Master's Thesis

Understanding the Linkages of Travel Behavior with Socioeconomic Characteristics and Spatial Environments in Dhaka City and Urban Transport Policy Applications

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September 2008

DECLARATION

It is hereby declared that this thesis entitled "**Understanding the Linkages of Travel Behavior with Socioeconomic Characteristics and Spatial Environments in Dhaka City and Urban Transport Policy Applications**" has not been, either in whole or in part, previously submitted elsewhere for the award of any degree or diploma.

September, 2008 **Md. Saidur Rahman**

DEDICATION

To My Family

ACKNOWLEDGMENTS

I would like to express my deepest sincere gratitude to my supervisor Dr. Akimasa FUJIWARA, Professor of Graduate School for International Development and Cooperation (IDEC), Hiroshima University, Japan for giving me a unique opportunity to work on such an important topic. His continuous guidance, invaluable suggestions, affectionate encouragement, generous help and important acumen are greatly acknowledged. His keen interest on the topic and enthusiastic support on my effort was a source of inspiration to carry out the study. He has paid much of the invaluable time and the painstaking effort for the whole research. I consider myself fortunate to work under his supervision.

Simultaneity, I would like to express my special appreciation to my sub-supervisor, Dr. Junyi ZHANG, Associate Professor, IDEC, Hiroshima University, Japan for his patient and circumspective guidance and support. I am grateful to my sub-supervisor, Dr. Yasushi HIGO, Professor, IDEC, Hiroshima University, Japan for his valuable comments on my thesis paper. I am also thankful to Dr. Makoto TSUKAI, Associate Professor, Department of Civil Engineering, Graduate School of Engineering, Hiroshima University, Japan and Dr. Hiroshi SHIMAMOTO, Assistant Professor, IDEC, Hiroshima University, Japan for their valuable suggestions and insights regarding this work.

I am very grateful to Professor Shamsul Hoque and Professor Jobair Bin Alam of Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka for their continuous support and cooperation.

I would like to convey my thanks to Mr. Makoto Chikaraishi, and Mr. Wonchul Kim, Doctoral Course Students and all other members of the Hiroshima University Transportation Engineering Laboratory (HiTEL) for their cooperation.

I gratefully acknowledge the facilities and assistance provided by the concerned authority of Japan Government Development Scholarship (JDS) Program both in Japan and Bangladesh. I highly appreciate the personnel of Bangladesh Railway and Bangladesh Government who helped me in getting my official permission for higher studies.

My special thanks to Mr. Rafiqul Islam, Director of Bangladesh Consultants Ltd. (BCL) who provided me the useful data for this study.

Finally, I would like to express my special indebtedness to my family and friends whose continuous encouragement and support was unremitting source of inspiration for this work.

ABSTRACT

Transportation is one of the key inputs in the economic activities of a country. Appropriate transportation systems are fundamental decisions about a city's future growth and development. Inadequate transportation system hampers economic activities and creates hindrances for development. An efficient and a rational transportation system not only increase accessibility and mobility, it improves the quality of life and sustains the economic activity that is the engine of growth for the city. Urban transportation planning can therefore be considered as an important activity to promote mobility and economic growth.

Analysis of travel pattern is an important research topic in the field of transportation engineering and urban planning, irrespective of developed and developing countries. It provides the background information necessary to better understand the complex relationship among urban structure, transportation system and people's activity participation. The growing volume and complexity of urban travel in developing countries has become a major concern to transportation planners, service sponsors in urban areas, and policy makers. Designing transport strategies which meet the common political aims for the environment and the society requires a deeper insight into the routines of individual travel behavior.

However, travel behavior analysis seems to have been considered as a neglected component of the planning of cities in the developing world. There is no systematic analysis of established relationships between various forms of land use and behaviors of trip makers to guide planning of major developments and activity centers. Much remains to be learned about how the poor in developing countries use transportation facilities. This deficiency limits the effectiveness of transportation policies and actions in meeting the needs of expanding urban populations in the developing world. Although Dhaka is one of the most populous cities of the world, few detailed transport-planning studies have been conducted; but none has effectively delivered the benefits of planning to the transportation system; which is clearly reflected by the inadequately planned and developed transportation system of the city.

Most of the transport planning studies of Dhaka city, to guide the policy-makers' decisions, were conducted by the foreign consultants who followed the approaches mostly appropriate for the developed countries and consequently faced the challenges and limitations common to the developing countries. High dependency on imported fossil fuel and the increasing trends of oil price seem to be potential threats to our socioeconomic growth, sustainable environment and millennium development goal. But these emerging issues of transport sector of

Dhaka have never been achieved proper attention in any transport planning study rather they have been overlooked in all previous studies. For better utilization of resources and formulation of the policies and effectiveness of actions in meeting the growing demand, a reliable study for Dhaka City exploring people's travel behavior as well as transport sector impacts on country's economy and environment is badly needed. In this connection, this study is devoted to develop and implement a comprehensive modeling framework to explore the linkages of travel behavior with socioeconomic characteristics and spatial environments in Dhaka City. In addition, an aggregate level assessment of transport sector energy demand under different policy scenarios is made to evaluate alternative policy options for the sustainable growth and development of the city.

The modeling framework presented in this study is to simulate the complex travel behavior of Dhaka City in order to assess & analyze the urban travel pattern and thus to evaluate the performance of the transportation system under the given travel condition. First of all, a series of mode choice models in traditional discrete choice approach (both multinomial and nested logit models) have been developed considering the dominant non-motorized mode rickshaw and all possible minor modes of travel representing heterogeneous travel market of Dhaka City for strategic purpose. Then a separate multivariate technique based on multinomial logistic regression analysis was developed to identify the effects of exogenous variables on mode choice behavior.

To understand the determinants of complex travel behavior, discrete choice models are also developed for trip frequency analysis. The trip frequency models developed in this study are estimated as binary choice logit–type models. In order to investigate the relative importance of the various attributes of persons, households and spatial environments for travel distance; four regression models are developed for each of the four trip purposes. Besides, several multistage disaggregate models are also developed for different market segments based on Dhaka's socioeconomic characteristics to identify the group specific differences in mode choices and to estimate travel behavior stratified by residential location types and household income levels. Moreover, some multiple cross-classification analyses (MCA) are also presented to clarify travel characteristics of people in Dhaka City. In all cases, a set of identifiable socioeconomic and land use attributes/variables are taken into consideration to determine their effects on travel behavior in aiming of getting clear understanding of existing travel pattern of the city and thus providing city planners a starting point for further exploration of the land use and transportation integration in local level planning.

Finally, an attempt has been made to evaluate the performance of the existing road-based transport infrastructure in terms of energy consumption and environmental impacts in order to suggest alternative planning options for energy-efficient and environment-friendly transport systems through an assessment of aggregate level transport sector energy demand and its consequences on economy and environment of the country.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BANBEIS	Bangladesh Bureau of Educational Information and Statistics
BBS	Bangladesh Bureau of Statistics
BR	Bangladesh Railway
BRTA	Bangladesh Road Transportation Authority
BRTC	Bangladesh Road Transportation Corporation
BTU	British Thermal Unit
CBD	Central Business District
CNG	Compressed natural Gas (here CNG Auto-rickshaw too)
DCC	Dhaka City Corporation
DIT	Dhaka Improvement Trust
DITS	Dhaka Integrated Transport Study
DUTP	Dhaka Urban Transport Project
GDP	Gross Domestic Products
HIS	Household Interview Survey
JICA	Japan International Cooperation Agency
LEAP	Long-range Energy Alternatives Planning
MCA	Multiple Classification Analysis
MNL	Multinomial Logit
MRT	Mass Rapid Transit
MV/MT	Motorized Vehicles/ Motorized Transport
NL	Nested Logit
NMV/NMT	Non-Motorized Vehicles/ Non-Motorized Transport
RAJUK	Rajdhani Unnayan Kartipakkha
RHD	Roads and Highways Department
SPZ	Specific Zone
STP	Strategic Transport Plan
TAZ	Traffic Analysis Zone
TLFD	Trip Length Frequency Distribution
TRB	Transportation Research Board
UTMS	Urban Transportation Modeling System
UTP	Urban Transport Plan
WB	World Bank

CHAPTER 1

INTRODUCTION

1.1 General

Cities are the powerhouses of economic growth for any country. According to Bartone et. al. (1994), around eighty percent of GDP growth in developing countries is expected to come from cities. For the purpose of economic activities, it is imperative to facilitate movements. Transportation system, the life of a city, provides the way for movements and medium for reaching destinations. An urban transportation system is one of the most elemental components of the socio-economic and physical structure of a city. Appropriate transportation systems are fundamental decisions about a city's future growth and development. A well-planned and developed transportation system not only provides opportunities for mobility of the people but also influences the city's growth pattern and the level of economic activity through its accessibility to land (Meyer et al, 1984). Inadequate transportation system hampers economic activities and creates hindrances for development. Thus an efficient and rational transportation system not only increases accessibility and mobility, it improves the quality of life and sustains the economic activity that is the engine of growth for the city. Urban transportation planning can therefore be considered as an important activity to promote mobility and economic growth.

In most of the developing countries, which are overburdened with huge population and extreme poverty, increasing economic activities and opportunities in the cities result in rapid increase in urban population and consequent need for transportation facilities. Authorities in these countries often fail to cope with the pressure of increasing population growth and economic activities in the cities, causing uncontrolled expansion of the cities, urban sprawl, traffic congestion and environmental degradation. The backbone of urban activities is the urban transportation network. The transportation network of an urban area is usually designed to accommodate the transportation activities of urban people. With growing population and diversified land use activities, transportation system needs to be updated or readjusted. Any lag between growing transportation demand and network capacity results in traffic congestion, thereby economic loss and environmental degradation. It is particularly true for developing countries like Bangladesh where the scarcity of resources, improper planning initiatives, lack of farsightedness and imaginary visions for optimum utilization of limited facilities and resources make the situation more complex and inferior.

Major reasons of such urban dilapidation are the inability of understanding the factors causing problem in local socioeconomic contexts and lack of proper planning to improve the situation. To cope with the situation, it is imperative to ensure proper use of available facilities and develop infrastructure through optimum utilization of resources. For planning purpose, it is necessary to obtain quantitative visualization of the consequences of the planning and development policies for comparison among alternative options. The transportation modeling is a fundamental operation within any urban transport planning exercise and to explore the linkages of people's travel behavior with individual and household socioeconomic attributes as well as spatial characteristics of the places where people reside, work and travel through are the utmost important factors. The principal objective of the modeling is to predict the demand for transportation facilities and services in the future by extrapolating present travel behavior, growth potential and changing socioeconomic circumstances.

Travel behavior and its relationship to urban form has been the subject of debate in developed countries like the US (Crane, 1998; Cervero,2002; Srinivasan,2002). The increase in personal mobility plays an important role in the spatial transformation in advanced economies, where networks and activity patterns of individuals and organizations are increasingly stretched out in geographical terms (Frandberg and Vilhelmson, 2003). Moreover, urban expansion is a current topic of debate among both academics and politicians. ………urban sprawl is now at the top of the political agenda (Dieleman, 2002). The growing volume and complexity of urban travel in developing countries has become a major concern to transportation planners, service sponsors in urban areas, and policy makers (Takyi, 1990). Designing transport strategies which meet the common political aims for the environment and the society requires a deeper insight into the routines of individual travel behavior. However, travel behavior analysis seems to have been considered as a neglected component of the planning of cities in the developing world. There is no systematic analysis of established relationships between various forms of land use and behaviors of trip makers to guide planning of major developments and activity centers. Much remains to be learned about how the poor in developing countries use transportation facilities (Srinivasan, S., and Rogers,P., 2005). Although Dhaka is one of the most populous cities of the world, few detailed transport-planning studies have been conducted; but none has effectively delivered the benefits of planning to the transportation system; which is clearly reflected by the inadequately planned and developed transportation system of the city.

Dhaka's transport environment is characterized by mixed-modes transports using the same road space, traffic congestion, delays, mismanagement, conflict of jurisdictions, poor coordination among organizations and increasing environmental problems. Transport service in Dhaka has several deficiencies resulting from a combination of factors - physical, developmental and institutional-cum-policy framework-related which lead to lower efficiency, higher transport costs, longer waiting & travel time, discomfort and more significantly, "transport unreliability" with major adverse consequence for the economy & environment. Unplanned urbanization, especially poor transportation planning and lower land utilization efficiency, has turned the city into a dangerous urban jungle. The existing road-based transportation system provides inefficient, unproductive, and unsafe level of services (Rahman, M.S., 2008). High dependency on imported fossil fuel and the future trends of oil price increase are exerting tremendous pressures on country's limited reserve currency and also polluting the environment.

Transport sector is a major consumer of energy in a country. The role of transportation has become even more important in the context of energy scarcity. Traditionally, transportation in Dhaka and rest of Bangladesh is based on an extensive roadway network, resulting in a burden on the economy through the import of gasoline as transport fuel. Due to rapid increase of fuel price in recent years dependency on gasoline is causing ever increasing pressure on national economy. The road based, energy intensive transport scenario has evolved due to lack of vision in long term transport policy.

In context of Bangladesh, Dhaka, the capital city of the country, has significant impacts on fuel consumption as the economic activity of the country is fully Dhaka oriented. In terms of transport energy consumption, Dhaka is the prime player because more or less half (more than 44% of country's all vehicles) of the total transport fleets (over 77% cars, 87% taxi, 68% microbus, 40% trucks) of the country are plying on Dhaka's road surface with higher intensity. As a result, the transport systems of Dhaka are not only exerting tremendous pressures on country's limited currency reserves for importing the fuel at increasing price, they are also adding environmental loadings which are delivering direct impacts to local as well as global warming .

