	100	10	16.7	9	11.4	6	9.8
Total Response	145	100	33	100	60	100	79	100	61	100

Source: Field Survey, 2008 F= Frequency; %= Percentage

5.3.6.4 Safety

Most of the respondents thought that the public bus, auto rickshaw and rickshaw are not safe for them. In case of public bus, bus drivers drive the bus recklessly. As a result, the office workers were not satisfied with that, but they have no choice. Though the private auto users were satisfied fully in respect of accessibility and privacy, some users ranked it as moderate (6.1%) and good (9.1%). From Table 5.12, it is seen that most of the respondents who come to office on foot ranked the safety aspect as moderate (42.6%) and good (31.1%).

Table 5.12 Office Workers Opinion about Safety of Chosen and Available Modes

Category Level	Modes									
	Public bus		Private auto		Auto rickshaw		Rickshaw		Walk	
	F	%	F	%	F	%	F	%	F	%
Very Poor	12	8.3	-	-	-	-	2	2.5	-	-
Poor	36	24.8	-	-	4	6.7	18	22.8	5	8.2
Moderate	37	25.5	2	6.1	21	35	23	29.1	11	18.0
Good	44	30.3	3	9.1	25	41.7	25	31.6	26	42.6
Very Good	16	11.0	28	84.8	10	16.7	11	13.9	19	31.1
Total Response	145	100	33	100	60	100	79	100	61	100

Source: Field Survey, 2008 F= Frequency; %= Percentage

5.3.6.5 Comfort

From Table 5.13, it is seen that most of the bus users (37.2%) thought that the comfort condition is poor. Very few users (1.4%) thought that it is in very good condition. In addition, private auto user (100%) ranked the comfort condition for their auto as very good.

Table 5.13 Office Workers Opinion about Comfort of Chosen and Available Modes

Category Level	Modes									
	Public bus		Private auto		Auto rickshaw		Rickshaw		Walk	
	F	%	F	%	F	%	F	%	F	%
Very Poor	19	13.1	-	-	-	-	2	2.5	1	1.6
Poor	54	37.2	-	-	1	1.7	12	15.2	5	8.2
Moderate	48	33.1	-	-	9	15	24	30.4	6	9.8
Good	22	15.2	-	-	29	48.3	32	40.5	26	42.6
Very Good	2	1.4	33	100	21	35	9	11.4	23	37.7
Total Response	145	100	33	100	60	100	79	100	61	100

Source: Field Survey, 2008 F= Frequency; %= Percentage

Chapter 6

Nested Logit Model and Mode Specific Choice Analysis

6 Nested Logit Model and Mode Specific Choice Analysis

There are nineteen variables in the data set potentially considered by the office workers for mode selection. Some of the variables are included as generic variables in the specification and also tried as alternative-specific variables.

Several models (around 120 models) were tested on the way to the final nested model specification by a trial and error process. The trial and error process is the key to modelling. As a result this calibration process was done by adding or deleting the variables from the specification based on the goodness of fit measures. Firstly, the statistical significance of each parameter in the model and the model as a whole were determined. Secondly, the reasonableness of the magnitude of the parameters of the model variables was examined. And thirdly, the cross-validation of the model was checked. In addition, the sign of the parameter was also checked.

6.1 Rationale for Selection of Variables / Hypothesis

A set of variables was considered as potential candidates to be included in the models during model specification and estimation process. However, some variables were discarded due to wrong sign of the parameters, statistical insignificance and/or poor goodness-of-fit statistics in the estimated models.

6.1.1 Expected Sign of Parameters

The expected sign of different variables are described in this section.

6.1.1.1 Constants Considered for Mode Choice Model Derivation

To capture the systematic effects 'constants' were specified for all alternative bundles except rickshaw alternative for Independence of Irrelevant Alternative (IIA), as the number of constants should be (n - 1) for n alternatives. In case of branches, the constants were specified for all except Non–Motorized Transport (NMT) for the same reason. The constants are expected to have smaller values to allow variables to explain more in the generated models. The sign of the constant term is not important for the evaluation of the model.

6.1.1.2 Variables Considered for Mode Choice Model Derivation

1. **Age (AGE)**

   - **Public Bus, Rickshaw and Walk**

The expected sign is negative for uncomfortable modes such as public bus, rickshaw walk etc. representing increase in age of the office workers decreases the utility of above modes.

- **Private Auto and Auto Rickshaw**

It is expected that this variable should have a positive parametric sign for comfortable modes private auto, auto rickshaw etc. representing increase in age increase the utility of these mode for the office workers.

2. **Sex (SEX)**

In this study, in case of sex data, 0 represents female and 1 represents male office workers. It is evident that mode choice is highly influenced by gender and female are more inclined to choose a comfortable mode. In this regard, it is expected that this variable should have a positive parametric sign representing increase in number (0 to 1) will increase utility of uncomfortable modes and a negative parametric sign representing increase in number will decrease utility of comfortable modes for the office workers.

3. **Family Size (FAMSIZ)**

This variable was used in the utility function of branch level i.e. for public, private and NMT. As for example, the expected sign is positive for low cost transportation such as public bus, rickshaw walk etc. representing increase in family size will increase the expenditure and the office workers will choose the low cost transportation.

On the other hand, it is expected that this variable should have a negative parametric sign for high cost transport modes i.e. private auto, auto rickshaw etc. representing increase in family size decrease the utility of these mode for the office workers.

4. **Household Income (HHINC)**

Many transport modellers like to use this variable as generic in the model. But it has a practical problem. When this variable is used as generic it applies to all. But the effect of this is different on different modes.

- **Public Bus, Rickshaw and Walk**

As for example, the expected sign is negative for low cost transportation such as public bus, rickshaw walk etc. representing increase in household income decrease the utility of low cost transportation.

- **Private Auto and Auto Rickshaw**

It is expected that this variable should have a positive parametric sign for high cost transportation such as private auto, auto rickshaw etc. representing increase in household income increase the utility of these mode choice for the office workers.

5. **Distance from Home to Office (DIST)**

- **Public Bus, Private Auto, Auto Rickshaw**

Based on the same argument, it is expected that DIST variable should have a positive parametric sign representing increase in distance increases utility of public bus, private auto and auto for the office workers.

- **Rickshaw and Walk**

DIST variable is an important variable for the rickshaw and walk. It is expected that this variable should have a negative parametric sign representing increase in distance decreases utility of rickshaw and walk for the office workers.

6. **In Vehicle Travel Time (IVTT)**

- **Public bus, Private Auto, Auto Rickshaw, Rickshaw and Walk**

It is assumed that office workers value differently the in-vehicle and out-of vehicle travel time. So, IVTT is considered in the corresponding utility functions. As increase of travel time would decrease utility of five different modes, so the expected sign of the parameter is negative.

7. **Out Vehicle Travel Time (OVTT)**

- **Public bus, Private Auto, Auto Rickshaw, Rickshaw and Walk**

It is expected that the variable, OVTT, should have a negative parametric sign representing increase in out vehicle travel time decrease utility of five different modes for the office workers.

8. **Cost of Travel (COST)**

- **Public bus, Private Auto, Auto Rickshaw, Rickshaw and Walk**

As increase of travel cost would also decrease utility of five different modes. As a result, the expected sign of the parameter is negative.

9. **Comfort of the Modes (COMFORT)**

It is expected that this variable should have a positive parametric sign representing increase of comfort level increase utility of five different modes for the office workers.

6.1.2 Statistical Significance

After examination in terms of sign of the coefficient estimates, the models were examined according to significance of individual coefficients. In practice, a significance level of 0.05 and 0.01 is customary, though other values are used. Since the sample size (250 office workers) was small in the study a significance level of 0.10 has been chosen in designing a decision rule, then there are about 10 chances in 100 that we would reject the hypothesis when it should be accepted; that is, we are about 90% confident that we have made the right decision.

The critical values for a two-tail test at the 90% confidence level (level of significance = 0.10) are ±1.64 which is shown in Appendix E.

6.1.3 Goodness-of-Fit Statistics

With the estimation of more than one specification it is useful to compare goodness of fit measures. For nested logit model, a specification with a higher maximum value of the likelihood function is considered to be better. It is more convenient to compare the value of the likelihood ratio index, σ^2 (RHO squared) of the models. RHO-squared is similar to the R^2 measure in regression models.

Adjusted likelihood ratio index, $\bar{\sigma}^2$ (Adjusted RHO-squared) is normalization of the RHO-square so that two models can be compared for concluding which is better in terms of goodness of fit. In the study, Adjusted RHO Squared has been considered for assessing goodness of fit.

6.2 Nested Logit Model

The nested logit structure is defined as a hierarchical choice structure that determines the joint choice. Although few more possible nested structures were tried, two nested structures are described here.

6.2.1 Alternate Nested Structure

At first, the nesting structure shown in Figure 6.1 was examined to develop nested logit model. Around twenty model specifications were examined. However, the inclusive value parameters in all specifications were negative. One model specification is shown in Appendix F. But the inclusive value parameter should lie within 0 to 1. As a result, this nesting structure was not chosen as final structure.

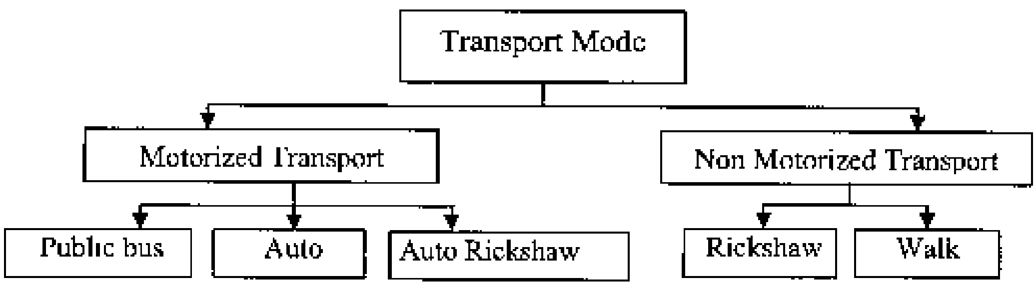


Figure 6.1 Alternate Structure of Nested Logit Model

6.2.2 Final Nested Structure

The final nesting structure to develop nested logit model is shown in Figure 6.2. In this case the inclusive value parameter was within 0 to 1 which fully complied with the standard. Then, around hundred model specifications were examined.

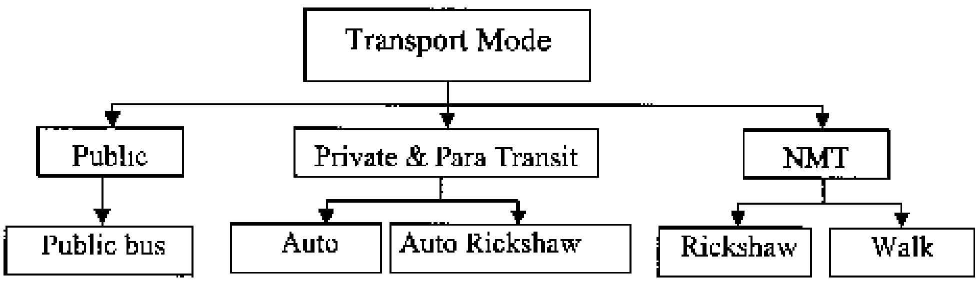


Figure 6.2 Final Structure of Nested Logit Model

There is only one limb, 'Transport Mode' consisting of three branches such as public, private and para-transit and non-motorized transport (NMT). The five transport modes chosen by the office workers were considered under these three branches. Around 100 model specifications considering this tree were estimated in the study to reach final nested logit model specification which complies with three selection criteria such as expected sign, *t*-statistics and the magnitudes of the variables and goodness of fit measures. Among 100 specifications, few significant specifications are briefly discussed here.

6.2.2.1 Model Specification 1

Many transport modellers like to use the variables as generic in the model. In the first specification this character of model was included (Appendix G-1). HHINC variable was considered as generic variable with an assumption that the variable contributes same appeal to all modes chosen by the office workers. In addition, in the branch level utility function HHINC variable was considered as alternative specific constants.

Constants, household income of the family (HHINC), in-vehicle (IVTT) and out-vehicle travel time (OVTT), cost of travel (COST) and age of the office workers (AGE) variables were considered in the corresponding utility functions.

In-vehicle (IVTT) and out-vehicle travel time (OVTT) and cost of travel (COST) variable are cost variables. As value increase of these variables would decrease utility of specific mode choice, so the expected sign of the parameter was negative in every chosen mode. However, HHINC and AGE have different effects on all five alternative modes.

From the result, it is seen that the co-efficient of inclusive value parameter is 1.66 which should lie between zero to one. Among fourteen variables, only seven variables show the expected sign. On the other hand, in most of the cases *t*-statistics are very poor in this specification. That is why this mode was not chosen as a final model for the mode choice of the office workers.

6.2.2.2 Model Specification 2

It is assumed that household income affects differently in case of choosing different modes such as public bus, private auto, auto rickshaw, rickshaw and walk. The higher income group is likely to choose private auto and auto rickshaw rather than public bus, rickshaw and walk. In this regard, HHINC was considered as alternative specific variable for each choice as well as for branch level utility functions.

From the result (see Appendix G-2), it is found that HHINC for five different modes gave the expected sign. In addition, COST for public bus, IVTT for rickshaw and AGE for rickshaw gave the expected signs. Among seventeen variables only eight variables gave expected sign and the *t*-statistics were also poor. In this regard, this model was not chosen as a final model for the mode choice of the office workers.

6.2.2.3 Model Specification 3

In specification 3, household income (HHINC) variable was not considered for five different alternatives. But HHINC as an alternative specific variable was considered for only branch level utility function. In addition, AGE, SEX and DIST were included in the utility functions of branch level. On the other hand, IVTT, OVTT, AGE, SEX, DIST were used in the utility functions for different modes.

From the result it is found that among twenty variables only seven variables gave expected results (see Appendix G-3). Some important variables such as IVTT and OVTT for different modes did not comply with the expected result. On the other hand, *t*-statistics were also very poor in the specifications. This model specification was therefore discarded.

6.2.2.4 Model Specification 4

Family size (FAMSIZ) variable in branch level with HHINC variable was considered in specification 4. On the other hand, OVTT for auto rickshaw and rickshaw as alternative specific variable was considered in this specification (see Appendix G-4).

From the result, it is seen that the inclusive value parameter is about 0.99 which complies with the standard value which should lie within 0 to1 for nested logit model. Among twenty one variables only ten variables show the expected sign. The specification includes all important variables for choosing an alternative, but due to wrong sign of different variables the model was not considered as final model.

6.2.2.5 Model Specification 5

Age, sex and comfort level as alternative mode specific variables were added in the model specification 5. The hypothesis is that the increase in comfort level might increase the probability of choosing the mode, so the expected sign is 'positive'. The hypothesis for the age variable is very interesting. The hypothesis for public bus, rickshaw and walk with respect to age are fully different. If age of the office workers increase, they will not be willing to choose the above modes. They will choose private auto and auto rickshaw as comfortable modes.

From the result, it is found that among twenty six variables about sixteen variables complied with the expected sign. IVTT for public bus, private auto and auto rickshaw did not show the expected signs (see Appendix G-5). On the other hand, OVTT and COST for auto rickshaw and rickshaw did not give the logical signs. So this model specification was also discarded.

6.2.2.6 Model Specification 6

In-vehicle travel time, out-vehicle travel time, cost and distance are very important parameters for choosing an alternative mode. In specification 6, DIST variable was added for public bus and auto rickshaw with all the variables included in the specification 4 (see Appendix G-6). Among twenty four variables about fifteen variables show the expected sign. IVTT variables for public bus, private auto and auto rickshaw did not give the expected sign. In addition, DIST variables did also not show the expected sign. The *t*-statistics were also very poor.

Different variables included in the above six specifications and from the results it is found that all specifications included some variables which did not comply with the expected sign and the *t*-statistics were also very poor. That is why, one of the six specifications could not be chosen as a final model for the mode choice of the office workers.

6.2.3 Model Summery

From the result and observation, it is seen that model specification 6 included most important variables like age, gender, family size, family income, distance, in vehicle and out vehicle travel time, cost of travel, distance and comfort level and also shows that more variables gave expected results compared to other specifications (see Table 6.1).