Today the mega city Dhaka is one of the world's polluted & congested cities. Its traffic congestion not only causes increased costs, loss of time & psychological strain, but also poses serious threats to our socioeconomic environment (Rahman, M.S., 2008). With its present situation of traffic systems, the city stands in dire need for a radical transformation in the structural sense. Until and unless there is immediate and effective solution, the system will collapse. We need to take comprehensive view of the present shortcomings and future potentialities of the metropolis to identify and work out plans for formulating strategies to standardize the efficiency of traffic flow and effectiveness of transportation system because choices about transportation system concern the kind of city we want to live in. To maintain the economic viability of this city and to keep its environment sustainable, an energy-efficient, environment-friendly transportation system is imperative. This study is devoted to identify the linkages of people's complex travel behavior pattern with socioeconomic characteristics and spatial environments of Dhaka City in order to analyze the baseline situation and finally to evaluate the alternative planning options (policy scenarios) based on aggregate level assessment of transport sector energy consumption and environmental loadings by different modes of transport to improve the present conditions.

1.2 Motivation of the Research

Sound transportation system and city sustainability are inextricably linked. In the era of globalization, city authorities recognize the need for their city to compete in the global marketplace, and urban transport is seen to be part of the 'package' to attract inward investment. The effectiveness with which transport policy is implemented, and the parallel complementary measures which are implemented, will substantially influence the city's future. With rapidly expanding urban growth and hence increasing travel demand of Dhaka city, extensive investments are expected for the development of urban transport infrastructures in future years. But the core question for decision-makers is how to achieve the city sustainability (environmentally safe and sound) and control the congestion with its associated pollution and safety costs within the means of government budgets.

Most of the transport planning studies of Dhaka city, to guide the policy-makers' decisions, were conducted by the foreign consultants who followed the approaches mostly appropriate for the developed countries and consequently faced the challenges and limitations common to the developing countries. For instance, the UTP model developed in the Strategic Transport Plan (STP) study conducted in 2005 ignored some important distinctive aspects of Dhaka's socio-economic and transport structure, like presence of wide difference in the socio-economic level of the people, different categories of people living in different zones in the city and the dominance of non motorized mode. Some assumptions made in the study have been found incorrect like trip productions and attractions are nearly same for each TAZ; household categories have no effect in the trip rates and there are only two modes (auto and public transport) available for modeling where as a significant portion (over 50%) of the trips is made by non-motorized modes and other minor modes.

On the other hand, Bangladesh is one of the least developed countries in the world having minimum access to the consumable energy for its limited economic activities and mostly dependent on imported fuel. Transport sector is one of the largest consumers of energy in the country with concerning growth rate. Dhaka, the primal and capital city of the country, has significant share in energy consumption as the central place of intense transport use (which mostly depends on imported fuel) as well as all economic activities. World fuel crisis as well as the future trends of oil price increase seems to be alarming for increasing travel activities and also for prospective economic growth of the country. Because, oil prices shocks have a stagflationary effect on the macroeconomy of an oil importing country like Bangladesh: they slow down the rate of growth (and may even reduce the level of output – i.e. cause a recession) and they lead to an increase in the price level and potentially an increase in the inflation rate. An oil price hike acts like a tax on consumption and, for a net oil importer (Nouriel Roubini, 2004). Besides, transportation is probably one of the sectors of society where policies aiming to reduce greenhouse gas emissions will be most important as it is one of the major contributors to the global warming though burning fossil fuels (oil, coal and gas). Reducing the consumption of fossil fuels is a key issue in the efforts to promote a *sustainable development,* as conceived by the UN World Commission on Environment and Development (the Brundtland Commission) in its report "Our Common Future" (WCED, 1987). The existing road-based transportation system and increasing motorization level in Dhaka are not only spending country's limited foreign currency reserve, but also pose serious threats to our environment. This is a crucial issue for future transportation planning of a country like Bangladesh where the transport sector is mostly dependent on imported fuels.

High dependency on imported fuel and the increasing trends of oil price seem to be upsetting to the prospective socioeconomic growth, target of sustainable environment and millennium development goal of the country. But these emerging issues of transport sector of Dhaka have never been achieved proper attention in any transport sector study rather they have been overlooked in all previous studies. Therefore, it is severely felt that familiarity with the reality of the area under interest is an essential prerequisite for the selection and development of an appropriate model. However, on the other hand all the locally developed research-based planning studies face the challenges of collection of the enormous amount of data and availability of sophisticated analytical tools required for the development of a comprehensive model. These difficulties can be overcome now since household data are available through the 2004 Household Interview Survey (HIS) conducted in the STP (2005) study and sophisticated analytical tools are also available to the people involved with this particular field of research.

For better utilization of resources and effectiveness of the policies and actions in meeting the growing demand, a reliable study on people's urban travel behavior and transport sector energy demand assessment for Dhaka City is badly needed. Nevertheless, to present a phenomenal presentation of the research work and make this study flexible for future enhancement and compatible with the complexity of the situation a comprehensive modeling framework is also needed. But no detail study on travel behavior as well as future transport energy demand assessment in Dhaka City considering the existing trends of growth and development has ever been conducted. This study develops and implements a comprehensive modeling framework to explore the linkages of travel behavior with socioeconomic characteristics and spatial environments in Dhaka City. In addition, an aggregate level assessment of transport sector energy demand under different policy scenarios is forecasted to evaluate alternative policy options for the sustainable growth and development of the city. The research framework developed in this study addresses the prevailing issues and attempts to overcome the limitations of the previous studies in terms of assumptions, principles and methods. The models developed in the study work on the 'strategic' level by restricting the number of analysis zones and spatial urban forms.

1.3 Objectives of the Research

The specific objectives of this research work are as follows:

- To identify the linkages of people's travel behavior with daily personal activities, household (HH) socioeconomic characteristics and spatial environments of the places where HH resides, people work & travel through in a fast growing developing city like Dhaka;
- To investigate on what ground a traveler shows propensity in selecting a specific mode of transport for a certain trip purpose and judge the influence of exogenous variables on his/her everyday travel behavior;
- To develop and calibrate a comprehensive mode choice models for Dhaka City including all possible minor and non-motorized modes;
- To explore how land use, residential location selection, network and accessibility characteristics affect HH trip linking and mode choices and their interaction on HH socioedemographic characteristics and urban forms and thus provide city planners a starting point for further exploration of the land use and transportation integration in local level planning; and
- To assess and forecast transport sector energy demand and its consequences on economy and environment in order to evaluate the performance of the existing transport infrastructure and thus to suggest alternative planning options for energy-efficient and environment-friendly transport systems for future Dhaka.

1.4 Scope of the Study

This study largely attempts to investigate the linkages of travel behavior with household & personal socioeconomic attributes and the characteristics of urban forms (level of urbanization) within which a travel takes place in the mega city Dhaka. To understand the mode choice behavior for different trip purposes is the central focus of the study. Separate multivariate modeling techniques are developed to measure the effects of exogenous variables on mode choices. As trip frequency and distance traveled by different modes of transport largely influence the travel behavior pattern in local contexts of a city, they are also analyzed within the scope of the study. Finally, an aggregate level assessment on Dhaka's transport sector energy demand and its consequent impacts on economy and environment are forecasted under different policy scenarios to evaluate the alternative policy options for future Dhaka.

In view of constraints, like computational facilities, time and information resources, the study is dedicated only to explore the influences of socioeconomic characteristics and spatial environments on the travel behavior in Dhaka City and evaluate some selected alternative planning options based on aggregate level energy consumption scenarios. To compute the energy demand scenario for long-range forecasting is very difficult task as it requires a number of assumptions on socioeconomic, demographic, transport demand, urbanization level and so on to generate alternative policy scenarios. Due to unavailability of sufficient information and time constraints, the future energy demand assessment is an aggregate level estimation based on modal share predicted by mode choice models and the details of the forecasting procedures are beyond the scope of the study. This analysis is basically based on trend analysis and does not include issues like price elasticity of fuel demand, economic change scenarios and change in the capacity and technology of vehicle. Moreover it does not examine possible options such as travel demand management, alternate fuels, and regulatory options. The framework used in this study has been rather static in nature due to data limitations and time constraints. Its significance can be enhanced by including dynamic interactions among demand, supply and price as well as environmental implications which are expected to be incorporated in future studies.

Again it is well recognized that changes in transportation system have always some long-term effects with corresponding land-use pattern changes. Such long term effects with changes in land-use pattern are out of the scope of this study. Moreover, the sequential four-steps modeling processes for travel demand forecasting are beyond the scope of this study.

1.5 Organization of the Thesis

This thesis consists of seven chapters, references and appendix. The first chapter deals with the introduction, research motivation, objectives and scope of research. Chapter two reviews the related literatures about travel behavior and travel demand modeling of developing countries and similar transport studies for Dhaka. It ends with a brief description of the existing transportation system of Dhaka City highlighting some emerging issues such as increasing travel demand, transport sector energy demand and consequent impacts on economy and environment etc. Chapter three starts with the modeling issues relevant to Dhaka city. It describes the modeling framework of the current study and outlines the entire modeling process. This chapter also describes the overall methodology of the research work. Chapter four describes the relevant background information of study area (Dhaka City) including demographic and socioeconomic characteristics, level of urbanization and existing land-use pattern of the city. This chapter describes the data used in this study in details including its source, types and collection procedures. It also describes the characteristics of the data and intra-zonal trip separation from the selected data for modeling. Chapter five describes the modeling development and calibration procedures in sequential steps which are the fundamental part of this research work. This chapter also presents some descriptive analysis in prior to estimation of each model. Chapter six describes the model results and discusses on need assessment for planning. It evaluates alternative planning options for the transportation system of future Dhaka based on the performance evaluation of existing transport infrastructure in context of energy consumption and environmental impacts. Summary, conclusions and future scope is presented in chapter seven.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Analysis of travel pattern is an important research topic in transportation research and urban planning, irrespective of developed and developing countries. It provides the background information necessary to better understand the complex relationship among urban structure, transportation system and people's activity participation (Zhang, J. and Fujiwara, A., 2005). A thorough understanding of existing travel pattern is necessary for identifying and analyzing existing traffic related problems (Chatterjee, A. and Venigalla, M.M., 2004). However, travel behavior analysis seems to have been considered as a neglected component of the planning of cities in the developing world. There is no systematic analysis of established relationships between various forms of land use and behaviors of trip makers to guide planning of major developments and activity centers. This deficiency limits the effectiveness of transportation policies and actions in meeting the needs of expanding urban populations in the developing world. In contrast, travel behavior analysis has been a major component of transportation planning in the developed world for many decades.

Transportation is one of the key inputs in the economic activities of a country. Generally, government ensures adequate transportation facilities in order to keep the economic activities alive. Providing transportation implies provision of infrastructure as well as ensuring supply of energy required for the service. Transport sector constitutes a major share of national energy demand and, in this connection, interaction between transportation system and energy requirement is well recognized by the researchers as well as decision makers (EC, 2004). Energy requirement from transport sector of a country depends on transportation infrastructure, which often evolves within the context of national transport policy. A transportation system can range from being extensively road and personal vehicle based and thus energy intensive to public transport based, prioritizing pedestrians and non-motorized form of transport. The transportation system of Bangladesh has been dynamically developed during last few decades since independence, into one based on extensive roadway network. Reliance on road transportation resulted in ever increasing demand on imported gasoline fuel. Due to rapid increase of fuel price in recent years this dependency is, in turn, generates considerable burden on the economy. The scenario has evolved due to lack of foresight in pursuing a long term transport policy towards sustainable transport. Considering increased demand for transport services in the future, as well as increased energy scarcity and energy price concerns, the future does not look very promising.

Although travel behavior analysis is a neglected component of urban transport planning, some studies have been made in developing countries. However, as my understanding, studies on transport sector energy demand and its consequences on economy and environment, especially for large cities of developing world like Dhaka have never been conducted. This chapter attempts to collate few travel behavior studies conducted in different countries of the developing world. A critical review of similar studies for Dhaka city is also presented later in this chapter. Besides, some theoretical aspects of travel behavior have also been discussed at the earliest. Finally, a brief description of existing transportation system of Dhaka City is presented at the last section.

2.2 Complexity of Travel Behavior

2.2.1 Overview

"Travel is a derived demand" – i.e. the demand for travel is derived from the demand for spatially separated activities. In other words, travel is a disutility that people try to minimize; and **travel behavior** is the study of what people do over space, and how people use transport. But this is a complex phenomenon (Figure 2-1) which largely depends on a number of factors such as travelers personal/household attributes, socioeconomic characteristics, purposes of trips, the places of origin-destination and the medium of transport under the constraints of time, cost, comfort, availability and so on. The growing volume and complexity of urban travel in developing countries has become a major concern to transportation planners, service sponsors in urban areas, and policy makers (Takyi, 1990).

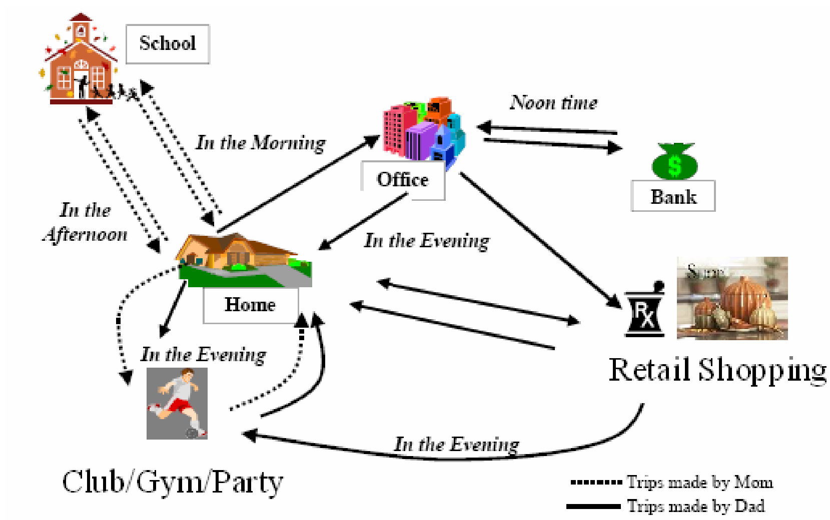


Figure 2-1: The Complexity of Trip Making Process by a Typical Household (adopted from Chatterjee, A. and Venigala, M.M.)

According to theories of transport geography and transport economics, the travel between different destinations is influenced on the one hand by the reasons people may have for going to a particular place, and on the other hand by the discomfort involved when traveling to this location (Jones, 1978; Beinborn, 1979); in other words, by the attractiveness of the locations and the friction of distance, respectively. The concept of friction of distance refers to the impediment, which occurs because places, objects or people are spatially separate: movement involves a cost (Lloyd and Dicken, 1977). By creating proximity as well as distance between activities, and by facilitating various modes of traveling, the urban structure makes up a set of incentives facilitating some kinds of travel behavior and discouraging other types of travel behavior.

The causes of travel behavior of course also include personal characteristics of the travelers, such as age, sex, income, professional status, as well as their values, norms, lifestyles and acquaintances. Human behavior is influenced by structural constraints and incentives (among which the material urban structure is only one category), as well as the resources, preferences and aspirations of individuals. Also symbolic and cultural features attributed to an area may affect the number of visitors attracted. The emerging travel habits are a result of people's resources, needs, and wishes, modified by the constraints and opportunities given by the structural conditions of society (Figure 2-2). Among the structural conditions, the spatial and physical urban structures of course make up only a few out of several categories, but for urban planning these very structures are of particular interest (Naes, 2005).

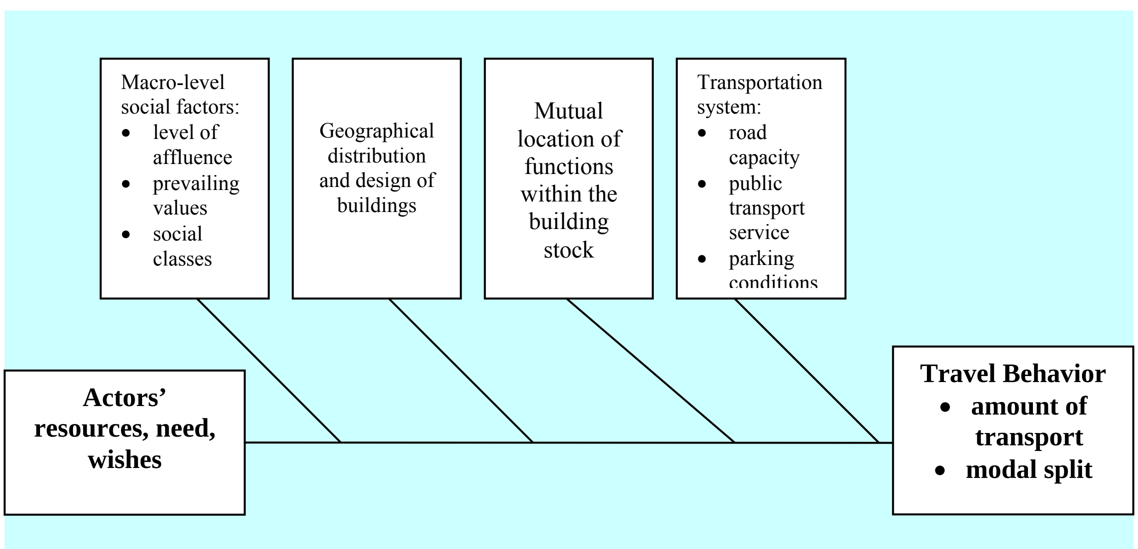


Figure 2-2: Travel Behavior as a Function of Land-use and Individual Characteristics of Travelers (adopted from Naes, 2005)

The situation is further complicated by the fact that increased accessibility may create new needs. For example, the increased accessibility facilitated by the shorter average distances between different functions (residences, jobs, service facilities etc.) in dense and concentrated cities, might be utilized by increasing the radius of action to include a wider range of opportunities, rather than by reducing the amount of travel. The multitude of structural and individual factors likely to influence transportation behavior make the study of relationship between land use and transportation a challenging exercise. (For a more thorough discussion of ontological and epistemological issues related to studies of the influences of land use on travel, see Næss and Saglie, 2000; Næss and Jensen, 2002.)

2.2.2 Activities, Facilities, Locations and Travel

According to activity-based approach (Jones, 1990; Fox, 1995; Vilhelmson, 1999), nearly all travel activity is considered to be derived from the need or wish to carry out other, stationary activities. Travel is thus a derived demand. Everyday life is considered as a sequence of activities conducted by individuals at different places during the 24 hour of day and night. Activities are carried out in order to fulfill physiological needs (eating, sleeping), institutional needs (work, education), personal obligations (childcare, shopping) and personal preferences (leisure activities) (Vilhelmson, 1999: 178). The activity and traveling patterns could be considered as the results of planning processes at an individual level. In daily life, this planning is carried out only for a few activities, as many daily activities are routine actions (Naes, 2005). The fact that many trips are based on routines implies that the persons do not, in their daily praxis reflect on whether or how they are going to make these trips. Many of our daily-life travel activities are probably carried out through practical consciousness. However, this does not mean that people are never reflective over such trips. Routines have not always been there—they emerge at some time. When a routine is 'born', different alternatives of action are usually considered within a discursive consciousness. Established routines can also be changed. For example, the travel mode may be reconsidered when starting at a new workplace or school.

For some facility types, we almost always choose the closest facility, because the various facilities are more or less equal (e.g. post offices) or have regulated catchment areas (e.g. social security offices). But for other facilities, quality differences or symbolic differences within each facility category may make people travel beyond the closest facility to a more attractive one (Naes, 2005).

Residential location is a prime determinant of almost all of travel decisions made by the households. In addition to short term transportation decisions such as those on daily trip chains, long term travel decisions such as decisions on automobile ownership are generally centered around the residential location (Senbil, M. and Fujiwara, A., 2005).

Destinations are the geographical locations towards which our trips are directed. Destinations are typically the facilities we visit in order to carry out our activities, e.g. workplace, school, kindergarten or restaurant. A person’s radius of action during a given period depends on, among others, the speeds by which the person can travel through space (Naes, 2005). A person who has a car at his/her disposal may reach a higher number of destinations during the day than a person who is left to use non-motorized modes of transport. Yet, the spatial reach of a person is not determined by travel speeds alone, but also by the time available for traveling (economic costs and inconvenience caused by traveling come in addition).

2.2.3 Lifestyle and Travel

The lifestyle is characterized as the interplay between individual motivations (needs, values, preferences, etc.), individual resources and the structure of the surroundings, combined with the actual actions carried out by the individual. Transport activity is itself a part of these actions and is thus included in lifestyle concept (Naes, 2005). People’s daily-life transport activity depends not only on the location of the residence relative to various facilities. The destinations we choose or need to visit depend to a high extent on our individual resources, obligations and interests within a number of fields. Also the travel modes of course depend on a number of individual characteristics of the travelers, and not only by urban structural features. Age, sex, economy, household composition, and workforce participation may influence both people's radius of action in daily life and their choices of transport modes. The possibility as well as the need for car ownership is also unevenly distributed among the population.

In addition to the above-mentioned socioeconomic factors, people may have various attitudes towards different travel modes and destinations. These attitudes may result from different importance being attached to factors like travel speed, comfort and flexibility, as well as the symbolic image attached to various means of transportation or districts of the city. The individual characteristics influencing how people attach different importance to such aspects of traveling, are often referred to as 'lifestyle factors'. Such factors may influence people's choice of facility within a number of facility categories, especially regarding leisure journeys, but also for example regarding shopping trips. Choices of travel modes and travel destinations are examples of situations where individuals may seek to indicate their belonging to a certain status group, or to signal their own individuality. Some individuals may also act as 'political consumers' (Lassen, 2002) within the field of transport, seeking to promote certain values through their choices of transport activities, e.g. the protection of nature and the environment (Tanner, 1999).

2.2.4 Center Hierarchies and Travel

The shorter traveling distances and lower proportion of car travel among inner-city dwellers found in many empirical studies have in particular been explained by the high concentration of workplaces, shops and other facilities traditionally found in the historical urban centers. Although some debaters (e.g. Allpass et al., 1968; Sieverts, 1999; Hansen, 2003) claim that the urban cores have lost much of their importance as centers, most cities still have a higher concentration of urban functions in the historical urban center and its immediate surroundings than in the peripheral parts of the urban area. This also applies to our case city, Dhaka Metropolitan Area. There are several reasons for this concentration. The German geographer Walter Christaller's Central Place Theory (1933/1996) offers one of the explanations. This theory has had a considerable influence on urban and regional planning in a number of countries (Berry and Parr, 1988).

The concentration of facilities in the downtown area increases the possibility for visitors to carry out several errands within a small geographic area, which in itself increases the competitiveness of the urban core as a location for retail and other services (Christaller, 1933/1966: 43, 105). However, the residents of a city do not visit the downtown area only for functional reasons. The city center is also the arena of a host of recreational and entertainment activities evolving around what Ploger (2002: 246–247) calls 'the Dionysian urban life'.

Downtown is also often the geographical point of gravity of the workplaces and service facilities that are not themselves located to the city center. Therefore, the average distance to the peripheral workplaces and facilities will also be shorter if we live close to the city center. Moreover, downtown is usually the major node for the public transport lines as well as for the road network.

Figure 2-3 shows schematically how the location of residences relative to the center of the city could be expected to affect the amount of transportation and the distribution between different modes of conveyance. If the residence is situated close to the center, the distances to downtown facilities as well as local service will be short. The shorter distances also imply that a higher share of the inner-city residents may find it acceptable to walk or bike to these destinations instead of using motorized transportation. A central location of residences could thus be expected to contribute to shorter average traveling distances as well as a lower proportion traveled by car. Both would contribute to limit the use of energy for everyday traveling purposes. Thus, among people who emphasize the opportunity of choosing among several work opportunities, shops and recreational facilities, people living close to the central parts of the region center city could be expected to travel less than those who live in more remote parts of the region.

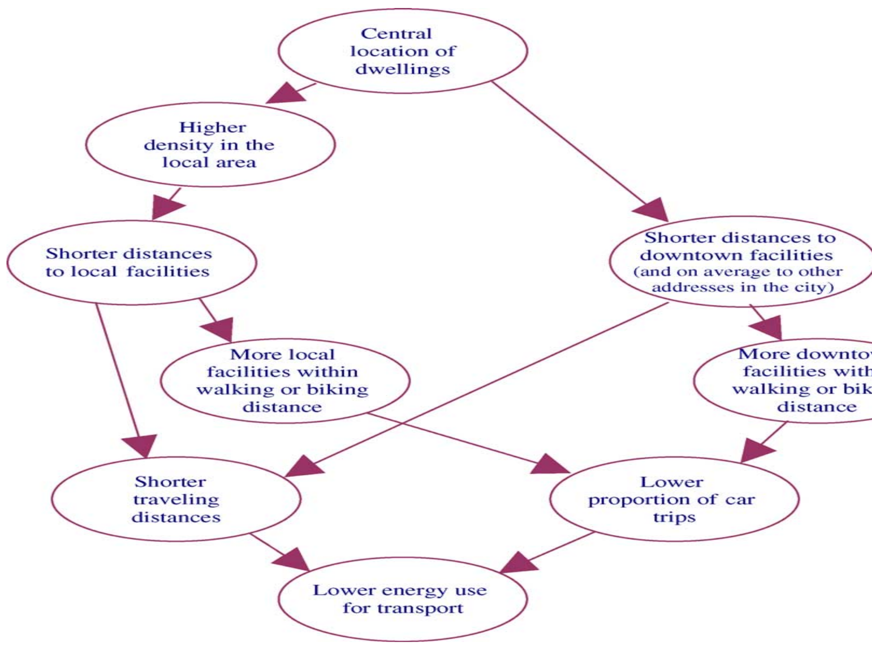


Figure 2-3: Schematic Illustration Showing Modes Choice Behavior Influenced by Urban Forms (adopted from Naes, 2005)

However, there is little reason to believe that the use of public transport will be significantly higher among inner-city residents than the average among those living in the outer areas. Of course, the provision of public transport services is likely to be higher in the downtown area, which is the main node of the public transport network in most cities. But because so many of the destinations of inner-city dwellers are within walking or biking distance, non-motorized transport will often be faster than going by transit. For short distances, the time it takes to walk to and from the transit stops and waiting for the bus or train to appear will often be long, compared to the time saved during the transit ride itself by choosing public instead of non-motorized transport. Public transport also lacks the flexibility characterizing both the car and the non-motorized modes of transport. In particular in areas with a low frequency of departures, the 'hidden waiting time' resulting from the need to adapt the times of departure and arrival to the route timetable reduces the attractiveness of the public transport mode (Naes, 2005).