Table 6.1 Model Summary

Model Specifications	No. of Variables	No. of Variables with Wrong Sign of Coefficient	RHO Squared	Adjusted RHO Squared
Model Specification 1	14	7	0.86737	0.84281
Model Specification 2	17	9	0.85443	0.82255
Model Specification 3	20	13	0.87379	0.84162
Model Specification 4	21	11	0.85999	0.82257
Model Specification 5	26	10	0.87749	0.83665
Model Specification 6	24	9	0.88711	0.85256

Source. Field Survey 2008 and Calculation

The overall fits of six models are excellent, with RHO-Squared and Adjusted RHO-Squared of six specifications was about to similar. In case of 1, 3 the value is quite higher than the specification 2 and 4. The Adjusted RHO Squared is the highest in the specification 6. The overall fit of specification 6 is excellent. As a result this specification of nested logit model was considered to describe in detail (see section 6.3).

6.3 Selected Model Specification

In this section model specification 6 is elaborately discussed. The utility functions of the competitive alternatives as well as the branch levels are:

U(pub_bus)=A0+**A1*HHINC**+A2*IVTT+A3*OVTT+**A4*COST**+A5*DIST (6.1)

U(pri_auto)=B0+**B1*HHINC** + B2*IVTT+**B3*COST** (6.2)

U(a_rick)=C0+**C1*HHINC**+ C2*IVTT+C3*OVTT+**C4*COST** (6.3)

U(rick)=**D1*IVTT+D2*OVTT**+D3*COST+D4*DIST (6.4)

U(walk)=E0+**E1*HHINC+ E2*AGE+E3*IVTT** (6.5)

U(public)=F0+**AB*HHINC+AC*FAMSIZ** (6.6)

U(pri_ptransit)=G0+**BC*HHINC+DC*FAMSIZ** (6.7)

U(nmt)=EF*HHINC (6.8)

6.3.1 Agreement with a Priori Expectation

The calibration of the nested logit model was made using the LIMDEP software. The results of specification 6 are tabulated below in Table 6.2, Table 6.3 and Figure 6.3. The significant variables include household income, in-vehicle travel time, out-vehicle travel time, cost of travel, age of the office workers and family size. From Table 6.2, all parameters including constants except constant for walk have relatively low value showing consistency of the model. It is also seen that HHINC variable for public bus, private auto, auto rickshaw and walk complied with the priori expectation. In addition, HHINC and FAMSIZ for the branch level (public and private) also comply with the expected sign. In case of rickshaw and walk mode, IVTT gave the expected sign. On the other hand, for public bus, private auto and auto rickshaw IVTT did not comply with priori expectation. Among twenty four variables about fifteen variables show the expected sign (see Table 6.2). The values of parameter DIST and IVTT show that they are very important variable for choosing public bus and private auto respectively. In addition, IVTT is also important for choosing auto rickshaw. In case of rickshaw, DIST variables show the significance and also IVTT is important for walk.

The inclusive value coefficient is within zero and one (0.99). This provides a statistical validation of using this nested logit structure. Unfortunately, all variables included in the model are statistically insignificant. The overall fit of the model is excellent, with a log likelihood ratio index of 0.85.

Table 6.2 Nested Logit Mode Choice Model for Office Workers in Dhaka City

Variables	Notation	Co-efficient	*t*-statistics
Attributes in the Utility Functions			
Constant for public bus	A0	-0.15727	-0.001
HHINC	A1	-0.00011	0.000
IVTT	A2	0.03707	0.329
OVTT	A3	0.04679	0.390
COST	A4	-0.05513	-0.282
DIST	A5	-0.17960	-0.278
Constant for private auto	B0	-2.98462	-0.024
HHINC	B1	0.00008	0.014
IVTT	B2	0.05180	0.132
COST	B3	-0.00976	-0.069
Constant for auto rickshaw	C0	-7.1013	-0.415
HHINC	C1	0.00008	0.022
IVTT	C2	0.08684	0.371
OVTT	C3	0.06113	0.331
COST	C4	-0.05003	-0.371
IVTT	D1	-0.07427	-0.393
OVTT	D2	0.02064	0.180
COST	D3	0.12570	0.421
DIST	D4	-1.2526	-0.451
Constant for walk	E0	14.02448	0.272

HHINC	E1	-0.00033	-0.170
AGE	E2	-0.08369	-0.319
IVTT	E3	-0.55238	-0.330
Attributes of Branch Choice Equations			
Constant for public transport	F0	1.36333	0.011
HHINC	AB	-0.00005	0.000
FAMSIZ	AC	0.21087	0.665
Constant for private transport	G0	1.3333	0.012
HHINC	BC	-0.00005	-0.012
FAMSIZ	DC	-0.26015	-0.123
HHINC	EF	0.00001	0.004
Inclusive Value Parameters			
Public to transport	Public	0.99	0.432
Private & para transit to transport	Private	0.99	0.432
NMT to transport	NMT	0.99	0.432
Number of observations		378	
$L^* (\beta)$		-40.47216	
$L^* (0)$		-358.5239	
$\rho^2 = 1 - L^* (\beta)/L^* (0)$ (RHO Squared)		0.88711	
Adjusted RHO Squared		0.85256	
Chi-squared		636.1034	
Degrees of freedom		30	

Source: Field Survey, 2008 and Calculation

The following mathematical specification of the mode choice model of office workers was derived from the equations 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8 and Table 6.2.

Figure 6.3 summarizes the utility equations for calculating the unconditional probability of alternative choice. The equations use the estimated coefficients and inclusive value parameters to calculate the utilities. Then, the probability equations are used to convert the utilities to probabilities. The definitions of all terms included in these calculations are presented in Table 6.3. The probabilities of choosing different modes are shown in Appendix H. The Table in Appendix H shows the actual as well as predicted probabilities of choosing five different modes. From this result, it is found that only 18 predictions differ from the actual mode choice.

Figure 6.3 Mathematical Specification of Nested Logit Model for Office Workers

1. Utility equations

U(pub_bus) = -0.15727-0.00011*HHINC+0.03707*IVTT+0.04679*OVTT -0.05513*COST-0.17960*DIST (6.9)

U(pri_auto) = -2.98462+0.00008*HHINC+0.05180*IVTT-0.00976*COST (6.10)

U(a_rick) = -7.1013+0.00008*HHINC+0.08684*IVTT+0.06113*OVTT -0.05003*COST (6.11)

U(rick) = -0.07427*IVTT+0.02064*OVTT+0.12570*COST -1.2526*DIST (6.12)

U(walk) = 14.02448-0.00033*HHINC-0.08369*AGE-0.55238*IVTT (6.13)

U(public) =1.36333-0.00005*HHINC+0.21087*FAMSIZ (6.14)

U(pri_ptransit) =1.3333+-0.00005*HHINC-0.26015*FAMSIZ (6.15)

U(nmt) =0.00001*HHINC (6.16)

2. Conditional probabilities of choosing different modes of primary choice

$$P(\text{Pub\_bus}|\text{Public}|\text{Tr}) = \frac{e^{U(pub\_bus)}}{e^{U(pub\_bus)}} \quad (6.17)$$

$$P(\text{Pri\_auto}|\text{Pri\_ptransit}|\text{Tr}) = \frac{e^{U(Pri\_auto)}}{e^{U(pri\_auto)} + e^{U(a\_rick)}} \quad (6.18)$$

$$P(\text{A\_rick}|\text{Pri\_ptransit}|\text{Tr}) = \frac{e^{U(a\_rick)}}{e^{U(pri\_auto)} + e^{U(a\_rick)}} \quad (6.19)$$

$$P(\text{Rick}|\text{NMT}|\text{Tr}) = \frac{e^{U(rick)}}{e^{U(rick)} + e^{U(walk)}} \quad (6.20)$$

$$P\,(\text{Walk}|\text{NMT}|\text{Tr}) = \frac{e^{U(walk)}}{e^{U(rick)} + e^{U(walk)}} \tag{6.21}$$

3. Inclusive values

$$I_{public} = \text{Ln}\,[e^{U(pub\_bus)}] \tag{6.22}$$

$$I_{pri\_ptransit} = \text{Ln}\,[e^{U(pri\_auto)} + e^{U(a\_rick)}] \tag{6.23}$$

$$I_{nmt} = \text{Ln}\,[e^{U(rick)} + e^{U(walk)}] \tag{6.24}$$

4. Probabilities of selecting an alternative from a choice set

$$P\,(\text{Public}) = \frac{e^{U(\tau_{public} I_{public})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}} \tag{6.25}$$

$$P\,(\text{Pri\_ptransit}) = \frac{e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}} \tag{6.26}$$

$$P\,(\text{NMT}) = \frac{e^{U(\tau_{nmt} I_{nmt})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}} \tag{6.27}$$

5. Unconditional probabilities of choosing an alternative

$$P\,(\text{Pub\_bus,Public}|\text{Tr}) = \left(\frac{e^{U(pub\_bus)}}{e^{U(pub\_bus)}}\right)\left(\frac{e^{U(\tau_{public} I_{public})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}}\right)$$

$$P\,(\text{Pri\_auto,Pri\_ptransit}|\text{Tr}) = \left(\frac{e^{U(Pri\_auto)}}{e^{U(pri\_auto)} + e^{U(a\_rick)}}\right)\left(\frac{e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}}\right)$$

$$P\,(\text{A\_rick,Pri\_ptransit}|\text{Tr}) = \left(\frac{e^{U(a\_rick)}}{e^{U(pri\_auto)} + e^{U(a\_rick)}}\right)\left(\frac{e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}}\right)$$

$$P\,(\text{Rick,NMT}|\text{Tr}) = \left(\frac{e^{U(rick)}}{e^{U(rick)} + e^{U(walk)}}\right)\left(\frac{e^{U(\tau_{nmt} I_{nmt})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}}\right)$$

$$P(\text{Walk,NMT}|\text{Tr}) = \left(\frac{e^{U(walk)}}{e^{U(rick)} + e^{U(walk)}}\right)\left(\frac{e^{U(\tau_{nmt} I_{nmt})}}{e^{U(\tau_{public} I_{public})} + e^{U(\tau_{pri\_ptransit} I_{pri\_ptransit})} + e^{U(\tau_{nmt} I_{nmt})}}\right)$$

where,

Utility equations

U(pub_bus) = Utility index of public bus

U(pri_auto) = Utility index of private auto

U(a_rick) =Utility index of auto rickshaw

U(rick) = Utility index of rickshaw

U(walk) = Utility index of walk

U(public) = Utility index of public transport

U(pri_ptransit) = Utility index of private and para transit transport

U(nmt) = Utility index of non-motorized transport

Conditional probabilities

P (Pub_bus|Public|Tr) = Probability of choosing public bus of choice-set public

P (Pri_auto|Pri_ptransit|Tr) = Probability of choosing private auto of choice-set private and para transit

P (a_rick|Pri_ptransit|Tr) = Probability of choosing auto rickshaw of choice-set private and para transit

P (rick|NMT|Tr) = Probability of choosing rickshaw of choice-set NMT

P (walk|NMT|Tr) = Probability of choosing walk of choice-set NMT

Inclusive values

I_{public} = Inclusive value of public transport

$I_{pri\_ptransit}$ = Inclusive value of private and para transit transport

I_{nmt} = Inclusive value of non-motorized transport

Unconditional probabilities

P (Pub_bus,Public|Tr) = Unconditional probability of choosing public bus

P (Pri_auto,Pri_ptransit|Tr) = Unconditional probability of choosing private auto

P (a_rick,Pri_ptransit|Tr) = Unconditional probability of choosing auto rickshaw

P (rick,NMT|Tr) = Unconditional probability of choosing rickshaw

P (walk,NMT|Tr) = Unconditional probability of choosing walk

6.4 Limitations of Nested Logit Models

One of the main objectives of this study was to develop a nested logit mode choice model for the office workers. After intensive investigation of the mode choice modelling for them, it is found from the study that it can not indicate a sensible nested logit mode choice model for the office worker. Although few more possible nested structures were tried, around 120 model specifications were examined to develop a nested logit model. Some specifications did not give any result using LIMDEP due to some errors. Though 120 models were found from the study, they could not be chosen as a final nested logit model for the office workers due to wrong sign of different variables, poor statistical significance etc. This may be happen due to lack of information, insufficient information, inaccurate/biased information, crude assumptions.

From all model specifications and analysis it is realized that in vehicle travel time, out-vehicle travel time, cost and distance variables did not give expected result. It may be happen due to their irrational interrelationship. In our country, travel time in any mode does not conform to the distance the mode traverses. As a result with the increase of time, cost is also increased in case of some modes like auto rickshaw. From the survey, one example has been depicted here.

An office worker travelled around 8 km from Mirpur 1 to Sheltech (Pvt.) Ltd., his job location daily with travel time of around 40-50 minutes and the costs of this travel in public bus and auto rickshaw were Tk 10 and Tk 50-80 (based on time) respectively. So, there was no logical relationship with in-vehicle and out-vehicle travel, cost and distance. But in ideal situation, the office workers should reach from his home to office of 8 Km distance within 15-20 minutes by bus. In Dhaka city the level of service of roads as well as transport modes are very poor. People suffer from serious traffic congestion in whole Dhaka city. The estimation process of model using LIMDEP is based on numerical data, but the dataset considered in this study includes such type of irrelevancy. As a result, the study can not develop a sensible nested logit model for the office workers.

On the other hand, the sample size was very small to describe the situation properly which added to the problem of developing a comprehensive mode choice model. Therefore it is very usual in such cases of model estimation that a model gives a result that highly conforms to expectations. In that sense, the results of the calibration process have been quite good. The results did specified the most important variables like age, gender, family size, family income, distance, in vehicle and out vehicle travel time, cost of travel, distance and comfort level. These specifications may be improved further with a larger and relevant data set and the study can find out the human behaviour more efficiently. The process developed in this study for the calibration of mode choice model using nested logit model can be carried out to prepare models of any similar study area.

Chapter 7

Policy Recommendations and Concluding Remarks

7 Policy Recommendations and Concluding Remarks

7.1 Policy Recommendations

The individual choice models are extremely adaptable to a very wide range of policy issues. But this study was an attempt to develop the nested logit mode choice model. The study did not consider the policy sensitivity analysis. For this reason, some recommendations for resolution of problems have been formulated based on the results obtained from generic analysis.

7.1.1 Increase Number of Public Bus

Public bus (52%) was the most frequently chosen mode (primary mode) of the office workers due to its low cost. Office workers commute from far away places by bus in the rush hour. As a result, they have to travel with great risks, often swinging from the handles of public buses. However, office workers' attitude towards bus was positive in the sense of cost. On the other hand, only 11% respondents choose private auto as their primary mode. In this regard, to meet the demand for transportation systems in the city immediately and in the future the authority should give emphasis on public transport. And the number of public bus must be increased at such a rate that it can cope with the existing as well as future demand and the demand can be determined by the individual choice model.

Over crowding is a major problem of public bus services especially during the peak periods. So, in this period, service should have higher frequencies and should maintain the regularity.

7.1.2 Enhance the Quality and Level of Service

Though the level of service including accessibility, convenience, privacy, safety and comfort was not so good in case of public bus most of the office workers choose it as their primary mode due to low cost. So level of service of public bus must be increased. The location of bus stoppage should be arranged in such a way so that they can get it very easily from their trip origin, preferable within convenient walking distance of around 10-15 minutes. Some office workers are not willing to use public bus for inadequate privacy, safety and comfort. So these facilities have to be improved for the buses so that the dependency on high cost transportation such as private auto and auto rickshaw will be reduced. If the level of service of bus increases, more and more people (mainly women and older people) will be encouraged to use the service.

7.1.3 Increase Pedestrian Safety

From the study it is found that about 22% office workers travel to their office on foot who are mostly low income people. The urban poor or low income people who mostly travel on foot face higher risk than the rest of the society. So, pedestrian safety must be ensured.

7.1.4 Estimate User Friendly Travel Cost

Travel cost is a prominent factor for choosing a transport mode. The office workers were not pleased with the travel cost of public bus, auto rickshaw and rickshaw because the cost of these modes has been increased day by day. On the other hand, though there is government regulated fare structure for auto rickshaw, but drivers do not follow the rules. They charge extra fare for travel. As a result, it creates pressure on the people for their movement. In this regard, government should fix up a reasonable rate for different modes and the regulated fare structure must be followed strictly.