2.3 Travel Behavior Studies in Developing Countries

2.3.1 Overview

Travel behavior analysis is a neglected component of urban transport planning in developing countries. Up to now, urban developments in developing countries have been done without sufficient and effective control. Due to these uncontrolled policies of economic and urban development, time-consuming and costly construction of new road infrastructure cannot catch up with the increasing traffic demand. As a result, travel demand and transport supply are seriously unbalanced (Zhang, J. and Fujiwara, A., 2005). However, few studies have been made in different parts of the developing world. The studies made in different developing countries that deserve mention and have relevance to the present study are presented in the following sections.

2.3.2 Kumsai, Ghana (1990)

Takyi (1990) made a household based travel behavior analysis that used the cross-classification method in a developing country context. This study was carried out in Kumasi, the second-largest city in Ghana, being a rapidly expanding urban center (population 700,000) with a growing demand for travel. The importance of selecting, defining, and classifying variables and using an appropriate analytic technique related to the socioeconomic values and travel behavior characteristics in developing countries was discussed. Trip rates, expressed as the average number of person-trips per household classified by purpose of trip and mode of travel, were established for four variables of the household (income, size, car ownership, and number of employed persons). Cross-classification trip rate analysis after performing a one-way ANOVA of the variables was also provided.

In this study, the influence of household size, household income and the number of employed persons per household on trip purpose was analyzed. Generally, household size was found influential in trip making particularly for the work, school, and shopping trips. Results indicated that an increase in household size beyond the average had no significant influence on the rate of social trips made since social trips are normally made by adults and larger households contain higher proportions of children. The influence of household income on trip purpose rates was similar to that of household size. However, income had no significant influence on work, shopping and school trips that are the basic trips of a household irrespective of its financial circumstance. Entertainment, social and other trips were particularly influenced by household income. Household employment level had a similar effect on trip rates. A significant number of trips were made to satisfy shopping and entertainment needs with increasing number of employed persons. Because incomes earned by employed members of the household, other than the head of the household, are not usually considered to be part of the "legitimate" household income, there is a tendency to use such incomes to satisfy personal wants; hence, the increase in shopping and entertainment trips.

This study also presented the influence of household size, income and car ownership on mode of travel. Generally, trotro (12 to 20-passenger minibus) or bus trips and walking trips increased with household size. Taxi and car trips tended to decrease for large households, indicating that modal choices of larger families are in favor of the cheaper and more available modes (trotro, bus, and walking) and against the more expensive ones (taxi and car). Regarding the influence of income on modal choice generally, car trip increased as household income increased. The study indicated that households prefer to use the mode of travel charging fares that are consistent with their levels of income. Regarding the effects of car ownership on modal choice, generally, the proportion of daily trips by car, bus, and taxi varied with the ownership. Although car-owning households made more car trips, a significant proportion of the members also used bus, trotro and taxi services.

This study especially in context of similar developing cities may be important for travel behavior analyses as a number of important socioeconomic characteristics were considered for the evaluation of trip making by different modes of transport.

2.3.3 Shanghai, China (1995)

Ho et al (1999) presented an urban transportation-planning model developed for the base year 1995 in Shanghai, which is a major commercial and industrial city in China. The city has experienced tremendous economic growth in the last decade, which has led to rapid and extensive development in the urban and transportation systems. The presented model attempted to analyze people's travel demand characteristics under such fast changing conditions. The modelers followed a modeling framework using a number of model elements with relatively simple structures so that the models can be calibrated and updated easily accommodating any major changes in transportation services and travel demand characteristics. For the modeling purpose, various kinds of variables were selected in such a way so that they can effectively reflect the regional economic growth as well as the urban and transportation development in Shanghai.

Some specific modeling issues, considered in the development of transportation modeling framework in the rapidly changing environment of Shanghai, may also become important in similar developing countries. Broadly, these issues were categorized into three aspects: the reliability of major forecast variables, such as population, employment and vehicle availability, etc., in both model calibration and model applications; the way to represent the emerging transportation services in the transportation planning models and the projection of such services into the future; the stability and heterogeneity of the people's socio-economic and travel demand characteristics under the rapidly changing environment.

The model followed traditional sequential process consisting of trip generation, trip distribution, modal split and traffic assignment. The model framework allows certain policy variables, such as vehicle ownership, land use development, etc., to be directly and effectively considered in various model elements. A specific feature of this model is a two-stage modal split process. After a traditional trip generation model estimating the zonal trip ends, the zonal walk trip ends were separated from the zonal total trip ends before the trip distribution model and the zonal total non-walk trip ends were split between personal motorized trips (automobiles, motorcycles, taxis etc.) and bike/transit trips. Thus, three kinds of trips are estimated on a trip end basis before the trip distribution procedure: walk trips, personal motorized trips and bike/transit trips. Subsequently, after trip distribution bike/transit trips were split into three different modes: bicycle, bus and rail. Such a multi-stage modal split process separated different travel market segments with distinct travel characteristics at the early stage of the modeling process.

The models therefore could handle the trips of various market segments with different individual model element with appropriate structure and variables. The multi-stage modal split procedure can effectively reflect the impacts of the development of the transportation system on modal split. The structures of individual sub-models are much simpler than a single modal split model (e.g. the post-distribution modal split model). These sub-models thus can be calibrated, implemented and updated easily. It has greater flexibility for modal split procedure modification, if necessary, to handle any new travel modes. Finally, the multi-stage procedure allows conducting a detailed demand analysis of individual travel modes.

The study demonstrates a practical modeling framework with an effective approach for dealing with the development conditions in Shanghai and has enormous potentials to be applied in similar developing countries.

2.3.4 Comparative Study on Eleven Asian Cities (1999)

Barter (1999) focuses on urban transport and its recent evolution in nine large cities in Asia including lower-middle-income cities: Surabaya, Manila, and Jakarta; the upper-middle-income cities: Bangkok, Kuala Lumpur, and Seoul; and the high-income cities: Singapore, Hong Kong and Tokyo. Recent trends in transport and land use development in these diverse cities provide a variety of patterns and processes for comparison. A central concern of this study is to identify and evaluate any distinct emerging models or paths of transport development in this rapidly motorizing region.

The study takes a broad perspective in time and space. An attempt has been made to gather data for the last few decades on each city and a brief historical review of 20^{th} century urban transport evolution provided. Nine cities from 8 Pacific Asian nations are compared with 11 European cities from 9 nations, 7 Canadian cities, 13 cities in the USA and 6 Australian cities. Although this leaves out significant regions of the globe, an effort has also been made to collect some information on a number of other cities in Pacific Asia, South Asia, Latin America, the Middle East, Southern and Eastern Europe and Africa.

The study presents a large set of urban data that has been compiled by the author and by a number of other researchers under the supervision of Dr. Jeffrey Kenworthy in the Institute for Science and Technology Policy (ISTP) of Murdoch University in Perth, West Australia.

This study does not try to statistically explain the urban transport pattern found in the region. Instead, the literature is drawn upon for an indication of the important influence on urban transport development. Awareness of these influences and analysis of the global data set, together provide the main tools for achieving the primary goals and these goals are to identify the development paths being followed by the urban transport and land-use systems of these Asian cities, to put them into an international comparative perspective and to understand their implications for these and other cities.

2.3.5 Hyderabad, India (2004)

IES (2004) study developed a 4-step transport demand model for Hyderabad, which is one of the fastest growing centers of urban development in India. The massive growth of the city has brought with it air quality and congestion problems. For various reasons, motorized two wheelers, auto rickshaws and private passenger cars, have displaced trip making traditionally accomplished by public transport and bicycle. Traffic congestion, the predominance of two-stroke vehicles in the traffic mix and inability of public transport to attract significant riderships have all been considered responsible for the severe air quality problems in Hyderabad. The objective of this study was to perform an analysis of policies to address these important issues in Hyderabad's transport sector.

The study process consisted of development of models, forecast of future travel demand and analysis of alternative strategies for handling the demand. In this particular study, an attempt was made to develop operational models using normally available variables, which can be forecasted with reasonable degree of accuracy. The standard and easily available planning variables at zonal levels such as population, employment, number of workers residing, number of students residing and student enrollment, etc. collected as a part of household survey and secondary data collected were used in the analysis.

This study is particular example of an operational model developed for a city of a developing country, India. The considerations made in this study and the methodology followed might become useful in developing travel demand model for a city of similar developing countries.

2.3.6 Chennai, India (2005)

Srinivasan, S. and Rogers, P. (2005) investigated the travel behavior pattern of low-income residents from two contrasting locations in the city of Chennai, India. Travel behavior and its relationship to urban form are the focus of this study. They analyzed the differences in travel behavior due to differences in accessibility to employment and services between the two settlement locations. The results indicate that differences in accessibility appear to strongly affect travel behavior. Residents in the centrally located settlement were more likely to use non-motorized modes for travel (walk or bicycle) than the peripherally located residents. They suggested that the policy makers of developing country like India should consider location of employment in the planning of new housing for low-income households.

In this study, two separate models were developed to investigate the travel behavior pattern of the city. To understand the determinants of travel behavior, discrete choice models were estimated for mode choice and trip frequency. The models were estimated by individual for mode choice and by household for trip frequency. Models estimated by trip for mode choice were similar to the model results estimated by individual and are not, therefore, discussed separately in this paper. Discrete choice models are applications of linear regression models where the dependent variable is of qualitative choice

For the mode choice model the choice is between NMT, combined transit (bus) and NMT and private vehicle (includes three wheelers and two wheelers). The model censored choice of mode. Thus, in the absence of a bus route to the destination the implication is that the mode bus will not be included as a mode choice for the person. Likewise, if the household did not own a vehicle the choice of private vehicle was not available to them. The model was estimated separately for persons with jobs and for all persons. The trip frequency model is estimated as a binary choice model between less than or average number of trips versus more than average number of trips (per person and per household).

This study is particularly important for our current study as the socioeconomic contexts of the two countries are very similar and travel behavior pattern of Dhaka and Chennai are resembles in terms of modes of transport use. The considerations made in this study and the methodology followed might become useful in developing travel behavior modeling for a city of similar developing countries.

2.4 Transport Studies for Dhaka City

2.4.1 Overview

Although Dhaka is a very old city, few detailed transport-planning studies have been conducted; but none have effectively achieved the basic objectives of the planning of the transportation system; this fact is clearly reflected by the inadequately planned and developed transportation system of the city. The first study on road network planning “Dhaka City Master Plan” was prepared in 1959 by then Dhaka Improvement Trust (DIT), covering roughly 830 square kilometer area with a population slightly exceeding 0.5 million. It provided a detailed plan for future construction of roads in the metropolis, (Khan, 2001). Another study was made on economy and engineering feasibility of the “Dhaka bypass” in 1968. In that study along with recommendations for design and construction of roads, some suggestions were made on traffic control and traffic management.

The Greater Dhaka Metropolitan Area Integrated Transport Study (DITS) (1991-1993) was an initiative of the Government of Bangladesh with assistance from UNDP for detail transportation planning of the mega city Dhaka. Recently another details study have been conducted by the initiative of Government under the heading of 'Strategic Transport Plan (STP, 2005)' to guide the development of transportation infrastructure of Greater Dhaka over the next 20 years. Moreover, an important study, the Dhaka Metropolitan Development Plan (DMDP, 1995-2015), was conducted in Government level to formulate long-term overall land use and development policies for the greater Dhaka City with new perspective for sustainable growth of Dhaka. Besides, a number of small-scale especially academic researches have also been conducted on the Transport issues Dhaka City.

Although few studies on transport planning have been conducted in Dhaka, most of the studies were conducted by the foreign consultants who followed the approaches mostly appropriate for the developed countries and consequently faced the challenges and limitations common to the developing countries. The common specific issues of developing country as well as the unique characteristics of Dhaka's transport are not addressed quite effectively sometimes ignoring some major issues.

The following sections present a review of literature on the different transportation studies on Dhaka City with special emphasis on transportation planning. An extensive literature survey of the documents on relevant researches and studies has been performed and some of them are abstracted in this chapter. A review of literatures reveals that, only a limited number of studies have been accomplished on Dhaka City and no studies have so far been accomplished to explore the linkages of travel behavior with socioeconomic characteristics and urban spatial environments although these are the fundamental parts of urban transport planning.

2.4.2 Greater Dhaka Metropolitan Area Integrated Transport Study

The Greater Dhaka Metropolitan Area Integrated Transport Study (DITS) (1991-1993) was an initiative of the Government of Bangladesh with assistance from UNDP. The project was aimed at collection of information about the demand for transport services and the infrastructure to deliver those services to greater Dhaka, preparation of an immediate action plan for the effective management of existing traffic and transport system, preparation of a sound basis for the development of policies and the strategic planning of longer term transport infrastructure investments in the Greater Dhaka Metropolitan Area. DITS began in 1991 and ended in 1993. DITS produced numerous recommendations within its Immediate Action Plan (IAP). Those vary from schemes at a micro level (such as how to improve traffic flow at a particular intersection) to macro level reviews of institutional matters. Recommendations had embraced projects ranging from capital investments to strategic policy advice involving little or no expenditure. Recognizing the need for a sustainable increase in investment in Dhaka's transport sector, Government of Bangladesh with the help of World Bank (WB) approved a project named Dhaka Urban Transport Project (DUTP). DUTP is a technical assistance project. It started in two phases. DUTP I ended in 1998 and DUTP II started in 1998 with reference to work of DUTP I. The main objective of this project was to provide detailed plan and scope for structural improvement of road transportation system of Dhaka city. DUTP-I resulted in the following main recommendations:

- Promotion of the operation of public busses
- Provision for pedestrian only areas in old Dhaka
- Provision of NMT (Non Motorized Transport) main route network
- Improvement of function of the major intersections by constructing flyovers at three locations
- Improvement of existing truck stands
- Development of a comprehensive parking policy

- Enhancement of management and enforcement capabilities of DCC, DMP and BRTA
- Provision of adequate compensation and reinstatement elsewhere for families, commerce, and establishments affected by the projects (new construction)
- Addressing a broad context of environmental issues

As part of this study, a strategic transport model was developed for forecasting travel demand within Greater Dhaka to test various alternative transport policies and strategies for the future. The model was intended to take account of the non-motorized vehicle mix within Dhaka. The major sources of data for the development of the model were Home Interview Survey, Roadside origin-destination survey and Traffic count survey. The DITS travel forecasting model followed classical four step modeling procedure i.e. Trip Generation, Trip Distribution, Modal Choice and Trip Assignment. A market segmentation approach was followed by dividing the transport market into three monthly income groups.