7.1.5 Introduce Mode Choice Modelling for Travel Demand Forecasting

For preparation of an immediate action for the effective management of the existing traffic and transportation system of Dhaka City, there is a crucial need to know the transport demand of different individuals. Therefore, introduction of transport mode choice modelling should be encouraged and followed for transportation planning project. This will facilitate proper forecasting and assessment of travel demand as well as appropriate scenario evaluation in transportation sectors in a more quantitative way which enables specific problem identification and their resolution.

To provide adequate transport facilities for the travellers it is essential to know the individual mode choice behaviour of them. As a result, demand of different modes and their supporting tools to move it smoothly can be estimated. In the context of present scenario, mode choice modelling of different groups should get emphasis in transport sector.

7.2 Implications of Individual Choice Models in Transportation Planning

The individual choice models have theoretical and practical characteristics of significance that have important implications in transportation planning. These are discussed in this section.

7.2.1 An Explicit Structure for All Relevant Travel Related Decisions

The models are based on an explicit theory of individual choice that includes the entire set of travel related decisions. They estimate the probabilities of choosing each travel alternative rather than stating any choice explicitly. A set of interdependent choice decisions, related to every aspect of a particular journey, can be modelled separately.

As these are all expressed in probability form, the modelled probabilities can then be multiplied together to produce a joint probability. These models, therefore provide a very convenient framework to consider the issues of trip frequency, destination choice, mode choice, route choice, time of travel choice, car ownership, housing and employment locations etc., all jointly in a consistent fashion.

7.2.2 Policy Sensitivity

The individual choice models are extremely adaptable to a very wide range of policy issues. Their property of policy sensitivity has made them an effective tool in the hands of the planners for use in evaluating alternative policies. They have also great potential in generating policy. These properties have great significance, particularly in local level planning and for urban public transport operation. The structure of the models permits almost any number of quantifiable policy variables, representing a change in the attributes of the alternatives (not just mode but route, destination, time etc., to be combined linearly into a single index of relative desirability. The parameters of these linear desirability functions (actually called utility functions), when standardised, indicate how people trade-off between the policy variables. This provides an important insight for the decision maker. The linear utility function also enables one to compute elasticity of demand and also cross elasticity of demand, which are important concepts in investigating the sensitivity of demand to small changes in a policy variable such as change in public transport fare or parking charge.

7.2.3 Individual Choice Models are based on Observation of Individual Choice Behaviour

The fact that individual choice models are based on individual observations has quite a number of important implications. First, it means these models are more data efficient than the conventional aggregate models. The amount of data required to calibrate individual choice models is considerably less than the conventional model because, for the latter, a substantial number of trip records are required to combine to produce statistically reliable zonal values. For an area with a considerable number of traffic zones the amount of individual observations becomes enormous. Even then, the amount of observations available for analysis reduces drastically because no trips are exchanged between the bulk of the possible pairs. Therefore, much less cost is involved in collecting data for calibrating individual choice models.

Secondly, while the individual choice models make use of the total variation in the data set, aggregate models can use only part of it. Much of the variation in a data is lost by the process of zonal aggregation. It may also be the case that intra-zonal variation is more significant than can be represented by a single cell count in a matrix. In such a situation the aggregate models seriously undermine the variability present in the data. On the other hand, individual choice models can incorporate all the variability of trip records. Use of individual observations also reduces the potential bias in model estimation due to simultaneous links from travel demand to level of-service attributes.

Thirdly, individual choice models are less likely to be biased by ecological correlation. But in aggregate models, there is danger of masking individual behaviour by unidentified characteristics that may be associated with a zone.

Fourthly, an individual choice model can be used for forecasting purposes at any level of aggregation. Aggregate forecasts can be made for geographical units such as traffic zones or socioeconomic units such as market segments. Conventional aggregate models, however, can only be applied at zone level or at some higher levels of geographical aggregation of these zones.

7.2.4 Explicit Theory of Choice Behaviour

The models are based upon explicit hypotheses about individual travel choice behaviour. If the hypotheses are the right ones then the models should be truly behavioural in nature. This implies that these models should be applicable in locations other than that for which the models were calibrated. That is, the models should be transferable over space, time, or culture, as long as the underlying assumptions about human choice behaviour remain the same. The transferability of individual choice models, in fact, holds the potential for major savings in travel demand modelling. However, no model can ever be fully specified to capture every detail of human behaviour. So for an 'imported', model some recalibration may be required, but the data requirements for such adjustment exercise are likely to be small and significantly less than carrying out a calibration exercise.

7.3 Concluding Remarks

Mode choice modelling has a very important place in modern urban transportation planning. Over all other travel decisions, exogenous control may be best exercised on modal choice. In view of the increasingly complex set of economic, social, political and environmental constraints which need to be taken into account in attempting to meet increasing travel demand, an imbalance between the supply and demand functions of travel may be dealt with through the manipulation of the supply function. Apart from making substitutes of supply, the supply situation can perhaps best be controlled for modal choice. There is essential need to estimate travel demand

and to know the mode choice behaviour of different individual to meet their demand for an adequate and efficient transport system.

The individual mode choice models are particularly useful for short run planning decisions and especially relating to the operation of public transport. They have particular relevance to local level planning.

This study was an attempt to develop a sensible mode choice model for the office workers but the study could not choose a final nested logit model for the office workers due to wrong sign of different variables and poor statistical significance. This may happen for lack of information, insufficient information, inaccurate/biased information, crude assumptions etc. The main source of error was the data obtained from the questionnaire survey. The whole success of individual choice modelling depends very much on the quality of data. Inclusion or exclusion of most socioeconomic variables from the models greatly affects the important travel attribute such as in vehicle travel time, costs, distance etc.

Therefore it is very unusual in such cases of model estimation that a model gives a result that highly conforms to expectations. In that sense, the results of the calibration process have been quite good. These specifications may be improved further with a larger and relevant data set and the study can find out the human behaviour more efficiently. The process developed in this study for the calibration of mode choice model using nested logit model can be carried out to prepare models of any similar study area.

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Appendices

Appendix A

Department of Urban and Regional Planning

Bangladesh University of Engineering and Technology

Questionnaire Based User Opinion Survey for the Research Titled:

NESTED-LOGIT MODE-CHOICE MODEL FOR OFFICE WORKERS: A CASE STUDY IN DHAKA CITY

Questionnaire No.........

Part for the interviewer

Name.. Time of interview... ....

Purpose of interview: Data will be used only for research purpose Date of interview: ....

Signature: ....

Part for the respondent:

1. General information

i. Name of the respondent :

ii. Designation :

iii. Branch name :

iv. Private organization :

v. Age ☐☐

vi. Gender ☐

Code: 1 = Male 2 = Female

vi. Religion ☐

Code: 1 = Muslim 2 = Hindu 3 = Christian 4 = Buddhist

5 = Others............................(please specify)

vii. Educational qualification ☐

Code: 1 = Illiterate 2 = Class I to X 3 = S.S. C

4 = H.S.C 5 = Bachelor degree 6 = Masters degree

7 = PhD 8 = Other……………….(please specify)

viii. Status of job ☐

Code: 1 = Part time 2 = Full time

2. Family size: (No of persons) ☐

3. Total income (monthly) Tk ☐☐☐☐☐☐

4. Structural pattern of your residence ☐

Code: 1. Katcha 2. Semi pucca 3. Pucca

4.Other…(please specify)

5. Family vehicle ownership ☐

Code: 1. Private auto 2. None

Information on the trip to office: (One way trip)

6. Trip origin: ……………………………………………………………

7. Trip destination: ……………………………………………………………

8. Frequency of the trip (weekly): ☐

9. Time of the trip: ……………………………………………………………

10. Monthly frequency of mode used for the trip:

Modes	Frequency	Modes	Frequency
1. Public bus		7. Motor cycle	
2. Micro bus		8. Rickshaw	
3. Private auto		9. Bicycle	
4. Auto rickshaw		10. Van	
5. Taxi		11. Walk	
6. Human hauler			

11. Distance from home to office ☐

(approximately in Km)

12. Total number of available modes [ ]

13. Trips made by different modes comprise several distinct time segments: access, waiting, in-vehicle time and egress time. Please estimate the approximate times taken for each segment in your trip.

Information	Most frequently chosen primary mode (Circle one mode only)	Which modes are available as alternatives for you? (Circle multiple answers if available)	Access time (in mins)	Typical waiting time (in mins)	In-vehicle travel time (in mins)	Egress time (in mins)	Travel cost (in Tk.)	Do you use supporting mode with the primary carrier? Code: 1 = Yes 2 = No	Which mode? Code: 1 = Rickshaw 2 = Walk 3 =Others (please specify)	Cost to avail supporting mode (in Tk.)
Public bus	1	1								
Micro bus	2	2								
Private auto	3	3								
Auto rickshaw	4	4								
Taxi	5	5								
Human hauler	6	6								
Motor cycle	7	7								
Rickshaw	8	8								
Bicycle	9	9								
Van	10	10								
Walk	11	11								

14. Level of service of used modes: Please circle the appropriate answers.

Modes	Parameter	Very Poor	Poor	Moderate	Good	Very Good
Public bus	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Micro bus	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Private auto	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Auto rickshaw	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Taxi	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Human hauler	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5

Level of service of used modes: Please circle the appropriate answers.

Modes	Parameter	Very Poor	Poor	Moderate	Good	Very Good
Motor cycle	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Rickshaw	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Bicycle	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Van	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5
Walk	Accessibility	1	2	3	4	5
	Convenience	1	2	3	4	5
	Privacy	1	2	3	4	5
	Safety	1	2	3	4	5
	Comfort	1	2	3	4	5

Appendix B

Appendix B

Coding of Different Variables in SPSS for Generic Analysis

name = Name of the office workers

designa = Designation of the office workers

priorg = Name of the private organization

1 = Sheltech	2 = BFL
3 = EPC	

age = Age of the office workers in years

1 = Less than 25 years	2 = 25 - 35 years
3 = 35 - 45 years	4 = 45 - 55 years
5 = More than 55 years	

gender = Gender of the office workers

1 = Male	2 = Female

religion = Religion of the office workers

1 = Muslim	2 = Hindu
3 = Christian	4 = Buddhist

eduqal = Educational qualification of the office workers

1 = Illiterate	2 = Class I to X
3 = S.S. C	4 = H.S C
5 = Diploma	6 = Bachelor Degree
7 = Masters Degree	8 = PhD

status = Status of the office workers, 1 = Full time 2 = Part time

fmlysize = Family size of the office workers

income = Monthly household income in Tk.

1 = Up to 5000	2 = 5001 -10000
3 = 10001 - 150000	4 = 15001 - 20000
5 = 20001 - 25000	6 = 25001 - 30000
7 = 30001 - 35000	8 = 35001 - 40000
9 = More than 40000	

resistru = Structural pattern of residence of office workers

fmlvow = Household car ownership

1 = Private automobile	2 = None

trporgin = Trip origin (Place)

trpdstin = Trip destination (Office)

1 = Sheltech (Pvt. Ltd.)	2 = EPC
3 = BFL	

frqoftrp = Frequency of trip (weekly)

distance = Distance from home to office in Km

nomodes = Total number of available modes

primode = Most frequently chosen mode (primary mode)

1 = Public bus	2 = Private auto
3 = Auto rickshaw	4 = Rickshaw
5 = Walk	

ivtt = In vehicle travel time in minutes

ovtt = Out vehicle travel time in minutes (adding access time, waiting time and egress time together)

acestime = Access time in minutes

waittime = Waiting time in minutes

egrstime = Egress time in minutes

cost = Cost of travel in Tk.

smode = Supporting mode with primary mode

1 = Yes	2 = No

smprim = supporting mode with primary mode

1 = Rickshaw	2 = Walk

avamod1 = Alternative Mode 1

1 = Public bus	2 = Private auto
3 = Auto rickshaw	4 = Rickshaw
5 = Walk	

avemod2 = Alternative Mode 2

1 = Public bus	2 = Private auto
3 = Auto rickshaw	4 = Rickshaw
5 = Walk	

paccess = Accessibility of public bus

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

pconvenc = Convenience of public bus

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

pprivacy =Privacy of public bus

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

psafety =Safety of public bus

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

pcomfort =Comfort of public bus

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

paaccess =Accessibility of private auto

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

paconcen =Convenience of private auto

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

paprivac =Privacy of private auto

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

pasafety = Safety of private auto

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

pacomfor = Comfort of private auto

1 = Very poor	2 = Poor
3 = Moderate	4 = Good

5 = Very good

aracess = Accessibility of auto rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

arconven = Convenience of auto rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

arprivac = Privacy of auto rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

arsafety = Safety of auto rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

arcomfor = Comfort of auto rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

racess = Accessibility of rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

rconvenc = Convenience of rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

rprivacy = Privacy of rickshaw

1 = Very poor	2 = Poor
3 = Moderate	4 = Good
5 = Very good	

rsafety = Safety of rickshaw

1 = Very poor	2 = Poor

3 = Moderate 4 = Good

5 = Very good

rcomfort = Comfort of rickshaw

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

wacess = Accessibility of walk

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

wconvenc = Convenience of walk

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

wprivacy = Privacy of walk

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

wsafety = Safety of walk

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

wcomfort = Comfort of walk

1 = Very poor 2 = Poor

3 = Moderate 4 = Good

5 = Very good

Appendix C

Appendix C

Table C-1: Data set of Two Hundred and Fifty Office Workers to Develop Nested Logit Model

ID	Variables (Socio-economic and Travel Attributes)																		
	age	sex	eduqal	status	famsiz	hhinc	hhcow	dist	ivtt	ovtt	cost	acess	convence	privacy	safety	comfort	Y	NIJ	ALTIJ
1	24	1	6	1	4	13000	0	3.00	20	2	20.00	5	4	5	4	3	1	1	4
2	30	1	6	1	2	30000	0	2.00	20	13	25.00	5	3	3	3	4	1	2	4
	30	1	6	1	2	30000	0	2.00	25	0	.00	3	5	3	4	5	0	2	5
3	24	1	6	1	5	13000	0	10.00	50	12	15.00	4	3	2	2	2	1	2	1
	24	1	6	1	5	13000	0	10.00	30	10	80.00	5	5	4	5	5	0	2	3
4	18	1	2	1	3	4000	0	2.00	15	0	.00	5	5	4	4	5	1	1	5
5	28	1	3	1	3	6000	0	.50	5	0	10.00	4	3	4	3	2	0	2	4
	28	1	3	1	3	6000	0	.50	10	0	.00	2	4	3	2	2	1	2	5
6	44	1	7	1	3	35000	0	7.00	25	20	60.00	4	3	4	3	4	1	2	3
	44	1	7	1	3	35000	0	7.00	45	0	45.00	2	3	4	3	3	0	2	4
7	27	1	6	1	10	13000	0	4.00	20	20	7.00	3	2	3	3	2	1	1	1
8	25	1	6	1	6	10000	0	16.00	45	20	15.00	3	4	4	5	4	1	1	1
9	29	1	6	1	6	10000	0	25.00	60	31	25.00	2	3	1	3	3	1	1	1
10	56	1	7	1	4	50000	0	7.00	45	24	15.00	3	3	3	4	3	1	1	1
11	52	0	7	1	4	35000	1	6.00	45	18	12.00	4	3	2	5	2	0	2	1
	52	0	7	1	4	35000	1	6.00	45	0	72.00	5	5	5	4	5	1	2	2
12	29	1	6	1	3	35000	0	10.00	30	30	15.00	2	3	2	3	2	1	1	1
13	28	1	6	1	3	22000	0	8.00	50	25	18.00	1	2	1	3	1	1	1	1
14	28	1	6	1	4	21000	0	9.50	45	22	15.00	5	5	2	5	3	1	3	1
	28	1	6	1	4	21000	0	9.50	25	18	70.00	1	2	4	2	4	0	3	3
	28	1	6	1	4	21000	0	9.50	35	8	35.00	2	1	3	3	2	0	3	4
15	30	0	6	1	2	23000	0	7.50	20	17	60.00	3	2	4	4	4	0	2	3
	30	0	6	1	2	23000	0	7.50	20	5	40.00	4	3	4	2	3	1	2	4
16	25	1	6	1	3	18000	0	3.50	20	16	10.00	4	3	2	3	3	1	2	1