2.4.3 Dhaka Metropolitan Development Plan

With new perspective, the Dhaka Metropolitan Development Plan (DMDP, 1995-2015) was prepared for sustainable growth of Dhaka with joint funding from the Government and the UNDP/UNCHS (HABITAT). The study leading to the DMDP addressed urban planning issues at three geographic level: sub-regional, urban and sub-urban and covered the area now defined as the RAJUK Area. The plan comprised of three levels. The first level, “The Structural Plan” provided a long term strategy including transport network for the 20 years (1995-2015) for the Greater Dhaka with population target of 15 million. The second level, “The Urban Area Plan” provided an interim mid-term strategy for 10 years (1995-2005) and covered for the development of urban areas within Metropolitan Dhaka. The third level, “The Detailed Area

Plan" provided detailed planning proposals and transport network for specific sub-areas of Dhaka, (Hafiz, 2001, Nagari, 2001).

2.4.4 Strategic Transport Plan for Dhaka

The need for a coordinated land use and transport plan for greater Dhaka gave rise to the Strategic Transport Plan (STP). In 2004, a project was undertaken by the Government of Bangladesh with the help of World Bank to prepare a long-term strategic level plan for the transportation system of Dhaka Metropolitan Area. As a part of the STP project, an urban transport planning model (UTP Model) was developed and used to forecast future travel demand resulting from different land use scenarios and transport strategies and to predict the performance of the existing, committed and alternative development strategies for Dhaka's urban transport network infrastructure, services and policies (STP, 2005).

The objectives of the STP (2005) study are to guide the development of transportation infrastructure over the next 20 years with aims:

- To provide the nucleus of a data base for Dhaka and to begin the process of establishing common standards and control for infrastructure planning and design;
- To provide knowledge regarding the simulation model used in the study and to ensure that future work in the area can be continued using the same methodology;
- To demonstrate a method for defining and evaluating alternative transportation strategies such as that future strategies can be evaluated with the same common approach; and
- To list the actions required to be taken in a systematic manner such that the ultimate strategic plan can be realized within a logical framework.

The STP covers many issues involving different types of transport, safety, pricing, the environment, travel demand management, and land use. But the UTP model developed in the STP (2005) study has some critical weaknesses in assumptions, principles, framework and methods. In order to select the preferred transportation strategy, the STP considered only the supply side of the transportation problem under an assumption of unconstrained travel demand for the period of twenty years, despite admitting that it is impossible for construction to meet uncontrolled growth in travel demand. While STP terms its work "multimodal", the study refers only to fuel-dependent transport, ignoring the contribution of pedestrians and fuel-free transport (48% of all trips) and short trips (76% of all trips) (Bari, 2007). Despite the important contributions of rail to passenger mobility, the STP team recommended the relocation of existing Kamlapur Station out of the city. if there remains a substantial demand for intercity travel at the heart of the city, what is the point of cutting the journey for such trips into pieces, thereby significantly increasing travel time, discomfort, and modal transfer penalties? (Bari, 2007)

2.4.5 Other Studies for Dhaka

Some other small-scale studies for urban transport issues of Dhaka were conducted in individual level especially in academic fields. Habib (2002) developed a transport-planning model, named as 'Dhaka Urban Transportation Model' (DUTM), to analyze present and future traffic congestion and resulting air pollution in Dhaka city. In this study, alternative planning options such as elimination of rickshaw and auto-rickshaw, improvement of road network, improvement of bus transit and introduction of rail transit system in Dhaka city were evaluated. The overall structure of the model followed the conventional sequential framework of four step modeling. The model incorporated both supply and demand side variables, which facilitated investigation of a wide range of plans. The developed model had the ability to correlate travel demand with socio-economic variables endogenously. On the other hand, mode related variables were considered in terms of time, cost, comfort etc. enabling the model to investigate the effects of changes in transportation system. The model had some strong points as well as limitations.

Alam (1992) performed a model based study on Dhaka city. He analyzed traffic optimization options by using traffic assignment model. Replogle (1992) made a comprehensive study on NMTs in different Asian cities. According to him, in Bangladesh, although rickshaw contributed majority of the road traffic, it accounted only 10 percent of traffic deaths. Major portion of rickshaw accidents were for the collision with buses and trucks. Ahsan (1990) investigated the status of public transport systems in Metropolitan Dhaka. Particular attention was given to the necessity of a functional and cost effective mass transit system. He pointed out that the existing mass transit system needed to be expanded in terms of both fleet size and route network. He also recommended to improve maintenance facilities, stop and terminal layouts, the quality of services and development of more advance forms of transit facility, such as rapid transit system.

Kiwan (1988) conducted a study on pedestrianization in Dhaka city. He worked on pedestrian traffic safety, mobility, accessibility and environment. He mainly focused on pedestrian-vehicle conflicts and provided a package of recommended measures and guidelines termed as Environmental Traffic Safety Planning and Management. Gallagher (1992) made a study on rickshaw of Bangladesh. He investigated the uses and characteristics of rickshaw, rickshaw pullers and growth trend of rickshaw. Gallagher found that 78 percent of rickshaws were carrying only passenger and 22 percent were carrying goods with passenger.

Firdous (1984) highlighted some of the problems in the bus operation in Metropolitan Dhaka. He pointed out the problems faced by the users. He argued that although there was an ever increasing demand for busses, the bus fleet did not increase keeping pace with the increase in population. Ara (1983) investigated the factors that are responsible for the selection of particular transport mode. In particular, he analyzed the travel behavior of some particular localities in the Metropolitan Dhaka. It was found that total family income was the most important factor in determining its members' choice of appropriate transport mode for different trip purposes. Other factors that influenced selection of travel mode were age and sex, car ownership etc.

Ahmed (1980), Ahmed and Hoque (1988) discussed different aspect of failure of traffic management and administration of Dhaka City. It was found that existing transport facilities were not adequate to meet travel demand and mixed mode situation, which resulted in traffic congestion and danger. Suggestions for modifications of traffic management and policies had been made. Hoque (1981, 1986) mainly dealt with different aspects of road safety. He identified several types of road accidents in Metropolitan Dhaka. He also pointed out their causes and recommended some remedial actions.

Shankland Cox Partnership (1979) Study was a comprehensive study on transport development in metropolitan Dhaka, which emphasized on the construction and management of road network. Baquee (1979) conducted a study regarding traffic problem in Old Dhaka emphasizing on nature, cause and probable solution of its traffic congestion. Gupta (1980) conducted a study regarding rickshaw pullers, rickshaw owners and role of rickshaw in Metropolitan Dhaka. He pointed out that if the growth of rickshaws was allowed to continue at prevailing rate without any restrictions, an increase in number would likely to exceed the limit. On the other hand, if rickshaws were eliminated from metropolis, the situation would create serious pressure on other modes of transportation, which were grossly inadequate at that time and would also have impact on general living conditions of the public, as the traveling cost in general would likely to elevate. The most serious impact, however, will be the employment situation, since a large number of people would be rendered jobless.

2.5 Transportation System of Dhaka City

2.5.1 Overview

Being the administrative, commercial & cultural capital of Bangladesh, the Mega City Dhaka has a major role to play in the socioeconomic development of the country and in the era of regional and sub-regional cooperation. But the existing transportation system is a major bottleneck for the development of the city. Unplanned urbanization, especially poor transportation planning and lower land utilization efficiency, has turned the city into a dangerous urban jungle (Rahman, M.S., 2008). The rapid rise in population along with increased and versatile urban land use patterns has generated considerable travel demand as well as numerous transport problems in Dhaka City. It has resulted in deterioration in accessibility, level of service, safety, comfort, operational efficiency and urban environment. The additional population in coming decades will add new dimensions to the urban fabric of Dhaka.

The transportation system of Dhaka is predominantly road based and non-motorized transportation (mainly rickshaws) has a substantial share. Although 37-km long rail-road passes through the heart of the city but little contribution to city's transport system due to policy constraints. There is a limited use of waterways, especially for freight movements. Dhaka's transport environment is characterized by mixed-modes transports using the same road space, traffic congestion, delays, mismanagement, conflict of jurisdictions, poor coordination among organizations and increasing environmental problems. The distribution of modal choices in Dhaka is unique among cities of comparable size in the world. Buses & minibuses are the cheapest mode available as mass transit and average cost of transport ranges from about 8% of household income for high income groups to 17% for low income groups (DITS, 1993). Large groups within the society have very poor access to transport services. Since 1995 to 2005, the roads of Dhaka have increased only by 5%. On the other hand, population has increased by 7 million and the traffic has increased by 134%. Although the motorization level in Dhaka is till very low comparing to similar sized cities of the world, the rate of increase of various types of vehicle in recent years is significant and it creates over-burden to the limited road-space. Besides, more than 100 open markets are on the streets and 3000 shopping malls besides roads without adequate parking provisions.

Transport service in Dhaka has several deficiencies resulting from a combination of factors - physical, developmental and institutional-cum-policy framework-related which lead to lower efficiency, higher transport costs, longer waiting and travel time, discomfort and more significantly, “transport unreliability” with major adverse consequence for the economy & environment. The present bus services provide inefficient, unproductive, and unsafe level of services. Long waiting, delay on plying, overloading, discomfort, and long walking distance from the residence/work place to bus stoppages are some of the obvious problems that confront the users in their daily life. In peak hours they very often load and unload in unspecified stops. It is a common practice in rush hours to deny access to the old, women, and children passengers, because this group has a tendency to avoid fighting during boarding and alighting (Rahman, M.S., 2008). Today the mega city Dhaka is one of the world’s crowded & congested cities. Many have expressed their apprehension that Dhaka is destined to be the world’s largest slum, if we make further delays to take corrective measures. Its traffic congestion not only causes increased costs, loss of time & psychological strain, but also poses serious threats to our socioeconomic environment. Until and unless there is immediate and effective solution, the system will collapse.

2.5.2 Road Transportation Network

Established on the bank of river Buriganga, Dhaka has been increasing in north-south direction. The road network basically determines the accessibility to the different locations of the metropolitan area. With the expansion of the city, the road network of the city has also been growing time to time. The major roads in the old part of Dhaka have been developed in the east-west direction and major roads in the new part have been developed in the north-south direction. The road network of the city had never been planned specifically in cognizance with the well-developed process of trip generation, trip distribution, modal split and route assignment. As a result, an irregular pattern of network, rather than a more efficient pattern such as gridiron or redial-circumferential pattern, has been developed. (Ahsan, 1990).

Dhaka's road network is nearly 3000 kms (STP, 2005), of which 200 km primary roads, 110 km secondary roads, 50 km feeder roads and rest 2640 km narrow roads, with few alternatives and connector roads and it represents the proportion of road surface to built-up area hardly 7% as against 25% recommended for a good city planning. Only 400 kms footpath is available for pedestrian of which 40% are being occupied illegally by vendors and others (STP, 2005). Here it is totally absence of effective bi-cycle lanes as well as safe walkways for pedestrians. Except for some primary roads, almost all other roads are single carriageway. With the exception of some well-planned residential areas, in most of the areas the road network is quite narrow and alignment is poor. Widths of streets, within the old part of Dhaka are narrower than other newly developed parts. All intersections are at grade intersections. Minor intersections are uncontrolled but major intersections are controlled manually with insufficient traffic policemen. Traffic signals are just ornaments of few intersections without practical application. There are some rotary and roundabouts. Only few intersections have chanalization measures. There are only a few pedestrian overpass and underpass, but most of them are ineffective to attract pedestrians for their faulty design and placement. At present there are only two flyovers, one at Mohakhali and another at Khilgaon, but they have also little contribution to improve the traffic situation of the city as a whole due to some deficiencies in planning.

2.5.3 Transport Modes

Metropolitan Dhaka has traditionally been served by a wide variety of transport modes. These modes can be broadly classified into two groups, the Motorized transport (viz. bus, mini-bus, truck, car, auto-rickshaw/CNG, auto-tempo, motorcycle etc.) and Non-motorized transports (viz. rickshaw, rickshaw van, bicycle, push cart etc.).

***Motorized Transport*:** Dhaka has a relatively low level of motorization compared to the developed and some other developing countries. Although the motorization level in Dhaka is till very low comparing to similar sized cities of the world, the rate of increase of various types of vehicles in recent years is significant. This increasing use of motor vehicles can change the modal split characteristics of Dhaka city. It may also help to alter land use patterns from compact to more dispersed, which in turn can reinforce the use of personalized motor vehicles. At present, motor vehicle ownership in Dhaka, including two-wheelers and three-wheelers, is just a little over 26 vehicles per 1,000 population. During the last decade (1995-2005), motor vehicle ownership in Dhaka has expanded at about 9 percent a year. This growth pattern is expected to continue with the growth of per capita incomes.

Figure 2-4 shows the incremental growth of motorized vehicles in Dhaka city over time (1994-2006). It indicates that there were only 139,675 registered motor vehicles in 1994, the vehicle population increased to 246,441 in 2000 and that reached as high as 412,540 by the year 2006. Over the period (1994-2006), the average growth rate of motorized vehicle is estimated to around 9.5% per year where the growth rates for private car, bus, auto-rickshaw and truck are 9.24%, 28%, 16% and 8% respectively. The composition of motorized vehicles in Dhaka in 2006 is shown in Figure 2-5.

Interestingly, Dhaka has almost half (44.41%) of total motor vehicles registered in the country although it represents only about 1% of the total land area. The Figure 2-6 shows the number and percentage of total motor vehicles in Dhaka City in 2005 against that of all in

Bangladesh. As shares of the country's total vehicle fleet, about 77% of private car, 86.81% of taxi, 35.25% of auto-rickshaws, 35.96% of motor cycles ply on Dhaka's road surface. More than 40% trucks and around 13% of bus and 23% of minibus run in Dhaka City.

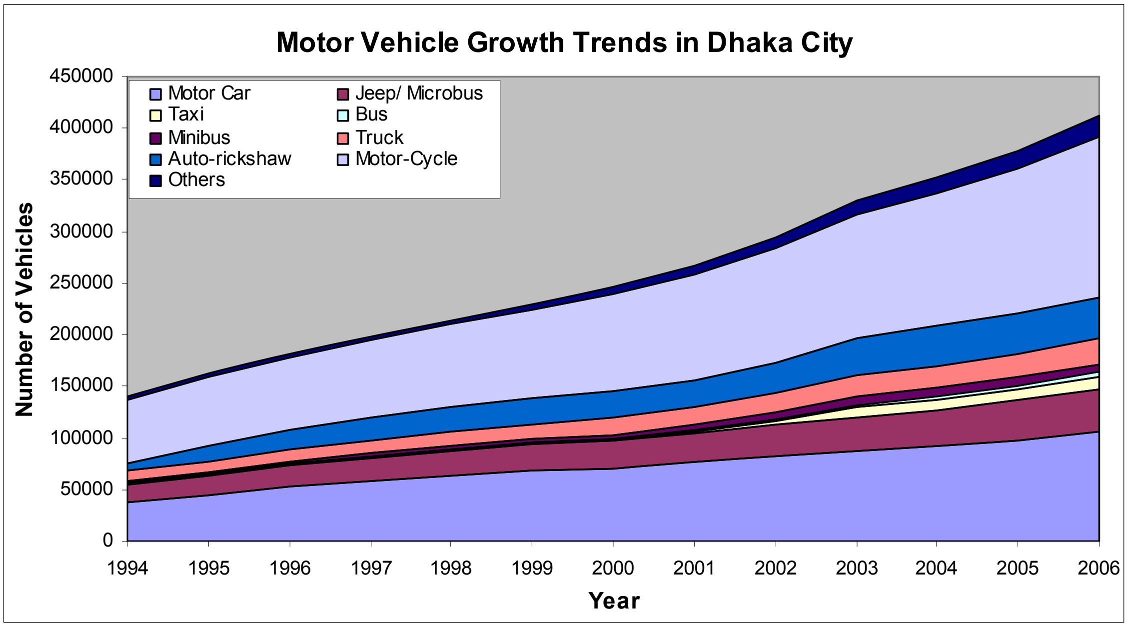


Figure 2-4: Motor Vehicles Growth Trends in Dhaka City: 1994-2006
Source: Bangladesh Road Transport Authority (BRTA), Dhaka (2006)

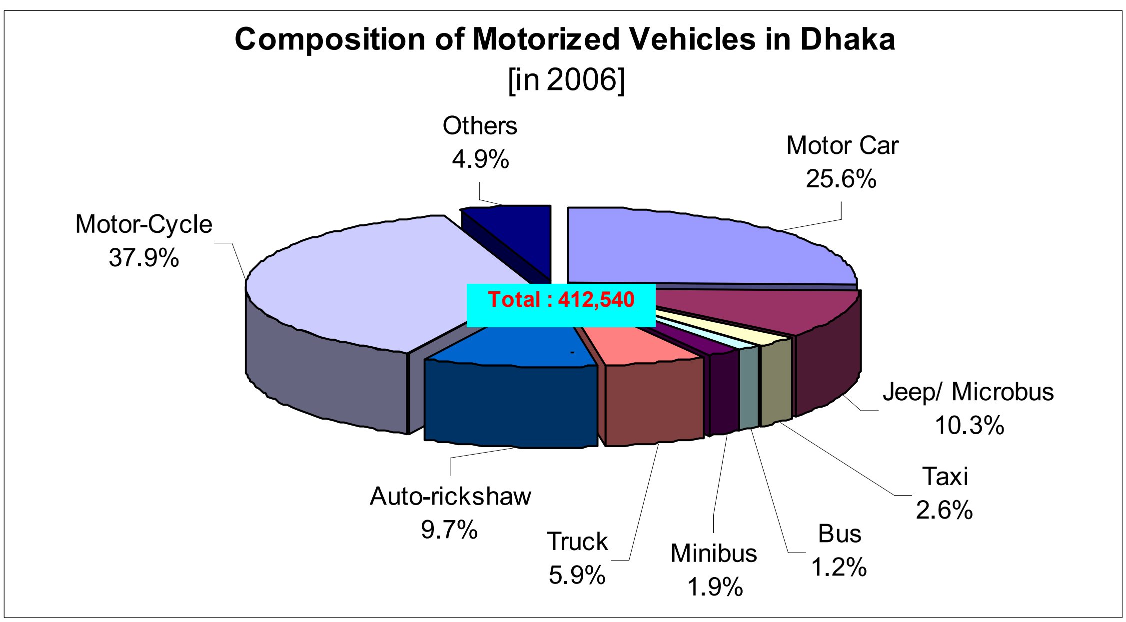


Figure 2-5: Composition of Motorized Transport in Dhaka in 2006
Source: Bangladesh Road Transport Authority (BRTA), Dhaka (2006)

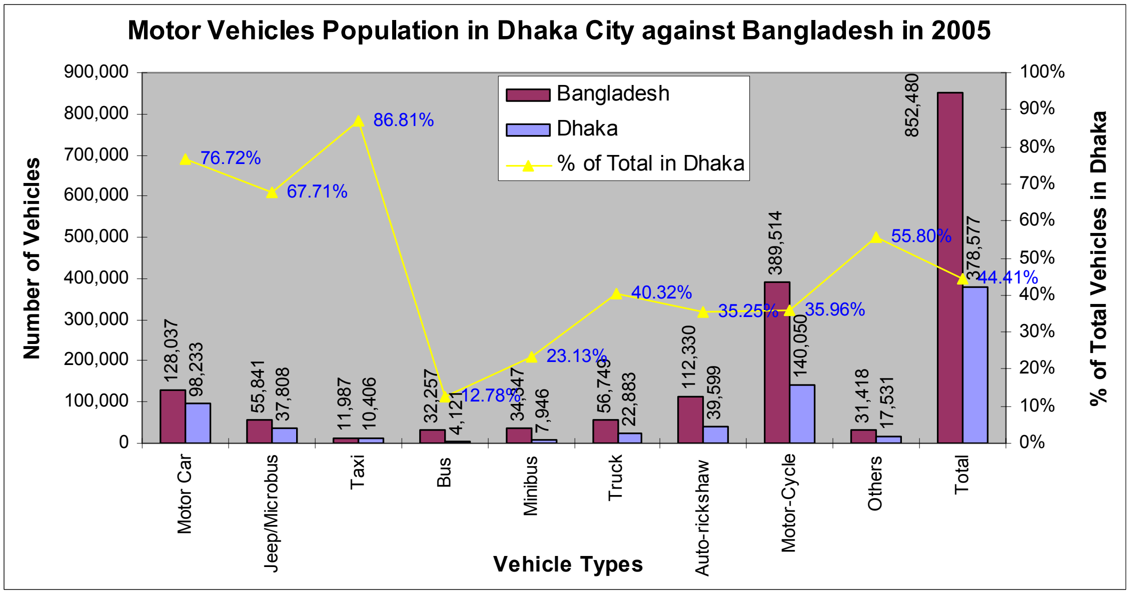


Figure 2-6: Motor Vehicles Population in Dhaka against all Vehicles of the Country
Source: Bangladesh Road Transport Authority (BRTA), Dhaka (2006)

Non-Motorized Transport: Rickshaws, the principal mode of non-motorized transport, are very significant modes of transport in Dhaka. In addition, rickshaws represent an important source of employment and income for a large share of population. Conceptually, although rickshaws offer a high degree of individualized service and have no adverse environmental impacts, an alternative view, however, is that rickshaws are inefficient, inhumane and unsafe as a means of transport. In addition to the motorized vehicles, there are significant numbers of rickshaws ply in the city. Reliable estimate of non-motorized vehicle fleet is more difficult to obtain. Dhaka City Corporation (DCC) limits the number of license issued to rickshaw owners to some 80,000. However, there is no effective means to determine the actual number of rickshaws currently in operation. Unofficial estimates claim that the number of rickshaws plying in Dhaka city is more than 500,000 (STP, 2005). Although non-motorized vehicles are not directly related to air pollution, the congestion exacerbated by such an abundance of non-motorized transport (NMT) is a relevant component of the transportation and air quality problem.

2.5.4 Travel Characteristics of People in Dhaka City

Household Income and Transport Usage: According to DITS (1993), on an average transport expenditure of people of Dhaka is around 12% of total household monthly income. Those people with income less than Taka 1500 per month spend relatively more; and around 17% of household monthly income. This is due to the necessity of people in this income group needing to spend more to gain access to work. The low level of expenditure as 8.4% of household income for households with monthly incomes of Taka 30,000 or over can be explained by car owners not including capital and other costs associated with owing a car in the reported daily expenditure. These costs are about 40% of the total costs running a car, which would bring the expenditure on transport to 14% of household monthly income for those households earning Taka 30,000 or more. Expenditure on transport services in Greater Dhaka, based on Household Interview survey (DITS, 1993) is about Tk. 1,100 crore (US$ 280 million) annually.

The STP Household Interview Survey (STP, 2005) shows there are increasing numbers of trips per household with increasing income level. The main users of transport in Dhaka are higher income households. It is seen that higher income groups are main users of most of the modes. The car is mostly used by the wealthiest segments of the society but also rickshaw use increases with income. The relatively even distribution across income classes of bus passengers emphasizes its importance in improving transport access of all income groups. Improved bus service will be particularly important to the lower and middle-income groups.

Mode Choice and Travel Pattern: A wide variety of transport modes are available to meet the travel needs of the people of Metropolitan Dhaka. The surveys by STP (2005), DITS (1993), DUTP-II (1998) revealed the fact that people are highly dependent on public transport, non-motorized modes and walking. The situation is likely to remain unchanged for years unless there is an increase in disposal income, which may shift people to private modes. According to

DUTP-II (1998), on the basis of number of trips; walking mode (60%) dominates, followed by rickshaw (19%). However, in terms of passenger-kilometer travel, bus travel dominates (46%), followed by rickshaw (16%), walk trips (12%), and private car (8%); the role of auto-rickshaw and tempo is relatively minor (about 4% each) (Monayem, 2001). But according to STP Study (2005), primary travel mode for all trips purposes vary greatly from the DUTP-II study. The primary mode of transport is particularly interesting, with about a third (34%) using rickshaws, almost half (44%) using buses, 14% walking and only 8% by other non-transit motorized vehicles like CNG, taxi etc. For trips that involve several modes of travel, “primary mode” is defined as the mode used for the longest (distance) part of trip. The study also shows that the average number of trips per HH is 8.5 and average trip length is 5.4 kms (STP, 2005).

According to DITS (1993), among the motorized transport in Greater Dhaka, busses run the highest passenger-miles per day (9520 passenger-miles) while motorcycle runs the lowest passenger miles (passenger-35 miles). On the other hand, among non-motorized transports, rickshaws contribute the highest average passenger miles per vehicle per day (72 miles) and bicycle runs the lowest average passenger miles (10 miles). So when the passenger miles per day is considered, rickshaw runs 10,800,000 miles, which is around 36 percent of the total passenger miles per day by all the modes in metropolitan Dhaka. Again if only mechanized transports and central metropolitan area of Dhaka are considered, then busses run the highest passenger-km per day (39.8% of total passenger-km) while car runs the lowest passenger-km (11.9% of total passenger-km), (Hoque and Alam, 2002). On the other hand, in terms of individual passenger trip, rickshaw is the highest and car is the lowest.

2.5.5 Growth of Travel Demand in Dhaka and Associated Impacts on Mobility

Bangladesh witnessed rapid growth of transport since Independence. The overall annual growth rate was nearly 8.2 per cent for freight transport and 8.4 per cent for passenger transport. Even then the transport intensity of the Bangladesh economy is considerably lower than that of many developing countries. The relative roles of transport modes are evolving with road transport expanding at the expense of railways and inland water transport because of its inherent technical and cost advantages. According to Bangladesh Transport Sector Study (1994), the volume of road transport increased by 88 per cent from 1985 through 1993, whereas the volume of transport by water as well as rail declined in almost equal proportion.