	25	1	6	1	3	18000	0	3.50	30	10	30.00	3	3	4	3	4	0	2	4
17	25	1	6	1	3	20000	0	.25	5	8	8.00	3	3	4	4	1	0	2	4
	25	1	6	1	3	20000	0	.25	5	0	.00	3	5	4	4	2	1	2	5
18	47	1	3	1	4	25000	0	.50	10	0	.00	4	5	3	3	2	1	1	5
19	19	1	2	1	8	4400	0	.50	5	0	00	2	5	3	3	4	1	1	5
20	29	0	5	1	2	15000	0	6.00	35	25	10.00	2	4	3	3	2	1	2	1
	29	0	5	1	2	15000	0	6.00	60	8	60.00	4	2	3	2	4	0	2	4
21	23	0	5	1	2	12000	0	7.00	40	30	22.00	2	4	3	2	2	1	2	1
	23	0	5	1	2	12000	0	7.00	45	5	35.00	4	2	3	3	4	0	2	4
22	33	1	4	1	7	17000	0	.50	5	0	.00	3	4	3	2	2	1	1	5
23	25	1	6	1	5	18500	0	3.50	20	13	4.00	3	4	2	2	3	1	2	1
	25	1	6	1	5	18500	0	3.50	30	15	30.00	2	3	4	4	4	0	2	4
24	27	0	6	1	2	18500	0	10.00	50	20	15.00	3	3	2	3	3	0	2	1
	27	0	6	1	2	18500	0	10.00	45	15	70.00	3	1	4	3	3	1	2	3
25	27	1	7	1	4	12000	0	8.00	45	15	20.00	4	3	3	5	4	1	3	1
	27	1	7	1	4	12000	0	8.00	30	22	80.00	1	2	3	5	5	0	3	3
	27	1	7	1	4	12000	0	8 00	60	10	10.00	2	1	5	3	5	0	3	4
26	29	1	7	1	6	15000	0	3.50	15	15	8.00	2	2	2	1	2	1	1	1
27	34	1	7	1	7	25000	0	1.50	30	15	18 00	2	3	4	4	4	1	1	4
28	28	1	6	1	7	11500	0	.50	6	0	.00	4	4	3	2	4	1	1	5
29	28	1	7	1	10	12000	1	10.00	60	19	15.00	2	3	2	2	2	1	3	1
	28	1	7	1	10	12000	1	10.00	30	0	120.00	2	2	4	4	4	0	3	2
	28	1	7	1	10	12000	1	10.00	30	21	70.00	2	2	4	4	4	0	3	3
30	30	1	7	1	4	18450	1	2.00	25	0	48.00	5	3	4	4	4	0	2	2
	30	1	7	1	4	18450	1	2.00	5	10	10.00	2	2	2	2	2	1	2	4
31	17	1	3	1	6	4000	2	1.50	10	5	12.00	3	2	3	4	4	0	2	4
	17	1	3	1	6	4000	0	1.50	15	0	.00	3	4	4	5	5	1	2	5
32	19	1	2	1	4	4400	0	.50	10	0	.00	2	5	3	4	4	1	1	5
33	25	1	2	1	8	4000	0	.50	20	0	.00	5	5	4	4	4	1	1	5
34	41	1	4	1	5	13000	0	1.00	10	5	10.00	3	1	3	4	5	0	2	4

	41	1	4	1	5	13000	0	1.00	12	0	.00	3	3	4	5	5	1	2	5
35	30	1	7	1	6	12000	0	8.00	30	20	10.00	2	3	3	4	2	1	2	1
	30	1	7	1	6	12000	0	8.00	25	15	60.00	1	1	4	4	4	0	2	3
36	27	1	6	1	9	12000	0	2.00	5	5	10.00	3	4	3	3	3	0	2	4
	27	1	6	1	9	12000	0	2.00	15	0	.00	3	4	3	3	3	1	2	5
37	36	1	7	1	2	35000	0	9 00	45	44	15.00	2	3	2	3	2	1	2	1
	36	1	7	1	2	35000	0	9.00	45	10	70.00	3	3	3	3	3	0	2	3
38	42	1	6	1	4	23000	0	3.00	10	16	6.00	4	3	4	3	4	1	2	1
	42	1	6	1	4	23000	0	3.00	20	6	15.00	4	3	4	2	3	0	2	4
39	23	1	6	1	4	13100	0	2.00	10	10	2.00	3	3	4	4	2	1	1	1
40	20	1	2	1	7	4400	0	.25	3	0	.00	4	5	4	4	4	1	1	5
41	31	1	7	1	6	23000	0	2.00	7	20	2.00	2	2	1	1	2	1	1	1
42	23	1	7	1	5	12000	0	3.50	40	34	10.00	3	4	5	4	4	1	2	1
	23	1	7	1	5	12000	0	3.50	25	10	60.00	3	4	3	3	4	0	2	3
43	28	1	7	1	7	14000	0	8.00	35	18	20.00	2	2	2	2	2	1	1	1
44	29	1	6	1	10	18000	0	2.00	10	7	8.00	3	3	1	4	3	1	2	1
	29	1	6	1	10	18000	0	2.00	16	5	20.00	3	3	5	3	5	0	2	4
45	27	1		1	7	12000	0	8.00	45	30	8.00	3	2	3	1	2	1	1	1
46	46	1		1	5	23250	0	4.00	15	10	20.00	3	3	4	4	4	1	1	4
47	25	1	3	1	9	5500	0	1.00	20	20	10.00	3	3	4	3	4	1	1	4
48	27	0	6	1	5	22000	0	7.25	30	5	70.00	4	4	3	2	3	1	2	3
	27	0	6	1	5	22000	0	7.25	40	0	35.00	4	3	3	2	3	0	2	4
49	32	1	7	1	4	50000	1	2.00	10	0	24.00	4	4	4	3	5	0	2	2
	32	1	7	1	4	50000	1	2.00	15	10	20.00	3	2	2	2	3	1	2	4
50	36	1	6	1	3	50000	0	.25	10	0	.00	5	5	5	3	4	1	1	5
51	31	1	6	1	5	18500	0	2.00	35	6	15.00	1	3	3	2	2	0	2	1
	31	1	6	1	5	18500	0	2.00	40	3	20.00	3	2	5	3	4	1	2	4
52	31	1	5	1	3	18500	0	20.00	60	35	12.00	2	3	3	2	1	1	1	1
53	43	1	5	1	4	19900	0	3 00	15	16	8.00	3	2	3	3	3	1	2	1
	43	1	5	1	4	19900	0	3.00	20	8	25.00	4	2	3	4	5	0	2	4

54	28	1	7	1	10	12000	0	6.00	25	20	10.00	1	1	2	2	1	1	2	1
	28	1	7	1	10	12000	0	6.00	15	30	65.00	1	2	3	3	4	0	2	3
55	31	1	6	1	2	30000	0	8.00	15	25	10.00	2	2	2	1	2	1	2	1
	31	1	6	1	2	30000	0	8.00	30	15	30.00	3	3	3	2	4	0	2	4
56	26	0	6	1	4	15500	1	11.00	45	0	132.00	5	5	5	5	5	1	2	2
	26	0	6	1	4	15500	1	11.00	45	20	85.00	1	2	3	3	4	0	2	3
57	26	1	6	1	5	12000	0	.50	10	0	10.00	4	3	5	4	3	1	2	4
	26	1	6	1	5	12000	0	.50	15	0	.00	3	3	4	5	4	0	2	5
58	23	1	2	1	4	4000	0	.25	8	0	.00	3	5	5	4	5	1	1	5
59	22	1	1	1	7	4000	0	.50	10	0	.00	2	3	3	4	5	1	1	5
60	24	1	2	1	6	4000	0	1.00	12	0	.00	4	4	4	3	4	1	1	5
61	35	1	3	1	3	5000	0	.50	8	0	.00	2	4	3	4	5	1	1	5
62	41	1	4	1	5	5000	0	1.00	15	0	.00	3	5	4	4	5	1	1	5
63	39	1	2	1	4	5000	0	6.50	20	25	4.00	3	2	3	2	1	1	1	1
64	45	1	2	1	3	5000	0	2.00	5	15	1.00	1	5	2	4	2	1	1	1
65	22	1	2	1	4	4200	0	1.00	14	0	.00	3	5	4	5	1	1	1	5
66	25	1	1	1	3	4400	0	2.00	20	0	.00	2	4	3	2	4	1	1	5
67	26	1	2	1	8	4000	0	2.00	5	15	2.00	2	4	3	2	2	1	1	1
68	20	1	2	1	7	4000	0	1.00	15	20	20.00	3	2	4	4	2	1	1	4
69	23	1	2	1	3	4000	0	.50	12	0	.00	4	4	3	4	2	1	1	5
70	60	1	7	1	9	50000	0	30.00	75	18	44.00	3	4	3	4	4	1	1	1
71	46	1	7	1	4	40000	0	7.00	30	48	10.00	2	3	1	4	3	1	3	1
	46	1	7	1	4	40000	0	7.00	30	30	70.00	2	4	5	3	5	0	3	3
	46	1	7	1	4	40000	0	7.00	50	20	50.00	3	4	5	2	4	0	3	4
72	26	1	6	1	5	15000	0	4.00	30	17	6.00	3	3	2	2	2	1	1	1
73	28	1	6	1	5	10000	0	1.00	4	16	1.00	4	3	2	2	3	0	2	1
	28	1	6	1	5	10000	0	1.00	12	3	15.00	4	4	3	2	4	1	2	4
74	30	1	7	1	2	30000	0	7 00	40	19	10.00	3	3	2	3	2	1	2	1
	30	1	7	1	2	30000	0	7.00	40	18	100.00	2	2	5	4	4	0	2	3
75	61	1	6	1	4	30000	1	5.00	20	29	10.00	2	3	3	3	2	0	2	1

	61	1	6	1	4	30000	1	5.00	20	0	60.00	4	4	4	4	4	1	2	2
76	25	0	6	1	4	9000	0	6.50	30	29	15.00	3	3	4	4	3	1	2	1
	25	0	6	1	4	9000	0	6.50	35	20	50.00	3	4	4	3	4	0	2	3
77	25	0	6	1	4	9000	0	3.00	15	26	8.00	2	3	3	3	3	1	2	1
	25	0	6	1	4	9000	0	3.00	50	0	35.00	4	4	4	4	4	0	2	4
78	24	1	6	1	5	9000	1	4.00	45	0	48.00	5	5	5	5	5	1	2	2
	24	1	6	1	5	9000	1	4.00	20	10	50.00	3	4	4	4	4	0	2	3
79	28	0	7	1	3	6000	0	1.00	10	0	15.00	5	5	5	5	5	1	1	4
80	41	1	7	1	5	14000	0	30.00	95	39	30.00	2	2	3	2	2	1	1	1
81	40	1	7	1	5	17000	0	7.50	50	19	12.00	2	2	3	3	2	1	1	1
82	57	1	6	1	3	14000	0	2.00	15	19	8.00	3	2	5	4	4	1	1	1
83	55	1	2	1	4	7250	0	11.50	30	38	8.00	3	2	3	3	3	1	1	1
84	42	1	6	1	4	17500	0	6.50	15	31	4.00	1	4	3	2	2	1	1	1
85	40	1	7	0	3	15000	0	2.00	20	20	40.00	2	1	5	4	4	0	2	3
	40	1	7	0	3	15000	0	2.00	20	10	15.00	4	3	3	2	4	1	2	4
86	23	0	6	1	6	8000	0	1.00	5	0	10.00	3	2	5	4	4	1	1	4
87	26	1	6	1	6	14000	1	1.00	10	0	12.00	5	5	5	5	5	1	2	2
	26	1	6	1	6	14000	1	1.00	15	5	12.00	3	2	2	2	2	0	2	4
88	25	1	6	1	6	10000	0	8.50	55	39	15.00	3	2	4	2	3	1	1	1
89	25	1	6	1	4	10000	0	4.00	30	17	10.00	4	4	2	2	2	1	1	1
90	40	1	6	1	3	30000	1	9.00	40	0	18.00	5	5	5	5	5	1	1	2
91	47	1	6	1	4	15000	0	6.00	45	47	10.00	2	2	2	3	2	1	1	1
92	24	1	6	1	5	10000	0	30.00	60	14	25.00	4	3	2	4	2	1	1	1
93	30	1	6	1	7	15000	0	9.00	30	14	12.00	3	3	2	4	3	1	2	1
	30	1	6	1	7	15000	0	9.00	20	20	80.00	2	2	4	3	4	0	2	3
94	30	1	7	1	1	410000	1	7.50	45	0	84.00	5	4	5	5	5	1	1	2
95	44	1	8	1	1	245000	1	9.00	45	0	108.00	5	5	5	5	5	1	1	2
96	51	1	6	1	4	35000	0	2.00	15	0	20.00	3	3	2	3	4	1	1	4
97	51	1	7	1	3	40000	0	2.00	15	13	25.00	3	3	2	3	4	1	1	4
98	48	1	7	1	2	45000	1	5.00	30	0	10.00	4	4	4	3	4	1	1	2

99	59	1	6	1	5	45000	1	3.00	15	0	6.00	5	5	5	5	5	1	1	2
100	55	1	7	1	6	55000	1	18.00	60	0	216.00	4	4	5	5	4	1	2	2
	55	1	7	1	6	55000	1	18.00	60	10	120.00	2	1	3	4	5	0	2	3
101	41	1	4	1	5	13500	0	1.00	5	15	1.00	4	4	3	4	3	1	2	1
	41	1	4	1	5	13500	0	1.00	10	11	12.00	4	3	3	2	2	0	2	4
102	59	1	6	1	5	45000	1	4.50	30	0	9.00	5	5	5	5	5	1	1	2
103	50	1	7	0	7	50000	1	.50	5	0	1.00	5	5	5	5	5	1	1	2
104	70	1	7	1	3	245000	1	.50	10	0	6.00	5	5	5	5	5	1	2	2
	70	1	7	1	3	245000	1	.50	12	5	15.00	2	4	3	3	3	0	2	4
105	70	1	8	1	1	245000	1	7.50	45	0	15.00	5	5	5	5	5	1	1	2
106	57	1	6	1	4	105000	1	.50	5	0	1.00	5	5	5	5	5	1	1	2
107	50	1	5	1	4	13000	0	1.00	2	13	1.00	3	2	2	4	2	0	2	1
	50	1	5	1	4	13000	0	1.00	15	0	12.00	4	2	4	3	3	1	2	4
108	42	1	6	1	4	10000	0	6.50	35	34	8.00	4	3	3	4	2	1	2	1
	42	1	6	1	4	10000	0	6.50	30	20	60.00	1	1	4	3	3	0	2	3
109	41	1	6	1	4	13000	0	6.50	35	15	8.00	4	2	3	5	2	1	1	1
110	38	1	2	1	4	6050	0	14.00	90	40	11.00	3	2	2	5	3	1	1	1
111	30	1	6	1	2	10000	0	6.50	20	24	15.00	4	4	3	2	1	1	1	1
112	40	1	4	1	3	11000	0	6.50	20	25	15.00	3	2	2	4	3	1	1	1
113	50	1	4	1	3	22000	0	10.00	40	20	15.00	3	2	2	1	2	1	2	1
	50	1	4	1	3	22000	0	10.00	35	25	70.00	2	1	4	3	5	0	2	3
114	27	0	7	1	4	6000	0	1.00	12	20	15.00	3	3	3	4	5	1	2	4
	27	0	7	1	4	6000	0	1.00	20	0	.00	3	5	2	4	4	0	2	5
115	35	1	3	1	3	5000	0	2.00	5	12	2.00	3	4	3	5	3	1	2	1
	35	1	3	1	3	5000	0	2.00	20	0	.00	3	3	3	4	4	0	2	5
116	40	1	4	1	5	5000	0	.50	15	0	.00	3	4	4	5	5	1	1	5
117	24	1	3	1	4	4500	0	6.50	20	20	10.00	3	3	3	4	3	1	1	1
118	20	1	2	1	6	4000	0	2.00	15	25	5.00	3	4	2	5	3	1	1	1
119	30	1	2	1	2	4200	0	2.00	5	10	2.00	3	4	2	5	5	1	1	1
120	26	1	2	1	1	4200	0	1.00	20	0	.00	4	5	5	5	5	1	1	5

121	30	1	3	1	4	15000	0	4.25	15	40	4.00	2	1	1	2	2	1	2	1
	30	1	3	1	4	15000	0	4.25	30	10	30.00	4	4	4	4	4	0	2	4
122	26	1	6	1	2	10000	0	2.00	10	10	12.00	1	2	3	2	3	1	1	4
123	26	0	6	1	4	10000	0	1 50	15	10	12.00	3	3	2	4	3	1	2	1
	26	0	6	1	4	10000	0	1.50	15	10	15.00	3	3	4	2	4	0	2	4
124	31	1	7	1	2	30000	0	3.00	30	30	6.00	2	2	1	3	1	1	2	1
	31	1	7	1	2	30000	0	3.00	35	20	35.00	2	4	4	4	4	0	2	4
125	27	1	6	1	3	22000	0	8.00	25	28	10.00	1	1	2	2	2	1	1	1
126	26	1	5	1	6	10000	0	3.00	15	39	8.00	2	1	3	3	3	1	3	1
	26	1	5	1	6	10000	0	3.00	15	28	50.00	2	2	4	3	5	0	3	3
	26	1	5	1	6	10000	0	3.00	25	13	25.00	2	2	3	3	3	0	3	4
127	34	1	6	1	3	16000	0	8.00	30	27	18.00	2	2	1	1	1	1	2	1
	34	1	6	1	3	16000	0	8.00	30	15	70.00	2	3	3	4	4	0	2	3
128	25	0	6	1	4	8000	0	3.00	25	15	6.00	1	1	1	1	1	1	2	1
	25	0	6	1	4	8000	0	3.00	30	10	30.00	4	4	4	4	4	0	2	4
129	37	0	6	1	5	20000	0	4.00	30	34	10.00	3	4	3	3	2	1	3	1
	37	0	6	1	5	20000	0	4.00	30	5	70.00	5	5	5	4	5	0	3	3
	37	0	6	1	5	20000	0	4.00	45	0	35.00	3	4	4	3	4	0	3	4
130	31	1	7	1	4	30000	0	8.00	20	35	10.00	3	4	4	4	3	1	2	1
	31	1	7	1	4	30000	0	8.00	35	0	30.00	3	4	4	3	4	0	2	4
131	26	1	6	1	6	7000	0	20.00	75	25	20.00	2	3	3	2	1	1	2	1
	26	1	6	1	6	7000	0	20.00	50	5	140.00	4	1	3	4	5	0	2	3
132	32	1	7	1	2	25000	0	7.00	40	18	12.00	2	5	2	3	2	1	2	1
	32	1	7	1	2	25000	0	7.00	25	5	80.00	4	3	5	5	5	0	2	3
133	30	1	6	1	4	16000	0	20.00	90	25	20.00	1	3	2	1	2	1	1	1
134	27	1	6	1	4	16000	0	10.50	60	37	10.00	2	4	5	5	3	1	1	1
135	26	0	7	1	2	7000	0	1.50	10	0	10.00	1	4	3	5	5	0	2	4
	26	0	7	1	2	7000	0	1.50	20	0	.00	4	3	4	4	3	1	2	5
136	26	1	7	1	3	10000	0	20.00	40	10	16.00	3	3	1	3	1	1	2	1
	26	1	7	1	3	10000	0	20.00	40	10	80.00	3	2	4	4	4	0	2	3

137	24	0	6	1	4	6000	0	1.50	10	0	8.00	3	3	4	4	4	0	2	4
	24	0	6	1	4	6000	0	1.50	15	0	.00	3	4	4	3	4	1	2	5
138	24	1	4	1	6	6000	0	4.00	30	10	25.00	4	3	3	4	4	1	1	4
139	30	1	6	1	1	4000	0	8.00	30	25	10.00	1	1	1	1	1	1	1	1
140	35	1	6	1	4	30000	0	7.00	40	15	15.00	2	2	2	3	3	0	2	1
	35	1	6	1	4	30000	0	7.00	25	18	60.00	4	4	4	3	4	1	2	3
141	28	1	6	1	5	13000	0	1.50	10	0	.00	3	4	4	4	5	1	1	5
142	26	0	6	1	2	20000	0	5.50	30	22	10.00	1	1	1	1	1	1	2	1
	26	0	6	1	2	20000	0	5.50	25	10	50.00	3	4	4	3	5	0	2	3
143	26	1	6	1	5	12000	0	8.00	30	25	10.00	2	1	1	2	2	1	2	1
	26	1	6	1	5	12000	0	8.00	20	15	80.00	3	2	3	3	3	0	2	3
144	26	1	6	1	4	5000	0	8.00	25	12	10.00	4	3	1	3	4	1	1	1
145	36	1	2	1	4	4400	0	1.00	10	0	.00	4	4	3	4	5	1	1	5
146	46	1	3	1	3	13500	0	20.00	60	29	20.00	1	2	1	2	2	1	1	1
147	27	1	6	1	1	10000	0	8.00	30	33	10.00	4	1	1	4	3	1	1	1
148	32	1	6	1	8	40000	0	2.00	30	5	20.00	3	3	3	2	2	1	1	4
149	26	1	3	1	4	8000	0	8.00	10	23	8.00	3	2	1	2	2	1	1	1
150	32	1	5	1	4	10000	0	10.00	20	45	15.00	3	2	2	2	2	1	2	1
	32	1	5	1	4	10000	0	10.00	30	10	35.00	4	4	3	3	3	0	2	4
151	30	1	6	1	3	15000	0	20.00	55	20	20.00	2	3	2	4	2	1	2	1
	30	1	6	1	3	15000	0	20.00	50	20	100.00	2	1	3	3	4	0	2	3
152	22	0	6	1	7	7000	0	3.00	15	25	10.00	3	2	2	3	2	0	2	1
	22	0	6	1	7	7000	0	3.00	30	10	25.00	4	3	4	3	3	1	2	4
153	31	1	2	1	5	4500	0	1.00	5	0	.00	4	5	3	3	3	1	1	5
154	26	1	2	1	4	2500	0	8.00	50	20	10.00	3	3	2	2	3	1	1	1
155	26	1	7	1	5	20000	0	20.00	60	30	20.00	3	2	2	2	1	1	2	1
	26	1	7	1	5	20000	0	20.00	50	35	110.00	3	3	3	4	3	0	2	3
156	20	1	5	1	5	8080	0	7.00	55	14	10.00	3	2	2	2	1	1	1	1
157	28	1	6	1	4	20000	0	.25	3	5	5.00	4	4	4	2	3	0	2	4
	28	1	6	1	4	20000	0	.25	5	0	.00	4	5	3	2	4	1	2	5

158	27	0	7	1	4	15000	0	4.00	10	25	12.00	2	4	1	3	2	0	3	1
	27	0	7	1	4	15000	0	4.00	20	0	60.00	3	1	4	3	4	0	3	3
	27	0	7	1	4	15000	0	4.00	30	10	35.00	2	2	3	2	3	1	3	4
159	28	1	7	1	11	15000	0	7.00	20	35	10.00	1	3	1	2	2	1	2	1
	28	1	7	1	11	15000	0	7.00	20	30	60.00	1	3	4	4	4	0	2	3
160	32	1	7	1	8	50000	1	25.00	45	0	50.00	5	5	5	5	5	1	1	2
161	29	1	7	1	9	20000	0	3.00	30	15	30.00	2	3	2	4	2	1	2	1
	29	1	7	1	9	20000	0	3.00	30	15	30.00	4	4	2	2	3	0	2	4
162	31	1	7	1	5	45000	1	20.00	50	0	40.00	5	5	5	5	5	1	1	2
163	25	1	6	1	4	6000	0	3 50	20	20	50.00	4	5	4	4	5	0	2	3
	25	1	6	1	4	6000	0	3.50	40	15	20.00	1	2	4	5	2	1	2	4
164	25	0	6	1	5	10000	0	8.00	15	22	70.00	1	2	3	2	3	1	2	3
	25	0	6	1	5	10000	0	8.00	40	10	40.00	2	1	3	1	1	0	2	4
165	26	1	6	1	5	15000	0	10.00	50	35	15.00	3	2	3	2	2	1	1	1
166	26	0	7	1	5	10000	0	3.00	15	10	8.00	4	3	3	4	3	1	2	1
	26	0	7	1	5	10000	0	3.00	35	0	40.00	4	3	4	4	3	0	2	4
167	33	1	7	1	3	19000	0	7.00	45	22	15.00	2	4	2	2	1	1	2	1
	33	1	7	1	3	19000	0	7.00	40	5	80.00	4	2	4	3	2	0	2	3
168	26	1	2	1	2	6500	0	7.00	45	25	15.00	3	2	3	4	3	1	2	1
	26	1	2	1	2	6500	0	7.00	35	10	60.00	3	2	4	4	4	0	2	3
169	24	1	7	1	5	12000	0	1.00	7	0	.00	4	5	4	3	4	1	1	5
170	29	1	7	1	7	15000	1	8.00	30	39	10.00	2	3	3	2	1	1	3	1
	29	1	7	1	7	15000	1	8.00	25	0	16.00	5	4	5	5	5	0	3	2
	29	1	7	1	7	15000	1	8.00	20	15	60.00	4	1	3	4	4	0	3	3
171	35	1	7	1	2	50000	1	7.00	35	0	14.00	5	5	5	5	5	1	1	2
172	26	1	6	1	4	9000	0	8.00	35	23	10.00	2	3	2	4	4	1	2	1
	26	1	6	1	4	9000	0	8.00	30	24	60.00	2	1	4	4	5	0	2	3
173	24	1	6	1	9	9000	0	.25	5	0	.00	2	5	4	5	5	1	1	5
174	28	1	7	1	7	18000	0	10.00	60	25	14.00	3	2	3	4	3	1	2	1
	28	1	7	1	7	18000	0	10.00	45	30	80.00	4	3	3	3	4	0	2	3

175	35	1	7	1	4	70000	1	20.00	60	0	40.00	5	5	5	5	5	1	1	2
176	31	1	7	1	3	20000	0	20.00	75	20	20.00	3	2	2	3	3	1	2	1
	31	1	7	1	3	20000	0	20.00	55	20	150.00	1	1	4	2	4	0	2	3
177	44	1	6	1	2	80000	1	3.00	30	20	12.00	1	1	1	1	1	0	3	1
	44	1	6	1	2	80000	1	3.00	25	0	.00	5	5	5	5	5	1	3	2
	44	1	6	1	2	80000	1	3 00	30	0	30.00	3	3	2	3	4	0	3	4
178	41	1	7	1	2	80000	1	3.00	25	0	6.00	5	5	5	5	5	1	1	2
179	37	1	7	1	4	20000	0	20.00	60	38	16.00	1	1	1	1	1	1	1	1
180	38	1	2	1	4	12200	0	6.00	50	30	14.00	3	2	3	3	3	1	2	1
	38	1	2	1	4	12200	0	6.00	25	30	80.00	2	3	4	4	3	0	2	3
181	23	0	5	1	5	6500	0	1.50	20	3	12.00	3	4	4	1	4	1	2	4
	23	0	5	1	5	6500	0	1.50	30	0	.00	2	4	4	4	4	0	2	5
182	32	0	6	1	4	23000	1	8.00	50	0	16.00	5	5	5	5	5	1	1	2
183	28	1	6	1	6	20000	0	.25	5	0	5.00	3	3	4	5	3	0	2	4
	28	1	6	1	6	20000	0	.25	5	0	.00	3	5	4	4	3	1	2	5
184	26	1	6	1	3	8000	0	.25	3	0	.00	3	5	5	5	5	1	1	5
185	32	1	7	1	5	15000	0	1.00	6	5	8.00	4	2	4	5	3	1	2	4
	32	1	7	1	5	15000	0	1.00	10	0	.00	2	4	3	4	4	0	2	5
186	27	1	6	1	3	8000	0	20.00	60	22	20.00	3	2	4	4	4	1	1	1
187	26	1	6	1	6	7000	0	20.00	75	31	20.00	2	3	4	3	3	1	1	1
188	31	1	6	1	4	8000	0	20.00	65	25	20.00	3	2	3	4	2	1	1	1
189	38	1	4	1	6	13000	0	20.00	70	30	20.00	3	2	4	3	3	1	2	1
	38	1	4	1	6	13000	0	20.00	50	23	100.00	2	1	4	4	4	0	2	3
190	38	1	6	1	3	45000	1	7.00	60	0	14.00	5	5	5	5	5	1	1	2
191	28	1	6	1	4	15000	0	10.00	55	30	14.00	1	2	3	3	3	1	2	1
	28	1	6	1	4	15000	0	10.00	60	20	40.00	3	2	3	4	2	0	2	4
192	25	1	6	1	6	7000	0	8.00	40	20	15.00	2	3	2	2	3	1	2	1
	25	1	6	1	6	7000	0	8.00	45	12	40.00	2	2	5	4	5	0	2	4
193	24	1	2	1	4	4500	0	1.00	8	0	.00	2	5	4	5	5	1	1	5
194	30	1	6	1	7	9000	0	3.00	20	15	10.00	3	4	2	4	3	1	2	1

	30	1	6	1	7	9000	0	3.00	30	14	35.00	2	2	4	3	2	0	2	4
195	26	1	6	1	4	14000	0	3.50	25	17	10.00	4	2	3	4	4	1	2	1
	26	1	6	1	4	14000	0	3.50	30	17	35.00	3	2	4	4	2	0	2	4
196	32	1	7	1	3	15000	0	.25	5	0	.00	4	5	3	5	5	1	1	5
197	22	1	2	1	6	6000	0	.25	4	0	.00	4	5	4	5	4	1	1	5
198	29	1	6	1	4	7000	0	8.00	45	30	12.00	1	2	3	4	2	1	2	1
	29	1	6	1	4	7000	0	8.00	45	25	40.00	2	1	4	3	2	0	2	4
199	30	1	4	1	5	6000	0	.25	5	0	.00	3	5	4	5	5	1	1	5
200	45	1	7	1	4	30000	0	3.50	20	27	8.00	2	3	3	5	3	1	2	1
	45	1	7	1	4	30000	0	3.50	25	12	25.00	2	1	5	3	5	0	2	3
201	40	1	7	1	3	30000	1	8.00	25	0	96.00	5	5	5	5	5	1	2	2
	40	1	7	1	3	30000	1	8.00	30	25	80.00	2	3	4	4	4	0	2	3
202	25	1	2	1	1	4000	0	.25	5	0	.00	3	5	4	4	4	1	1	5
203	22	1	3	1	3	4500	0	.25	6	0	.00	3	5	5	5	4	1	1	5
204	27	1	6	1	4	8000	0	20.00	60	25	20.00	3	2	3	4	3	1	1	1
205	26	1	6	1	2	8000	0	7.00	30	23	10.00	2	3	2	2	2	1	1	1
206	29	1	7	1	6	15000	0	10.00	60	15	20.00	3	2	2	4	3	1	1	1
207	27	1	6	1	4	7000	0	20.00	65	15	20.00	2	3	3	3	3	1	1	1
208	38	1	7	1	3	20000	0	20.00	55	10	20.00	2	3	3	4	4	1	2	1
	38	1	7	1	3	20000	0	20.00	45	20	120.00	3	2	4	3	5	0	2	3
209	29	0	7	1	2	20000	1	7.00	25	0	14.00	5	5	5	5	5	1	1	2
210	24	1	2	1	5	4500	0	1.00	10	0	.00	3	5	4	4	4	1	1	5
211	36	1	7	1	4	30000	0	20.00	60	12	20.00	2	3	2	2	2	0	2	1
	36	1	7	1	4	30000	0	20.00	50	26	120.00	2	3	4	5	5	1	2	3
212	47	1	7	1	3	50000	1	1.00	10	0	2.00	5	5	5	5	5	1	1	2
213	28	1	6	1	4	8000	0	5.00	27	21	10.00	2	2	3	3	2	1	1	1
214	29	1	6	1	2	16000	0	8.00	30	22	10.00	4	3	2	3	3	1	2	1
	29	1	6	1	2	16000	0	8.00	30	20	70.00	2	1	4	5	4	0	2	3
215	27	1	6	1	3	12000	0	2.00	15	30	8.00	1	4	3	4	3	0	2	1
	27	1	6	1	3	12000	0	2.00	25	10	30.00	4	3	4	4	3	1	2	4