Dhaka, the capital city of such rapid growing developing country, is dominant in terms of population concentration, economy, trade and commerce, education, and administration. Dhaka city is growing with accelerating rate but unfortunately, transport infrastructure development of the city could not keep pace with the travel and transport demand of growing population and area. Its present traffic congestion not only causes increased costs, loss of time & psychological strain, but also poses serious threats to our socioeconomic environment.

Although the motorization level in Dhaka is till very low comparing to similar sized cities of the world, the rate of increase of various types of vehicles in recent years is significant. From the comparison of two studies (STP in 2004 and DITS in 1994) we can see that there has been a tremendous change in the transport system of Dhaka since 1994. The average growth of fleet during 1995-2006 was 10% at compound rate higher than the assumed national average of 8%. Traffic on some of the main corridors experienced 15% annual growth of motorized traffic only. The rate of motorized traffic growth will continue to the tune of above 10% per annum in next decades considering the past trend of transport and economic growth. In context of Bangladesh, the overall share of motorized vehicles by Dhaka City is alarming. Figure 6-13 shows the incremental growth of motorized vehicles in Dhaka city against all of Bangladesh over time. More than 44% of all vehicle fleets are concentrated within the small area (less than 1% of total land area of the country) of Dhaka. Moreover, more than 500,000 rickshaws ply on Dhaka's limited roads surface (STP, 2005). Besides, there are around 100 open markets on the streets and 3000 shopping malls beside the roads without adequate parking provisions. Most of the signals are manually controlled and insufficient traffic policemen are to control the traffic. One can easily imagine the real scenario of transport services of such a city where over 14 million people are concentrated.

The transportation system of Dhaka is predominantly road based and non-motorized transportation (mainly rickshaws) has a substantial share. Dhaka's transport environment is characterized by mixed-modes transports using the same road space, traffic congestion, delays, mismanagement, conflict of jurisdictions, poor coordination among organizations and increasing environmental problems. The distribution of modal choices in Dhaka is unique among cities of comparable size in the world. Despite a high preponderance of walking, suitable pedestrian facilities have been neglected and have, in most cases, only been added as an afterthought to road improvements.

According to certain estimates, there are only about 400 kilometers of footpath within the DCC area and nearly 40% percent of which are being occupied illegally. Available information indicates that pedestrians are involved in half of all road collisions in the city. two-thirds of all traffic related fatalities are pedestrians. In spite of this, pedestrian volumes of 10,000 to 20,000 per day are common and reach as high as 30,000 to 50,000 per day in the Old City area. During the peak hour pedestrian counts of 1,000 to 3,000 per hour are common and reach as high as 5,000 in Old City Area (STP, 2005). In Dhaka, only 2% of the households own a bicycle and bicycles are not being used as a significant mode of transport especially due to high cost (30% import duty, 15% VAT, 40% supplementary duty and 8.5% other taxes on all parts &

accessories as well as on all bicycle categories), safety and security, culture and so called status/ego problems.

Rickshaws are very significant mode of transport in Dhaka. Rickshaw volumes of 20,000 to 40,000 per day are common and reach as high as 60,000 in the Old City area. During the peak hour, rickshaw volumes of 2,000 to 4,000 per hour are common. In terms of vehicles, buses accounted for 10% of all vehicles, 16% of motorized vehicles and 25% of 4-wheeled motorized vehicles. In addition to buses (more than 4,000 large and around 8,000 mini buses) operating within the city, some other 1,200 intercity buses are in fact plying on the city road everyday. The volume of buses along selected high demand corridors approaches 500 buses per hour per direction and bus passenger flows at 24 locations of the city in the range of 10,000 to 20,000 passengers per hour per direction. On the other hand, due to policy constraints the contribution of Bangladesh Railway to urban public transport is very small although a 37-kilometer long railroad passes in a north-south direction through the heart of the city.

Dhaka is the commercial, industrial, and governmental center of the country. The rapid expansion of the city has brought with it a rapid growth in the quantity of goods being transported in addition to huge passenger demand. There are around 60,000 trucks in all of Bangladesh – 20,000 operating in Dhaka (local), 20,000 operating to and from Dhaka (inter-district), and 20,000 operating in other parts of the Country outside Dhaka.

Since DITS 1994, the growth of travel trips has occurred more than 10% per year considering all modes of transport. The growth of trips by vehicular traffic mode was tremendous. The numbered NMT rickshaw trip has increased from 1.48 million a day to 6.35 million a day, more than 4 times higher in 2004 that in 1994. The motorized transit mode has increased from a tiny 0.38 million a day to 8.23 million a day, more than 21 times higher while the non-transit trips also increased from 0.9 million a day to 1.49 million a day representing approximately double within this 10 years span. The walk trip on the contrary declined from

5.15 million a day to 2.62 million a day in 2004, which is 50% of the earlier figure estimated in 1994.

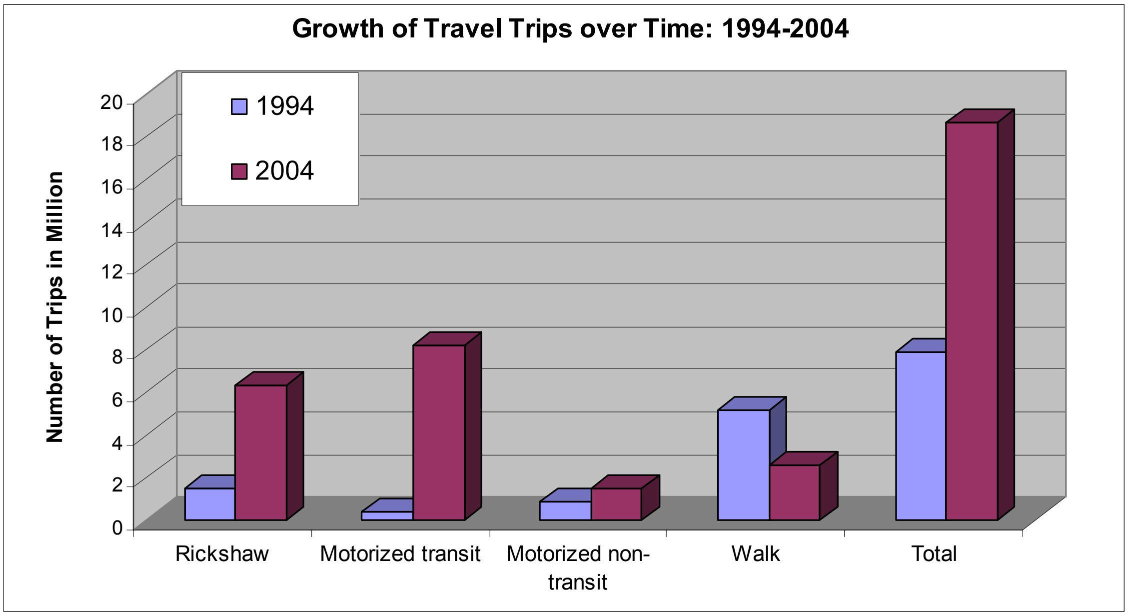


Figure 2-7: Growth of Travel Trips in Dhaka City: 1994-2004
Source: STP (2005) and DITS (2004)

The Figure 2-7 represents the growth of travel trips in Dhaka city over last ten years (994-2004). The growth of vehicular trips need special attention as it has increased from 2.76 million a day in 1994 to 15.44 million a day in 2004, an increase of about 6 times. The unauthorized growth of rickshaws has multiplied the traffic problems in Dhaka.

Transport service in Dhaka has several deficiencies resulting from a combination of factors - physical, developmental and institutional-cum-policy framework-related which lead to lower efficiency, higher transport costs, longer waiting & travel time, discomfort and more significantly, "transport unreliability" with major adverse consequence for the economy & environment. An example of the absence of good traffic management and coordination among agencies is the chaotic disorder that exists in many areas of Dhaka today. Rapid population growth, the absence of planning control and poor economic conditions have contributed to the lack of organization on the public rights-of-way. There is also a high level of operation disorder, which significantly diminishes the efficiency and effectiveness of the existing transport systems.

Today the mega city Dhaka is one of the world's crowded & congested cities. Many have expressed their apprehension that Dhaka is destined to be the world's largest slum, if we make further delays to take corrective measures. With its present situation of traffic systems, the city stands in dire need for a radical transformation in the structural sense. Until and unless there is immediate and effective solution, the system will collapse. We need to take comprehensive view of the present shortcomings and future potentialities of the metropolis to identify and work out plans for formulating strategies to standardize the efficiency of traffic flow and effectiveness of transportation system because choices about transportation system concern the kind of city we want to live in. To maintain the economic viability of this city and to keep its environment sustainable, an efficient mass transportation system is imperative.

2.5.6 Road Traffic Congestion in Dhaka City

The common terms that can be used to describe the present condition of Dhaka City are: congestion, delays, pollution, etc. These are the symptoms of transportation system deficiencies of Dhaka. The congestion is growing day by day in Dhaka like many other developing mega cities particularly in Asia (STP, 2005). The situation here is being complicated due partly to the existing of an overwhelming number of non-motorized slow vehicles sharing the same road space. It is observed that more than 70% of the road way often occupied by NMT (STP, 2005). In addition to inadequate road space for ever growing traffic all the intersections and crossings are at grade. The economic loss due to congestion in Dhaka City was estimated at $140million per annum in major arterials and corridors only (Economic Loss Due to Traffic Congestion, DTCB, 2003). If the congestion in the whole city network is considered including narrow roads, NMT roads, lanes and bi-lanes the figure will go up enormously. In this connection the example of Bangkok city can be mentioned. World Bank Report, 2002 estimated that the loss due to congestion (economic) in late 90s in Bangkok ranges between $272 million to 1 billion a year.

The population of Dhaka has grown in 50 years from less than a million to over ten million.. Motor vehicle ownership faces a growth rate of average 10% annually (Monayem, 2001). According to DITS (1993), although compared to other large cities of the world, Dhaka has a very low level of motorization, intermingle of motorized and non-motorized modes results in a very low speed travel in its streets. With increasing rate of motorization, together with heterogeneous mix of traffic, the road traffic situation of Dhaka is degrading day by day. This picture becomes clear during the morning and evening peak hours, when long queue of vehicles remain stagnant for long time on roads. It might sound inane that we are in a hurry, because we are actually late. If the society reacts very slowly, if at all, the result will be like in Mexico city, where twenty percent of workers used to spend more than 3 hours traveling to and from work place everyday, and 10% people has that over 5 hours (DSM, 2001).

The causes of traffic congestion in Dhaka city can be divided into three broad categories (Habib, 2002). These are site-specific causes, transportation system capacity related causes and planning or policy related causes. The site-specific causes are mainly traffic management related problems. The important maneuverings like left turning, through movement along the intersections etc. are often seriously obstructed for the poor quality and in maximum cases absence of traffic management system, uncontrolled parking of both motorized and non-motorized vehicles etc. In many locations of the road network, the effective roadway spaces are reduced by roadside activities, presence of dustbins, hawkers etc. Such reduction in effective roadway spaces in links and intersections creates bottlenecks to traffic flow and causes congestion.

The transportation system of Dhaka city is mainly road based. The population of the city is increasing day by day but the capacity of the road network is not increasing at the same pace.

The lag between increasing travel demand and system capacity is resulting traffic congestion. Another important factor is the uncontrolled increase in rickshaw traffic. As there is no segregation of motorized and non-motorized traffic in the network, the increasing rickshaws are occupying the maximum roadway space and compelling the other modes to move slowly and creating congestion. The overall transportation system of Dhaka city has not been developed in a planned way rather it has been developed in dynamic response to increasing travel demand. Even there is no definite policy to a sustainable transportation system. Uncontrolled land-use together with increasing migration of rural people towards Dhaka is increasing pressure on transportation system and creating traffic congestion and other related problems.

2.5.7 Transport Energy Demand and Its Economic Consequences

2.5.7.1 Overview

Per capita energy consumption reflects the level of industrial development, the structure of the economy and patterns of overall development of a country. Changes in energy consumption over time can reflect changes in the level and balance of various economic activities and changes in the efficiency of energy use (including increases or decreases in wasteful consumption). Thus, the economic development of a country is highly dependent on its level of energy consumption by different sectors, which are the drivers of economic growth of a county.

Bangladesh is one of the least developed countries (LDC) in the world and it consumes minimum energy for its limited economic activities comparing to other countries. In terms of GDP, Bangladesh ranked 121st position out of 152 countries in 2002 and in terms of energy consumption it ranked 169th out of 198 countries in 2001 (UN Common Database, 2001 and

2002). Figures A-1 and A-2 in Appendix-A show the trends of economic growth and energy consumption level of Bangladesh respectively.

Transport sector is one of the largest consumers of commercial energy in Bangladesh and Dhaka has significant shares, as the transport intensity as well as economic activities in Dhaka is incomparable to any parts of the country. In terms of number of vehicles and activities, the transportation system of Dhaka plays vital role in Bangladesh. Dhaka shares about half of the total motorized transport fleet (as described in earlier sections) in Bangladesh and the intensity of use is relatively higher than any parts of the country. As a result, the transport sector of Dhaka consumes a significant amount of imported fuel. Besides, the environmental degradation for using fossil fuel in Dhaka is very alarming. In this context, the future energy usage policy for Dhaka demands special attention. In the following sections, we discuss the energy scenario of Bangladesh considering the global context, which definitely imply the importance of transport policy on energy demand for Dhaka as well as for the nation.