216	23	1	2	1	4	4000	0	8.00	35	24	12.00	2	3	2	4	4	1	1	1
217	28	1	6	1	5	7000	0	6.00	45	25	12.00	2	3	3	5	5	1	1	1
218	35	1	3	1	4	5000	0	.25	6	0	.00	4	5	5	5	5	1	1	5
219	28	1	3	1	3	4000	0	.25	5	0	.00	3	5	4	5	4	1	1	5
220	32	1	7	1	2	20000	0	3.00	10	12	6.00	2	3	2	2	1	0	2	1
	32	1	7	1	2	20000	0	3.00	25	12	30.00	4	3	4	4	4	1	2	4
221	27	1	2	1	4	4500	0	1.00	10	0	.00	4	4	3	5	4	1	1	5
222	31	1	6	1	5	16000	0	6.00	40	20	12.00	2	3	2	4	4	1	2	1
	31	1	6	1	5	16000	0	6.00	35	30	70.00	2	3	4	5	5	0	2	3
223	45	1	2	1	3	5000	0	.25	8	0	.00	4	5	3	5	5	1	1	5
224	34	1	3	1	7	11000	0	20.00	55	20	20.00	3	2	2	4	4	1	2	1
	34	1	3	1	7	11000	0	20.00	45	35	120.00	3	2	5	5	5	0	2	3
225	28	1	4	1	4	6000	0	1.00	10	0	.00	2	4	3	4	4	1	1	5
226	26	1	6	1	5	7000	0	3.00	15	10	10.00	3	4	3	4	3	1	2	1
	26	1	6	1	5	7000	0	3.00	30	10	30.00	2	2	4	5	3	0	2	4
227	25	1	6	1	3	12000	0	8.00	30	24	10.00	2	3	2	4	3	1	2	1
	25	1	6	1	3	12000	0	8.00	25	28	60.00	3	2	4	4	5	0	2	3
228	29	1	7	1	2	15000	0	10.00	60	20	14.00	1	2	2	3	2	1	3	1
	29	1	7	1	2	15000	0	10.00	45	30	65.00	2	2	5	5	4	0	3	3
	29	1	7	1	2	15000	0	10.00	60	10	45.00	3	2	4	5	3	0	3	4
229	23	1	2	1	4	4000	0	.50	12	0	.00	2	4	3	4	3	1	1	5
230	24	1	2	1	5	4000	0	.25	5	0	.00	4	5	4	5	5	1	1	5
231	26	1	6	1	4	12000	0	1.50	5	10	2.00	3	4	2	5	4	1	2	1
	26	1	6	1	4	12000	0	1.50	12	5	15.00	3	2	4	5	4	0	2	4
232	26	1	6	1	2	8000	0	2.00	15	30	8.00	3	5	2	4	4	0	2	1
	26	1	6	1	2	8000	0	2.00	20	21	30.00	2	4	3	4	4	1	2	4
233	31	1	7	1	3	15000	0	8.00	35	20	10.00	2	3	2	5	4	1	2	1
	31	1	7	1	3	15000	0	8.00	25	27	60.00	3	3	4	5	3	0	2	3
234	33	1	6	1	5	20000	0	8.00	35	26	10.00	4	2	3	4	3	1	2	1
	33	1	6	1	5	20000	0	8.00	25	20	60.00	4	2	5	5	5	0	2	3

235	30	1	6	1	4	10000	0	.25	5	2	5.00	3	3	4	5	5	0	2	4
	30	1	6	1	4	10000	0	.25	6	0	.00	3	5	4	5	4	1	2	5
236	34	1	7	1	7	22000	0	3.50	20	15	10.00	4	3	2	5	4	1	2	1
	34	1	7	1	7	22000	0	3.50	30	15	35.00	2	2	3	5	3	0	2	4
237	33	1	7	1	4	30000	1	12.00	45	20	15 00	5	5	5	5	5	1	1	2
238	29	1	7	1	3	15000	0	1.50	10	20	6.00	2	3	2	3	4	0	2	1
	29	1	7	1	3	15000	0	1.50	15	10	20.00	4	3	4	5	4	1	2	4
239	24	1	6	1	2	7000	0	4.50	25	12	10 00	3	3	4	5	4	1	1	1
240	35	1	7	1	4	30000	0	7.00	30	20	12.00	2	3	2	2	2	0	2	1
	35	1	7	1	4	30000	0	7.00	25	30	50.00	3	3	4	4	5	1	2	3
241	31	1	7	1	5	15000	0	6.00	45	25	12.00	3	2	3	4	4	1	2	1
	31	1	7	1	5	15000	0	6.00	35	31	50.00	1	2	4	4	4	0	2	3
242	30	1	7	1	4	15000	0	11.00	50	25	15.00	4	2	2	4	4	1	2	1
	30	1	7	1	4	15000	0	11.00	40	31	70.00	2	2	5	4	5	0	2	3
243	25	1	6	1	3	8000	0	20.00	60	25	20.00	2	2	3	3	2	1	1	1
244	36	1	7	1	4	30000	1	7.00	40	30	15.00	2	3	2	3	3	1	3	1
	36	1	7	1	4	30000	1	7.00	25	0	84.00	5	4	5	5	5	0	3	2
	36	1	7	1	4	30000	1	7.00	30	20	50.00	1	2	3	4	4	0	3	3
245	31	1	2	1	7	5000	0	.50	15	0	.00	2	4	3	4	5	1	1	5
246	41	1	2	1	2	5000	0	.25	4	0	.00	3	5	3	4	3	1	1	5
247	47	1	2	1	3	5000	0	1.00	10	0	.00	4	5	4	3	4	1	1	5
248	24	1	3	1	1	4000	0	.25	5	0	.00	5	5	4	3	4	1	1	5
249	22	1	3	1	2	4000	0	.50	10	0	.00	3	4	3	4	5	1	1	5
250	20	1	2	1	4	4000	0	.25	5	0	.00	2	5	4	3	5	1	1	5

Appendix D

Appendix D

Different Socio-Economic and Mode Specific Variables of the Office Workers

Table D.1 Age Group Distribution of the Office Workers

Age groups	Frequency of Office Workers	In Percentage
Less than 25 yrs	57	22.8
25 - 35 yrs	132	52.8
35 - 45 yrs	36	14.4
45 - 55 yrs	16	6.4
More than 55 yrs	9	3.6
Total	250	100

Table D.2 Educational Qualification of the Office Workers

Educational Qualification of the Office Workers	Frequency of Office Workers	In Percentage
Illiterate	2	0.8
Class I to X	36	14.4
S.S.C	16	6.4
H.S.C	11	4.4
Diploma	11	4.4
Bachelor Degree	103	41.2
Masters Degree	69	27.6
PhD	2	0.8
Total	250	100

Table D.3 Income Group based on Monthly Income of the Office Workers

Monthly Income (in Tk)	Income Group	Frequency of Office Workers	In Percentage
Less than 10000	Lower	105	42
10001-20000	Middle	87	34.8
More than 20000	Higher	58	23.2
Total		250	100

Table D.4 Family Vehicle Ownership of the Office Workers

Ownership	Frequency	In Percentage
Private auto	33	13.2
None	217	86.8
Total	250	100.0%

Table D.5 Relation between Age Group Distribution and Most Frequently Chosen Mode

Age groups (in years)	Most frequently chosen mode					Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk	
Less than 25	21	1	1	8	26	57
25 - 35	80	10	4	18	20	132
35 - 45	20	6	2	1	7	36
45 - 55	5	5	-	4	2	16
More than 55	3	6	-	-	-	9
Total	129	28	7	31	55	250

Table D.6 Relation between Gender Distribution and Most Frequently Chosen Mode

Gender of the Office Workers	Most frequently chosen mode					Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk	
Female	9	4	3	7	2	25
Male	120	24	4	24	53	225
Total	129	28	7	31	55	250

Table D.7 Relation between Job Status and Most Frequently Chosen Mode

Job Status	Most frequently chosen mode					Total	% of Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk		
Part time	-	1	-	1	-	2	0.8
Full time	129	27	7	30	55	248	99.2
Total	129	28	7	31	55	250	100.0

Table D.8 Relation between Total Income (Monthly) and Most Frequently Chosen Mode

Monthly Income (in Tk)	Most frequently chosen mode					Total
	Public bus	Private auto	Auto rickshaw	Rickshaw	Walk	
Up to10000	48	1	1	12	43	105
10001-20000	62	3	1	11	10	87
More than 20000	19	24	5	8	2	58
Total	129	28	7	31	55	205

Table D.9 Most Frequently Chosen Mode of the Office Workers

Name of modes	Frequency	In Percentage
Public Bus	129	52
Private Auto	28	11
Auto Rickshaw	7	3
Rickshaw	31	12
Walk	55	22
Total	250	100

Table D.10 Time Spent to Reach to Chosen Mode by Rickshaw / Walk

Time Spent	Supporting modes			
	Rickshaw		Walk	
	Frequency	In Percentage	Frequency	In Percentage
Less than 5 min	22	40	46	56.8
5 – 10 min	23	41.82	31	38.3
10 -15 min	7	12.73	3	3.7
15 - 20 min	2	3.60	-	-
20 – 25 min	1	1.81	-	-
More than 25 min	-	-	1	1.2
Total Response	55	100	81	100

Table D.11 Waiting Time for Most Frequently Chosen Mode

Waiting Time	Most frequently chosen mode					
	Public bus	%	Auto rickshaw	%	Rickshaw	%
Less than 5 min	32	24.8	1	14.3	16	51.6
5 - 10	47	36.4	2	28.6	9	29.0
10 -15	33	25.6	2	28.6	4	12.9
15 - 20	10	7.8	2	28.6	2	6.5
20 - 25	1	0.8	-	-	-	-
More than 25	6	4.7	-	-	-	-
Total	129	100	7	100	31	100

Appendix E

Appendix E

Areas under the Standard Normal Curve from 0 to Z

z	0	1	2	3	4	5	6	7	8	9
0.0	.0000	.0040	0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0754
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2258	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2518	.2549
0.7	.2580	.2612	.2642	2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	2967	.2996	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	4192	.4207	.4222	.4236	.4251	.4265	.4272	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	4793	.4798	.4803	.4808	4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.5	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
3.6	.4998	.4998	4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.7	.4999	.4999	4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.8	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

Source: Spigel, Murray R. (1992)

Appendix F

Appendix F

Model Specification of Alternate Nested Structure

U(pub_bus)=A0+A1*AGE+A2*IVTT+A3*OVTT
U(pri_auto)=B0+B1*IVTT
U(a_rick)=C0+C1*IVTT+ C2*OVTT
U(rick)=D1*IVTT+D2*OVTT
U(walk)=E0+E1*AGE+E2*DIST
U(mt)=F0+AB*HHINC+BC*DIST
U(nmt)=EF*HHINC+GH*AGE

```
+---------------------------------------------------+
| FIML  Nested Multinomial Logit Model               |
| Maximum Likelihood Estimates                       |
| Dependent variable                        Y        |
| Weighting variable                      ONE        |
| Number of observations                  378        |
| Iterations completed                     57        |
| Log likelihood function           -38.72168        |
| Restricted log likelihood         -413.0699        |
| Chi-squared                        748.6964        |
| Degrees of freedom                       20        |
| Significance level                 .0000000        |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj        |
| No coefficients   -413.0699  .90626  .88890        |
| Constants only.  Must be computed directly.        |
|                  Use NLOGIT ;...; RHS=ONE $        |
| At start values    -49.8566  .22334  .07951        |
| Response data are given as ind. choice.            |
| The model has 2 levels.                            |
| Coefs. for branch level begin with FD              |
| Number of obs.=   250, skipped   0 bad obs.        |
+---------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	6.938431789	18.514294	.375	.7078	
A1	-.1016714535	.83776163E-01	-1.214	.2249	
A2	.1088033674	.99829629E-01	1.090	.2758	
A3	.2858030597	.13088213	2.184	.0290	
B0	11.13899784	18.770178	.593	.5529	
B1	.1109963108	.24283693	.457	.6476	
C0	6.573428318	18.021573	.365	.7153	
C1	.8808678808E-01	.11457446	.769	.4420	
C2	.8495470107E-01	.98546634E-01	.862	.3886	
D1	.4594725467	.33224832	1.383	.1667	
D2	.1057273967	.15151802	.698	.4853	
E0	4.099216405	4.0680599	1.008	.3136	
E1	-.9234430454E-02	.12230107	-.076	.9398	
E2	1.709939499	2.1447089	.797	.4253	
	Attributes of Branch Choice Equations				
FD	-.6619468123	1.7321078	-.382	.7023	
AB	.2132704988E-04	.70425160E-04	.303	.7620	
BC	.6619737565	.44832479	1.477	.1398	
EF	-.2538621347E-04	.25112194E-04	-1.011	.3121	
GH	.3268925895E-01	.52603498E-01	.621	.5343	
	Inclusive Value Parameters				
MT	-.1040020848	.11824840	-.880	.3791	
NMT	-.1040020848	.11824840	-.880	.3791	

Appendix G

Appendix G-1: Model Specification 1

U(pub_bus)=A0+A1*HHINC+A2*IVTT+A3*OVTT+A4*COST
U(pri_auto)=B0+A1*HHINC + B1*IVTT+B2*COST
U(a_rick)=C0+A1*HHINC+ C1*IVTT+C2*COST
U(rick)=A1*HHINC + D1*IVTT+D2*COST
U(walk)=E0+E1*AGE
U(public)=F0+AB*HHINC
U(private)=F0+BC*HHINC
U(nmt)=EF*HHINC

Run result

```
+---------------------------------------------+
| FIML: Nested Multinomial Logit Model        |
| Maximum Likelihood Estimates                |
| Dependent variable                      Y   |
| Weighting variable                    ONE   |
| Number of observations                378   |
| Iterations completed                  101   |
| Log likelihood function         -47.55109   |
| Restricted log likelihood       -358.5239   |
| Chi-squared                      621.9456   |
| Degrees of freedom                     20   |
| Significance level               .0000000   |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| No coefficients  -358.5239  .86737  .84281  |
| Constants only.  Must be computed directly. |
|                  Use NLOGIT ;...; RHS=ONE $ |
| At start values   -63.3532  .24943  .11043  |
| Response data are given as ind. choice.     |
| The model has 2 levels.                     |
| Coefs. for branch level begin with F0       |
| Number of obs.=   250, skipped   0 bad obs. |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	2.390250540	13.090016	.183	.8551	
A1	-.1936845950E-04	.89088063E-04	-.217	.8279	
A2	.3451579675E-01	.86913367E-01	.397	.6913	
A3	.2865244696E-01	.57935896E-01	.495	.6209	
A4	-.4392021160E-01	.95581984E-01	-.460	.6459	
B0	1.573525193	15.234545	.103	.9177	
B1	.6746891645E-01	.16220245	.416	.6774	
B2	-.1031164946E-01	.21819727E-01	-.473	.6365	
C0	-3.016181433	4.4487955	-.678	.4978	
C1	1560984264E-01	.59981919E-01	.260	.7947	
C2	.3824347052E-02	.22132011E-01	.173	.8628	
D1	-.3614153976E-01	.48157083E-01	-.750	.4530	
D2	.9561261584E-02	.47416517E-01	202	.8402	
E0	2.026432070	3.3697965	.601	.5476	
E1	-.7468865610E-01	.13577637	-.550	.5823	
	Attributes of Branch Choice Equations				
F0	-4.806754219	29.915088	-.161	.8723	
AB	-.1481774225E-03	.61567289E-04	-2.407	.0161	
BC	-.1049428257E-03	.73932349E-04	-1.419	.1558	
EF	-.1221285931E-03	.72068482E-04	-1.695	.0901	
	Inclusive Value Parameters				
PUBLIC	1.669485325	3.0584444	.546	.5852	
PRIVATE	1.669485325	3.0584444	.546	.5852	
NMT	1.669485325	3.0584444	.546	.5852	

Appendix G-2: Model Specification 2

U(pub_bus)=A0+A1*HHINC+A2*IVTT+A3*OVTT+A4*COST
U(pri_auto)=B0+B1*HHINC + B2*IVTT+B3*COST
U(a_rick)=C0+C1*HHINC+ C2*IVTT+C3*COST
U(rick)=D1*IVTT+D2*COST
U(walk)=E0+E1*HHINC+ E2*AGE
U(public)=F0+AB*HHINC
U(private)=F0+BC*HHINC
U(nmt)=EF*HHINC

Run result

```
+--------------------------------------------------+
| FIML. Nested Multinomial Logit Model              |
| Maximum Likelihood Estimates                      |
| Dependent variable                        Y       |
| Weighting variable                       ONE      |
| Number of observations                   378      |
| Iterations completed                     101      |
| Log likelihood function            -52.18864      |
| Restricted log likelihood          -358.5239      |
| Chi-squared                         612.6705      |
| Degrees of freedom                        23      |
| Significance level                  .0000000      |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj       |
| No coefficients  -358.5239  .85443  .82255        |
| Constants only.  Must be computed directly.       |
|                  Use NLOGIT ;...; RHS=ONE $       |
| At start values   -59.4919  .12276 -.06940        |
| Response data are given as ind. choice.           |
| Hessian was not PD. Using BHHH estimator.         |
| The model has 2 levels.                           |
| Coefs. for branch level begin with F0             |
| Number of obs.=   250, skipped   0 bad obs.       |
+--------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	- 5348514632	169.82171	-.003	.9975	
A1	-.5104974871E-04	547.35121	.000	1 0000	
A2	.7471724940E-01	.28065818	.266	.7901	
A3	.5041736603E-01	.18100677	.279	.7806	
A4	-.6950389630E-01	.26131634	-.266	.7903	
B0	-2.844215578	171.78921	-.017	.9868	
B1	.1204713527E-03	.57549292E-02	.021	.9833	
B2	.1106626319	.39202481	.282	.7777	
B3	.8673115723E-02	.75603741E-01	.115	.9087	
C0	-4.593262868	15.637183	-.294	.7690	
C1	.1300993499E-03	.12385472E-02	.105	.9163	
C2	.4308796448E-01	.17478250	.247	.8053	
C3	.8974837675E-02	.48697869E-01	.184	.8538	
D1	-.4134109181E-01	.13080164	-.316	.7520	
D2	.1915476201E-01	.90429907E-01	.212	.8322	
E0	1.667287633	3.7959587	439	.6605	
E1	-.4222311865E-05	.76903949E-04	-.055	.9562	
E2	-.4383469417E-01	.13013589	-.337	.7362	
	Attributes of Branch Choice Equations				
F0	1.754131677	169.58710	.010	.9917	
AB	-.2392678045E-04	547.35102	.000	1.0000	
BC	-.9356068019E-04	.56187407E-02	-.017	.9867	

EF	.2319537997E-04	.12362087E-02	.019	.9850
	Inclusive Value Parameters			
PUBLIC	.9999996582	3.5275523	.283	.7768
PRIVATE	.9999996582	3.5275523	.283	.7768
NMT	.9999996582	3.5275523	.283	.7768

Appendix G-3: Model Specification 3

U(pub_bus)=A0+A1*AGE+A2*IVTT+A3*OVTT
U(pri_auto)=B0+B1*IVTT
U(a_rick)=C0+C1*SEX+C2*IVTT+ C2*OVTT
U(rick)=D1*SEX+D2*IVTT+D3*OVTT
U(walk)=E0+E1*AGE+E2*SEX+E3*DIST
U(public)=F0+AB*SEX+BC*HHINC+CD*DIST
U(private)=F0+DE*HHINC+EF*DIST
U(nmt)=GH*HHINC+HI*AGE

Run result

```
+----------------------------------------------+
| FIML: Nested Multinomial Logit Model          |
| Maximum Likelihood Estimates                  |
| Dependent variable                    Y       |
| Weighting variable                  ONE       |
| Number of observations              378       |
| Iterations completed                101       |
| Log likelihood function       -45.24779       |
| Restricted log likelihood     -358.5239       |
| Chi-squared                    626.5522       |
| Degrees of freedom                   26       |
| Significance level             .0000000       |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj   |
| No coefficients   -358.5239  .87379  .84162   |
| Constants only.  Must be computed directly.   |
|                  Use NLOGIT ;...; RHS=ONE $   |
| At start values    -53 9036  .16058 -.05339   |
| Response data are given as ind. choice.       |
| Hessian was not PD. Using BHHH estimator.     |
| The model has 2 levels.                       |
| Coefs. for branch level begin with F0         |
| Number of obs.=   250, skipped   0 bad obs.   |
+----------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	.2739447206	13.561278	.020	.9839	
A1	-.4609256249E-01	.12294976	-.375	.7077	
A2	.1135468352E-01	.68199185E-01	.166	8678	
A3	.7057490606E-01	.12853689	.549	.5830	
B0	-1.672804564	13.751224	-.122	.9032	
B1	.9574211230E-01	.23650657	.405	.6856	
C0	-3.039055510	7.6584488	-.397	.6915	
C1	-2.306828301	11 482014	-.201	.8408	
C2	.5637656485E-01	.16197382	.348	.7278	
C3	.8843575473E-01	.19659463	.450	.6528	
D1	-1.178111573	11.138732	-.106	.9158	
D2	-.3412620701E-01	.87642360E-01	-.389	.6970	
D3	.1480487786	.25233547	.587	.5574	
E0	3.172691992	5.1970863	.610	.5415	
E1	-.5279001207E-01	.15715804	-.336	.7369	

E2	-.3720291894	11.226578	-.033	.9736
E3	-1.052093989	1.5591282	-.675	.4998
	Attributes of Branch Choice Equations			
F0	2.346819425	12.977466	.181	.8565
AB	1.032867125	11.119158	.093	.9260
BC	-.1962583424E-03	.15727514E-03	-1.248	.2121
CD	.1396551362	.27396078	.510	.6102
DE	-.1552644479E-03	.15820208E-03	-.981	3264
EF	-.1945076821E-01	.87029964	-.022	.9822
GH	-.1823934049E-03	.15754374E-03	-1.158	.2470
HI	.9476206596E-01	.11670385	.812	.4168
	Inclusive Value Parameters			
PUBLIC	.9970533783	1.7838450	.559	.5762
PRIVATE	.9970533783	1.7838450	.559	.5762
NMT	.9970533783	1.7838450	.559	.5762

Appendix G-4: Model Specification 4

U(pub_bus)=A0+A1*HHINC+A2*IVTT+A3*OVTT+A4*COST
U(pri_auto)=B0+B1*HHINC + B2*IVTT+B3*COST
U(a_rick)=C0+C1*HHINC+ C2*IVTT+C3*OVTT+C4*COST
U(rick)=D1*IVTT+D2*OVTT+D3*COST
U(walk)=E0+E1*HHINC+ E2*AGE
U(public)=F0+AB*HHINC+AC*FAMSIZ
U(private)=F0+BC*HHINC+DC*FAMSIZ
U(nmt)=EF*HHINC

Run result

```
+-----------------------------------------------+
| FIML: Nested Multinomial Logit Model          |
| Maximum Likelihood Estimates                  |
| Dependent variable                    Y       |
| Weighting variable                  ONE       |
| Number of observations              378       |
| Iterations completed                101       |
| Log likelihood function       -50.19546       |
| Restricted log likelihood     -358.5239       |
| Chi-squared                    616.6568       |
| Degrees of freedom                   27       |
| Significance level             .0000000       |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj   |
| No coefficients  -358.5239  .85999  .82257    |
| Constants only.  Must be computed directly    |
|                  Use NLOGIT ;...; RHS=ONE $   |
| At start values   -56.5496  .11236 -.12493    |
| Response data are given as ind. choice.       |
| Hessian was not PD. Using BHHH estimator.     |
| The model has 2 levels.                       |
| Coefs. for branch level begin with F0         |
| Number of obs.=   250, skipped   0 bad obs.   |
+-----------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	-.2046052075	206.15383	-.001	.9992	
A1	-.7062119352E-04	836.09258	.000	1.0000	
A2	.8199680842E-01	.15641514	.524	.6001	
A3	.5869098697E-01	.10234790	.573	.5663	

A4	-.5470618953E-01	.18329402	-.298	.7654
B0	-2.011445142	206.78686	-.010	.9922
B1	.8336949043E-04	.71093691E-02	.012	.9906
B2	.1075144218	.34579904	.311	.7559
B3	.1037964031E-01	.99982938E-01	.104	.9173
C0	-4.761999961	8.9188984	-.534	.5934
C1	.8076548580E-04	.13908157E-02	.058	.9537
C2	.7306088095E-01	.14395358	.508	.6118
C3	.4429933546E-01	.12906224	.343	.7314
C4	.1775463411E-02	.38824404E-01	.046	.9635
D1	-.2584845898E-01	.76100892E-01	-.340	.7341
D2	.1077533731	.16205695	.665	.5061
D3	-.1126273329E-01	.81865823E-01	-.138	.8906
E0	1.746216011	3.6296132	.481	.6304
E1	.7627339313E-05	.10075511E-03	.076	.9397
E2	-.3875976457E-01	.12804721	-.303	.7621
	Attributes of Branch Choice Equations			
F0	1.363329238	206.09384	.007	.9947
AB	-.5766371445E-04	836.09250	.000	1.0000
AC	.2108733733	.31077216	.679	.4974
BC	-.6578380784E-04	.69696185E-02	-.009	.9925
DC	-.2601525696	2.0160196	-.129	.8973
EF	.7032917880E-05	.13874227E-02	.005	.9960
	Inclusive Value Parameters			
PUBLIC	.9999999012	1.6930936	.591	.5548
PRIVATE	.9999999012	1.6930936	.591	.5548
NMT	.9999999012	1.6930936	.591	.5548

Appendix G-5: Model Specification 5

U(pub_bus)=A0+A1*AGE+A2*IVTT+A3*OVTT+A4*COST
U(pri_auto)=B0+B1*HHINC +B2*IVTT+B3*COST+B4*COMFORT
U(a_rick)=C0+C1*IVTT+C2*OVTT+C3*COST
U(rick)=D1*SEX+D2*IVTT+D3*OVTT+D4*COST
U(walk)=E0+E1*AGE+E2*SEX+E3*HHINC+E4*DIST
U(public)=F0+AB*SEX+BC*HHINC+CD*DIST
U(private)=F0+DE*HHINC+EF*DIST
U(nmt)=GH*HHINC+HI*AGE

Run result

```
+---------------------------------------------------+
| FIML: Nested Multinomial Logit Model               |
| Maximum Likelihood Estimates                       |
| Dependent variable                        Y        |
| Weighting variable                      ONE        |
| Number of observations                  378        |
| Iterations completed                    101        |
| Log likelihood function           -43.92347        |
| Restricted log likelihood         -358.5239        |
| Chi-squared                        629.2008        |
| Degrees of freedom                       32        |
| Significance level                 .0000000        |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj        |
| No coefficients  -358.5239  .87749  .83665         |
| Constants only.  Must be computed directly.        |
|                  Use NLOGIT ;...; RHS=ONE $        |
| At start values    -54.6518  .19630 -.07160        |
| Response data are given as ind. choice.            |
| Hessian was not PD. Using BHHH estimator.          |
| The model has 2 levels.                            |
| Coefs. for branch level begin with F0              |
| Number of obs.=   250, skipped   0 bad obs.        |
+---------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	-.3381820745	106.37658	-.003	.9975	
A1	-.3281636024E-01	.13639286	-.241	.8099	
A2	.6428993484E-01	.14364325	.448	.6545	
A3	.5990253595E-01	.10771155	.556	.5781	
A4	-.6162819011E-01	.17157687	-.359	.7195	
B0	-7.329735467	115.24234	-.064	.9493	
B1	.1600599099E-03	.6266B702E-02	.026	.9796	
B2	.9672352495E-01	.37062753	.261	.7941	
B3	-.8099246023E-02	.94418494E-01	-.086	.9316	
B4	1.233745472	4.9459262	.249	.8030	
C0	-3.875476514	8.6449407	-.448	.6539	
C1	.6746058001E-01	.17614193	383	.7017	
C2	.6575978089E-01	.16578469	.397	.6916	
C3	.1218639559E-01	.54211687E-01	.225	.8221	
D1	.4445384027	2.9263889	.152	.8793	
D2	-.2704532679E-01	.87390394E-01	-.309	.7570	
D3	1073117998	.16082430	667	.5046	
D4	.7200462790E-02	.96824230E-01	.074	.9407	
E0	3.349848294	4.0871912	.820	.4124	
E1	-.4916295247E-01	.13855018	-.355	.7227	
E2	.5957617888	3.7639820	.158	.8742	
E3	- 2186149619E-04	.18504540E-03	-.118	.9060	
E4	-.7901252309	1.2528093	-.631	.5282	
	Attributes of Branch Choice Equations				
F0	1.741632909	104.75743	.017	.9867	
AB	1.404475081	2.8144357	.499	.6178	
BC	-.1233273064E-03	.15135279E-03	-.815	.4152	
CD	.9186546241E-01	.32185677	.285	.7753	
DE	-.2389583763E-03	.61732744E-02	-.039	.9691	
EF	.1444037472	1.1349057	.127	.8988	
GH	-.1054277353E-03	.17057477E-03	-.618	.5365	
HI	.4080700620E-01	.12864241	.317	.7511	
	Inclusive Value Parameters				
PUBLIC	.9850905642	1.6339001	.603	.5466	
PRIVATE	.9850905642	1.6339001	.603	.5466	
NMT	.9850905642	1.6339001	.603	.5466	

Appendix G-6: Model Specification 6

U(pub_bus)=A0+A1*HHINC+A2*IVTT+A3*OVTT+A4*COST+A5*DIST
U(pri_auto)=B0+B1*HHINC + B2*IVTT+B3*COST
U(a_rick)=C0+C1*HHINC+ C2*IVTT+C3*OVTT+C4*COST
U(rick)=D1*IVTT+D2*OVTT+D3*COST+D4*DIST
U(walk)=E0+E1*HHINC+ E2*AGE+E3*IVTT
U(public)=F0+AB*HHINC+AC*FAMSIZ
U(private)=F0+BC*HHINC+DC*FAMSIZ
U(nmt)=EF*HHINC

Run result

```
+----------------------------------------------------------+
| FIML: Nested Multinomial Logit Model                      |
| Maximum Likelihood Estimates                              |
| Dependent variable                                 Y      |
| Weighting variable                               ONE      |
| Number of observations                           378      |
| Iterations completed                             101      |
| Log likelihood function                    -40.47216      |
| Restricted log likelihood                  -358 5239      |
| Chi-squared                                 636.1034      |
| Degrees of freedom                                30      |
| Significance level                          .0000000      |
| R2=1-LogL/LogL*   Log-L fncn   R-sqrd   RsqAdj            |
| No coefficients   -358.5239   .88711   .85256             |
| Constants only.   Must be computed directly.              |
|                   Use NLOGIT ;...; RHS=ONE $              |
| At start values    -47.1019   .14075 -.12228              |
| Response data are given as ind. choice.                   |
| Hessian was not PD. Using BHHH estimator.                 |
| The model has 2 levels.                                   |
| Coefs. for branch level begin with F0                     |
| Number of obs.=   250, skipped   0 bad obs.               |
+----------------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Attributes in the Utility Functions				
A0	-.1572723812	122.35126	-.001	.9990	
A1	-.1115930642E-03	915.89353	.000	1.0000	
A2	.3707319987E-01	.11253174	.329	.7418	
A3	.4678673917E-01	.11988012	.390	.6963	
A4	-.5513012475E-01	.19521037	-.282	.7776	
A5	-.1796030052	.64638229	-.278	.7811	
B0	-2.984616660	123.12650	-.024	.9807	
B1	.8335972935E-04	.58592566E-02	.014	.9886	
B2	.5179965627E-01	.39269295	.132	.8951	
B3	-.9761146430E-02	.14100210	-.069	.9448	
C0	-7.101287098	17.111448	-.415	.6781	
C1	.8474980102E-04	.38002257E-02	.022	.9822	
C2	.8684320009E-01	.23408897	.371	.7106	
C3	.6113234056E-01	.18454562	.331	.7404	
C4	-.5002571186E-01	.13489340	-.371	.7107	
D1	-.7427943703E-01	.18905572	-.393	.6944	
D2	.2063950359E-01	.11490674	.180	.8575	
D3	.1257066598	.29846652	.421	.6736	
D4	-1.252641212	2.7762002	-.451	.6518	
E0	14.02447821	51.564005	.272	.7856	
E1	-.3296826370E-03	.19449829E-02	-.170	.8654	
E2	-.8368526170E-01	.26254393	-.319	7499	
E3	-.5523835387	1.6716512	-.330	.7411	
	Attributes of Branch Choice Equations				
F0	1.363329222	122.22833	.011	.9911	
AB	-.5952129510E-04	915.89344	.000	1.0000	
AC	.2108733897	.31710907	.665	.5061	
BC	-.5159466423E-04	.44560371E-02	-.012	.9908	
DC	-.2601525625	2.1200681	-.123	.9023	
EF	.1326359622E-04	.37842942E-02	.004	.9972	
	Inclusive Value Parameters				
PUBLIC	.9999999069	2.3147727	.432	.6657	
PRIVATE	.9999999069	2.3147727	.432	.6657	
NMT	.9999999069	2.3147727	.432	.6657	

Appendix H

<u>Appendix H:</u> Predicted Probabilities of Model Specification 6

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
1	.0000	.0000	.0000	1.0000*+	.0000
2	.0000	.0000	.0000	1.0000*+	.0000
3	.9987*+	.0000	.0013	.0000	.0000
4	.0000	.0000	.0000	.0000	1.0000*+
5	.0000	.0000	.0000	.0195	.9805*+
6	.0000	.0000	.9044*+	.0956	.0000
7	1.0000*+	.0000	.0000	.0000	.0000
8	1.0000*+	.0000	.0000	.0000	.0000
9	1.0000*+	.0000	.0000	.0000	.0000
10	1.0000*+	.0000	.0000	.0000	.0000
11	.0375	.9625*+	.0000	.0000	.0000
12	1.0000*+	.0000	.0000	.0000	.0000
13	1.0000*+	.0000	.0000	.0000	.0000
14	.9846*+	.0000	.0152	.0003	.0000
15	.0000	.0000	.5166 +	.4834*	.0000
16	.8123*+	.0000	.0000	.1877	.0000
17	.0000	.0000	.0000	.1100	.8900*+
18	.0000	.0000	.0000	.0000	1.0000*+
19	.0000	.0000	.0000	.0000	1.0000*+
20	.9814*+	.0000	.0000	.0186	.0000
21	.9994*+	.0000	.0000	.0006	.0000
22	.0000	.0000	.0000	.0000	1.0000*+
23	.8678*+	.0000	.0000	.1322	.0000
24	.9447 +	.0000	.0553*	.0000	.0000
25	.9974*+	.0000	.0026	.0000	.0000
26	1.0000*+	.0000	.0000	.0000	.0000
27	.0000	.0000	.0000	1.0000*+	.0000
28	.0000	.0000	.0000	.0000	1.0000*+
29	.9945*+	.0054	.0001	.0000	.0000
30	.0000	.4798	.0000	.5202*+	.0000
31	.0000	.0000	.0000	.0179	.9821*+
32	.0000	.0000	.0000	.0000	1.0000*+
33	.0000	.0000	.0000	.0000	1.0000*+
34	.0000	.0000	.0000	.4221	.5779*+
35	.9985*+	.0000	.0015	.0000	.0000
36	.0000	.0000	.0000	.2613	.7387*+
37	.5100*+	.0000	.4900	.0000	.0000
38	.7846*+	.0000	.0000	.2154	.0000
39	1.0000*+	.0000	.0000	.0000	.0000
40	.0000	.0000	.0000	.0000	1.0000*+
41	1.0000*+	.0000	.0000	.0000	.0000
42	.9998*+	.0000	.0002	.0000	.0000
43	1.0000*+	.0000	.0000	.0000	.0000
44	.7252*+	.0000	.0000	.2748	.0000
45	1.0000*+	.0000	.0000	.0000	.0000
46	.0000	.0000	.0000	1.0000*+	.0000
47	.0000	.0000	.0000	1.0000*+	.0000
48	.0000	.0000	.8225*+	.1775	.0000

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
49	.0000	.3649	.0000	.6351*+	.0000
50	.0000	.0000	.0000	.0000	1.0000*+
51	.8949 +	.0000	.0000	.1051*	.0000
52	1.0000*+	.0000	.0000	.0000	.0000
53	.6550*+	.0000	.0000	.3450	.0000
54	.9995*+	.0000	.0005	.0000	.0000
55	.9821*+	.0000	.0000	.0179	.0000
56	.0000	.9861*+	.0139	.0000	.0000
57	.0000	.0000	.0000	.5698*+	.4302
58	.0000	.0000	.0000	.0000	1.0000*+
59	.0000	.0000	.0000	.0000	1.0000*+
60	.0000	.0000	.0000	.0000	1.0000*+
61	.0000	.0000	.0000	.0000	1.0000*+
62	.0000	.0000	.0000	.0000	1.0000*+
63	1.0000*+	.0000	.0000	.0000	.0000
64	1.0000*+	.0000	.0000	.0000	.0000
65	.0000	.0000	.0000	.0000	1.0000*+
66	.0000	.0000	.0000	.0000	1.0000*+
67	1.0000*+	.0000	.0000	.0000	.0000
68	.0000	.0000	.0000	1.0000*+	.0000
69	.0000	.0000	.0000	.0000	1.0000*+
70	1.0000*+	.0000	.0000	.0000	.0000
71	.3654*	.0000	.5856 +	.0490	.0000
72	1.0000*+	.0000	.0000	.0000	.0000
73	.7816 +	.0000	.0000	.2184*	.0000
74	.8854*+	.0000	.1146	.0000	.0000
75	.2357	.7643*+	.0000	.0000	.0000
76	.9962*+	.0000	.0038	.0000	.0000
77	.9860*+	.0000	.0000	.0140	.0000
78	.0000	.9978*+	.0022	.0000	.0000
79	.0000	.0000	.0000	1.0000*+	.0000
80	1.0000*+	.0000	.0000	.0000	.0000
81	1.0000*+	.0000	.0000	.0000	.0000
82	1.0000*+	.0000	.0000	.0000	.0000
83	1.0000*+	.0000	.0000	.0000	.0000
84	1.0000*+	.0000	.0000	.0000	.0000
85	.0000	.0000	.0402	.9598*+	.0000
86	.0000	.0000	.0000	1.0000*+	.0000
87	.0000	.1459*	.0000	.8541 +	.0000
88	1.0000*+	.0000	.0000	.0000	.0000
89	1.0000*+	.0000	.0000	.0000	.0000
90	.0000	1.0000*+	.0000	.0000	.0000
91	1.0000*+	.0000	.0000	.0000	.0000
92	1.0000*+	.0000	.0000	.0000	.0000
93	.9985*+	.0000	.0015	.0000	.0000
94	.0000	1.0000*+	.0000	.0000	.0000
95	.0000	1.0000*+	.0000	.0000	.0000
96	.0000	.0000	.0000	1.0000*+	.0000
97	.0000	.0000	.0000	1.0000*+	.0000

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
98	.0000	1.0000*+	.0000	.0000	.0000
99	.0000	1.0000*+	.0000	.0000	.0000
100	.0000	.9946*+	.0054	.0000	.0000
101	.6646*+	.0000	.0000	.3354	.0000
102	.0000	1.0000*+	.0000	.0000	.0000
103	.0000	1.0000*+	.0000	.0000	.0000
104	.0000	.8928*+	.0000	.1072	.0000
105	.0000	1.0000*+	.0000	.0000	.0000
106	.0000	1.0000*+	.0000	.0000	.0000
107	.7228 +	.0000	.0000	.2772*	.0000
108	.9991*+	.0000	.0009	.0000	.0000
109	1.0000*+	.0000	.0000	.0000	.0000
110	1.0000*+	.0000	.0000	.0000	.0000
111	1.0000*+	.0000	.0000	.0000	.0000
112	1.0000*+	.0000	.0000	.0000	.0000
113	.8850*+	.0000	.1150	.0000	.0000
114	.0000	.0000	.0000	.8046*+	.1954
115	.9459*+	.0000	.0000	.0000	.0541
116	.0000	.0000	.0000	.0000	1.0000*+
117	1.0000*+	.0000	.0000	.0000	.0000
118	1.0000*+	.0000	.0000	.0000	.0000
119	1.0000*+	.0000	.0000	.0000	.0000
120	.0000	.0000	.0000	.0000	1.0000*+
121	.9866*+	.0000	.0000	.0134	.0000
122	.0000	.0000	.0000	1.0000*+	.0000
123	.7685*+	.0000	.0000	.2315	.0000
124	.3291*	.0000	.0000	.6709 +	.0000
125	1.0000*+	.0000	.0000	.0000	.0000
126	.9853*+	.0000	.0004	.0143	.0000
127	.9916*+	.0000	.0084	.0000	.0000
128	.9659*+	.0000	.0000	.0341	.0000
129	.9795*+	.0000	.0019	.0187	.0000
130	.9969*+	.0000	.0000	.0031	.0000
131	.9999*+	.0000	.0001	.0000	.0000
132	.9861*+	.0000	.0139	.0000	.0000
133	1.0000*+	.0000	.0000	.0000	.0000
134	1.0000*+	.0000	.0000	.0000	.0000
135	.0000	.0000	.0000	.5355 +	.4645*
136	.9776*+	.0000	.0224	.0000	.0000
137	.0000	.0000	.0000	.0333	.9667*+
138	.0000	.0000	.0000	1.0000*+	.0000
139	1.0000*+	.0000	.0000	.0000	.0000
140	.7868 +	.0000	.2132*	.0000	.0000
141	.0000	.0000	.0000	.0000	1.0000*+
142	.9808*+	.0000	.0192	.0000	.0000
143	.9996*+	.0000	.0004	.0000	.0000
144	1.0000*+	.0000	.0000	.0000	.0000
145	.0000	.0000	.0000	.0000	1.0000*+
146	1.0000*+	.0000	.0000	.0000	.0000

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
147	1.0000*+	.0000	.0000	.0000	.0000
148	.0000	.0000	.0000	1.0000*+	.0000
149	1.0000*+	.0000	.0000	.0000	.0000
150	1.0000*+	.0000	.0000	.0000	.0000
151	.9437*+	.0000	.0563	.0000	.0000
152	.9907 +	.0000	.0000	.0093*	.0000
153	.0000	.0000	.0000	.0000	1.0000*+
154	1.0000*+	.0000	.0000	.0000	.0000
155	.9001*+	.0000	.0999	.0000	.0000
156	1.0000*+	.0000	.0000	.0000	.0000
157	.0000	.0000	.0000	.1062	.8938*+
158	.8877 +	.0000	.0011	.1112*	.0000
159	.9989*+	.0000	.0011	.0000	.0000
160	.0000	1.0000*+	.0000	.0000	.0000
161	.7197*+	.0000	.0000	.2803	.0000
162	.0000	1.0000*+	.0000	.0000	.0000
163	.0000	.0000	.1568	.8432*+	.0000
164	.0000	.0000	.6264*+	.3736	.0000
165	1.0000*+	.0000	.0000	.0000	.0000
166	.8570*+	.0000	.0000	.1430	.0000
167	.9927*+	.0000	.0073	.0000	.0000
168	.9992*+	.0000	.0008	.0000	.0000
169	.0000	.0000	.0000	.0000	1.0000*+
170	.9472*+	.0526	.0002	.0000	.0000
171	.0000	1.0000*+	.0000	.0000	.0000
172	.9979*+	.0000	.0021	.0000	.0000
173	.0000	.0000	.0000	.0000	1.0000*+
174	.9861*+	.0000	.0139	.0000	.0000
175	.0000	1.0000*+	.0000	.0000	.0000
176	.9872*+	.0000	.0128	.0000	.0000
177	.0000	.9452*+	.0000	.0548	.0000
178	.0000	1.0000*+	.0000	.0000	.0000
179	1.0000*+	.0000	.0000	.0000	.0000
180	.9994*+	.0000	.0006	.0000	.0000
181	.0000	.0000	.0000	.9920*+	.0080
182	.0000	1.0000*+	.0000	.0000	.0000
183	.0000	.0000	.0000	.0846	.9154*+
184	.0000	.0000	.0000	.0000	1.0000*+
185	.0000	.0000	.0000	.1874*	.8126 +
186	1.0000*+	.0000	.0000	.0000	.0000
187	1.0000*+	.0000	.0000	.0000	.0000
188	1.0000*+	.0000	.0000	.0000	.0000
189	.9919*+	.0000	.0081	.0000	.0000
190	.0000	1.0000*+	.0000	.0000	.0000
191	1.0000*+	.0000	.0000	.0000	.0000
192	.9999*+	.0000	.0000	.0001	.0000
193	.0000	.0000	.0000	.0000	1.0000*+
194	.9354*+	.0000	.0000	.0646	.0000
195	.8668*+	.0000	.0000	.1332	.0000

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
196	.0000	.0000	.0000	.0000	1.0000*+
197	.0000	.0000	.0000	.0000	1.0000*+
198	.9999*+	.0000	.0000	.0001	.0000
199	.0000	.0000	.0000	.0000	1.0000*+
200	.6805*+	.0000	.3195	.0000	.0000
201	.0000	.9866*+	.0134	.0000	.0000
202	.0000	.0000	.0000	.0000	1.0000*+
203	.0000	.0000	.0000	.0000	1.0000*+
204	1.0000*+	.0000	.0000	.0000	.0000
205	1.0000*+	.0000	.0000	.0000	.0000
206	1.0000*+	.0000	.0000	.0000	.0000
207	1.0000*+	.0000	.0000	.0000	.0000
208	.9247*+	.0000	.0753	.0000	.0000
209	.0000	1.0000*+	.0000	.0000	.0000
210	.0000	.0000	.0000	.0000	1.0000*+
211	.4104	.0000	.5896*+	.0000	.0000
212	.0000	1.0000*+	.0000	.0000	.0000
213	1.0000*+	.0000	.0000	.0000	.0000
214	.9886*+	.0000	.0114	.0000	.0000
215	.7632 +	.0000	.0000	.2368*	.0000
216	1.0000*+	.0000	.0000	.0000	.0000
217	1.0000*+	.0000	.0000	.0000	.0000
218	.0000	.0000	.0000	.0000	1.0000*+
219	.0000	.0000	.0000	.0000	1.0000*+
220	.4010	.0000	.0000	.5990*+	.0000
221	.0000	.0000	.0000	.0000	1.0000*+
222	.9898*+	.0000	.0102	.0000	.0000
223	.0000	.0000	.0000	.0000	1.0000*+
224	.9945*+	.0000	.0055	.0000	.0000
225	.0000	.0000	.0000	.0000	1.0000*+
226	.9485*+	.0000	.0000	.0515	.0000
227	.9947*+	.0000	.0053	.0000	.0000
228	.9522*+	.0000	.0477	.0000	.0000
229	.0000	.0000	.0000	.0000	1.0000*+
230	.0000	.0000	.0000	.0000	1.0000*+
231	.7093*+	.0000	.0000	.2907	.0000
232	.7500 +	.0000	.0000	.2500*	.0000
233	.9893*+	.0000	.0107	.0000	.0000
234	.9876*+	.0000	.0124	.0000	.0000
235	.0000	.0000	.0000	.0073	.9927*+
236	.6884*+	.0000	.0000	.3116	.0000
237	.0000	1.0000*+	.0000	.0000	.0000
238	.5130 +	.0000	.0000	.4870*	.0000
239	1.0000*+	.0000	.0000	.0000	.0000
240	.5251 +	.0000	.4749*	.0000	.0000
241	.9851*+	.0000	.0149	.0000	.0000
242	.9751*+	.0000	.0249	.0000	.0000
243	1.0000*+	.0000	.0000	.0000	.0000
244	.2522*	.7191 +	.0286	.0000	.0000

Predicted Probabilities (* marks actual and + marks prediction)

Indiv	PUB_BUS	PRI_AUTO	A_RICK	RICK	WALK
245	.0000	.0000	.0000	.0000	1.0000*+
246	.0000	.0000	.0000	.0000	1.0000*+
247	.0000	.0000	.0000	.0000	1.0000*+
248	.0000	.0000	.0000	.0000	1.0000*+
249	.0000	.0000	.0000	.0000	1.0000*+
250	.0000	.0000	.0000	.0000	1.0000*+