2.5.7.2 Transport Sector Energy Demand and Overall Energy Scenario of Bangladesh

Bangladesh is one of the least developed countries of the world with huge shortage of consumable energy. Bangladesh's per capita energy consumption is very low, the lowest within the Indian sub-continent. Approximately 40% of the total energy demand of the country is supplied by indigenous biomass based fuels and the rest primarily from fossil fuels (Alam, 2007). Agricultural residues, animal dung and fuel-wood are the most important biomass fuels. Although there is no reliable data in relation to sustainable supply of biomass fuel and their consumption, there are reports claiming that the quality of productive resources is degrading gradually due to overexploitation. Since a large portion of the energy demand is met by such indigenous traditional sources, it is obvious that these directly help the majority poor rural households to maintain their energy security throughout the year.

Energy demand projection for a developing country like Bangladesh is an extremely difficult thing to perform. This is because economic growth, which is the main driver for energy growth, is very difficult to predict (Report published by Ministry of Energy and Mineral Resources, GOB, 2002). It is axiomatic that if a developing country continues to achieve economic growth energy demand will keep on rising. Apart from mature economies, a decline in energy demand signals economic decline or recession.

Aggregate commercial energy demand in Bangladesh at present is about 1000 Trillion BTU with an average growth rate of 8 percent (Figure A-3 in Appendix-A and Table B-1 in Appendix-B). Of this total commercial energy, over 50% percent comes from natural gas (including electricity as electricity is primarily produced by natural gas) and rest (around 47%) from imported petroleum fuel. Coal and coke only constitute 0.61% fuel supply. In 2004-05 financial year about 2.69 million ton of petroleum fuel was imported at a cost of US$1.17 billion, which is about 1.95 percent of the country's GDP and 15 percent of current account balance (BBS, 2005). Since Bangladesh has some gas reserves, there has been an increased reliance on gas and gas usage has been increasing at an average rate of 8.4 percent per year for the last five years. It is also expected that coal will play a significant role as an energy source in the future. Figures A-4 and A-5 (Appendix-A) present the estimated energy demand and supply of the country over time.

Projections by Power System Master Plan (PSMP) put the likely growth in energy demand in Bangladesh at 10% per annum. Assuming the same rate of growth in demand for petroleum and diesel, calculations reveal that demand for these energy products is going to be around 6 times in 2030. keeping in view the current import bill of the country for these fuels, limited available reserve of commercial energy and increasing exploration activities there, the domestic production is not going to meet this increasing demand and thus there will be a large deficit between demand and supply of commercial energy (Figure A-6 in Appendix-A).

Transport sector is the second largest consumer of energy in the country with a concerning growth rate. Consumption of petroleum grew at the rate of 8.07 % on an average in recent years (BBS, 2005), which is higher than average GDP growth, as can be expected from the explanation in the previous section. Total energy consumption in transport sector is responsible for over 24 percent of total energy consumption by different sectors and over 51% of all petroleum consumption (Table B-1 in Appendix-B). Total energy consumption in the transportation sector in the country was 152.11 trillion BTU in 1999-2000 and 239.84 trillion BTU in 2004-2005 which is projected to reach 2860 Trillion BTU in 2030 if the current trend continues. As transportation is dependent on fossil fuel, all the observations discussed above imply increased liability of transportation sector in national economy

Since independence in 1971, petroleum sector has been served by the state-owned Bangladesh Petroleum Corporation (BPC). The organization is responsible for importing crude oil and petroleum products and operating the only petroleum refinery plant in the country. The prices of BPC's petroleum products are strictly regulated by the government. Since the price within the country is kept artificially lower than the world market, BPC has been operating under loss in recent years. Moreover, government has lowered taxes on fuels used by the poor, such as kerosene and diesel, while taxes on gasoline remain much higher. Since January 2003, government approved price increases a few times, effectively reducing subsidies and deficit in BPC's accounts. However, with the continued increase in prices of crude oil and petroleum product in international market, government response has been very slow with relatively small increase in price. As a result of the Government's policy, diesel and kerosene has been effectively subsidized at 18.2% and 19.1% respectively, of import/border prices in 2004, translating into a total subsidy of $170.5 million during that fiscal year. For 2005, estimated loss increased to $445.4 million (about 0.7% of GDP). In September 2006 government approved an increase in prices of petroleum products in an effort to reduce BPC's expected loss for 2006 to US$260 million (0.4% of GDP), from an initial estimate of US$615 million (1.0% of GDP).

2.5.7.3 Effects of Transport Energy Demand on the Economy of Bangladesh

Oil prices shocks have a stagflationary effect on the macroeconomy of an oil importing country: they slow down the rate of growth (and may even reduce the level of output – i.e. cause a recession) and they lead to an increase in the price level and potentially an increase in the inflation rate. An oil price hike acts like a tax on consumption and, for a net oil importer (Nouriel Roubini, 2004). The existing trends of oil price increase (Figure A-7 in Appendix A) is alarming to our economy.

In 2005, given current average market price of fuel to be about $60 per barrel, transport sector fuel demand of about 1.7 million ton was creating a burden of $773 million on the economy of Bangladesh which amounts to 1.37 percent of country's GDP. On-road fuel demand is expected to increase from 50 trillion BTU in 2003-2004 to 220 trillion BTU in 2020 and about 470 Trillion BTU in 2030 under Business-as-Usual (BAU) scenario. Diesel demand is projected to increase from 1.2 million tons in 2005 to 4 million ton in 2020 and more than 8 million ton in 2030. Moreover, as discussed previously, the price of fuel is also expected to increase. Figure A-8 (Appendix-A) summarizes the joint effect of demand and price increase at different price level, assuming inelastic scenario. An increase of fuel price to $120 per barrel will result in a situation where more than 15 percent of GDP being consumed for importing fuel to keep road sector running. Considering Current Account Balance of $339 million the country barely possesses resources to procure only two weeks' transport sector fuel at present. As reported by the World Bank oil price increase, between December 2002 and April 2006, caused the economy and terms-of-trade to shrink by 1.2 and 2.9 percent of GDP respectively.

2.5.7.4 Effects of Transport Policy on Energy Demand and Its Consequences

Transport in all its facets is a remarkably diverse sector. The different modes—roads, railways, urban transport, ports and maritime transport, inland waterways, airports and aviation, and combinations of these—serve particular parts of a wide spectrum of freight and passenger transport demands. While some modes do compete in some markets, they are not always close substitutes and in many circumstances are not substitutes at all. Each mode makes different but complementary contributions to the development of a country, and each faces specific issues.

In the last couple of decades, transportation has been one of the most important priority sectors to the government and donor agencies for investment in Bangladesh. During this period about US$40 billion has been invested in transport sector of the country. Particularly, the road sector has attracted a major share of the allocation, far exceeding investments in other modes. Currently, about 90 percent of transport sector budgetary allocation is invested for road sector development. Consequently, roadway inventory and number of registered vehicles has been experiencing a very high growth rate. Because of indiscriminate investment in road sector the volume of road network in the country has increased from 3764 km in 1971 to 270,711 km in 2006 with 50,736km of paved road. Moreover National Land Transport Policy, which has been approved by the government in 2005, sets vision for further enhancement of road network. Plans have also been approved to construct elevated expressway and flyovers without commensurate consideration for mass transit, railways and waterways.

It is evident that increased energy demand in transport sector of Bangladesh is closely related with government's policy bias towards road transport sector. As the demand is satisfied by mainly imported fuel government's policy has obvious repercussion on economy. Under business as usual scenario, its consequent effect on economy is expected to swell in future.

2.5.8 Traffic Induced Pollution in Dhaka City

Air pollution is recognized as a major health hazard. Vehicle emissions are increasingly being recognized as the dominant cause of air pollution and health problems in Dhaka city (Bhuiyan, 2001). The pressing demands for motorized form of personal mobility are generating pressures on road network and resulting in congestion, which threatens the sustainability of the socio-economic progress. Our country generally has been much slower than other industrialized countries in recognizing these risks and taking technical steps to reduce air pollution from automobiles. A few meaningful research works have been done in Bangladesh in this regard. Most recently a detail study was carried out by Jaigirdar (1998) to identify the motor vehicle induced pollution in Dhaka City.

Air pollution situation in Dhaka is also worsening due to the rapid growth in the motorization level. Although the number of motorized three-four wheelers is not large, being only about two hundred thousand, the emissions from the vehicles are particularly substantial due to congestion, poor fuel quality, highly polluting old buses, low technology of the vehicle fleet, weak maintenance culture and overloading and over-fuelling of heavy vehicles. Vehicle emission inventory is given in Table B-2 (Appendix-B). The main pollutant of concern in Dhaka is the particulate matter and motor vehicles are major contributors to PM pollution. PM levels in Dhaka range from 2 to 4 times Bangladeshi standards, but up to 12 times worse than WHO guidelines in the most heavily polluted commercial locations in Dhaka (SDNP, 2005). Most of the vehicular PM pollution (> 80%) comes from the diesel vehicles in Dhaka (BCAS, 2005). Ambient SO_2 levels are nearly five times national standards in commercial area, and nearly ten times above WHO guidelines.

Motor vehicle has increased largely over the years; and so general levels of road traffic noise have increased through this period. The noise levels measured at different parts of Dhaka city few years ago by Society for Assistance to Hearing Impaired Children (SAHIC) varied between 68 and 106 decibels. At some intersections the noise level was above 100 decibels, while at some other thoroughfares 70 to 100 decibels were recorded. The lowest level was 68 decibels, measured in the diplomatic zone, as opposed to the 45-decibel-tolerance level, recommended by WHO.

2.5.9 Traffic Accident in Dhaka City

Road traffic accident is also an important problem due to rapid motorization. Dhaka is accounted for 23% of country's road accidents (Hoque et al, 2006). Among them 39% fatal, 44% injury and 16% are collision type accidents. According to the same study, highest frequency accidents (44%) are 'pedestrian-motorized vehicle' collision type although Dhaka is the one of the least motorized mega cities in the world. Non motorized passengers are the next vulnerable road user in Dhaka involving 18% of accidents. With rapid motorization it is apprehended that Dhaka's road traffic accident situation will be deteriorated in future.

2.5.10 Road Transport Management

Traffic management is the maximum use of existing road space, using traffic operations enforcement, materials and equipment to achieve safe and efficient movement of people and goods. But an example of the absence of good traffic management and coordination among agencies is the chaotic disorder that exists in many areas of Dhaka today. Rapid population growth, the absence of planning control and poor economic conditions have contributed to the lack of organization on the public rights-of-way. There is also a high level of operation disorder, which significantly diminishes the efficiency and effectiveness of the existing transport systems.

Dhaka has a multi-modal transport infrastructure which caters to the needs of intra-city and inter-city passenger and freight traffic. Most of this traffic (95 percent) is handled by road based transport system. Rail, water, and air transport system primarily cater to the intercity travel segment and hardly play any role in city transport. Many agencies are involved in providing, operating and maintaining the infrastructure and services within each mode of transport.

Evidently, government agencies have the main provider and operator of transport infrastructure and services. Two major factors have contributed to such a situation. The relatively high investment required and high risk involved in the provision and management of infrastructure had hitherto discouraged the private sector from entering into this area. But this has changed dramatically in the past two decades. In the case of services, governments have felt that by controlling entry, product characteristics, price levels, profit rates etc. through regulatory mechanisms or direct control, the public would be protected from being exploited by the private operators. Experience in many countries with de-regulated markets has demonstrated that such government interventions were not as efficient as was thought to be.

The changing focus in transport policy implies a substantial change in the role of government. It should get away from being a supplier, operator, and service provider. Instead it should concentrate on being an effective regulator, a facilitator for private sector participation, custodian of environmental and social interests. This means that the government needs to create the proper institutional framework for competition, set economically efficient user charges for the use of publicly provided infrastructure, allocate the scarce public resources carefully and increase involve the community in the decision making process. These will ensure better transport facility for the city dwellers.

2.6 Summary

This chapter has reviewed some transportation studies related to present research conducted in developing countries as well as the studies conducted for Dhaka City. The approaches followed in similar developing countries have been reviewed. At the same time, the approaches and limitations of the transport models of Dhaka city have been critically reviewed.

As a result of this critical comparison and review, the present study attempts to make a modeling framework in order to overcome the shortcomings of the traditional assumptions of urban travel demand analysis and to eliminate the error that might be introduced into forecasts of future urban travel behavior in Dhaka. From the above review, it appeared that most of the transport studies in metropolitan Dhaka were related to the transport inventory and traffic management. Some of them dealt with mass transit system in the metropolitan area. There had been no study dedicated to explore the relationship of travel behavior with socioeconomic characteristics and urban structures and their evaluation techniques for transportation planning especially in context of transport sector energy demand and its consequent on country's economy and environment. This chapter also elaborately discussed the existing transportation system of Dhaka emphasizing the trends of increasing travel demand, people's travel pattern, vehicular growth rate, and transport energy issues highlighting its resulting impacts on environment and the economy of Bangladesh as a whole.

CHAPTER 3

RESEARCH DESIGN AND MODELING FRAMEWORK

3.1 General

The need for transportation model as a planning tool is particularly important due to the extent and diverse characteristics of transportation systems as well as the complexity of people's travel behavior. The demand for transportation is integrally related with economic activities, land-use, population and its distribution etc. The development of transportation system involves huge amount of money and substantial amount of time and also has long-term effects on the society and environment. Because of these reasons any decisions regarding transport sector needs adequate planning, which should be justified by careful analysis on the basis of transportation models. For effectively dealing with traffic congestion and associated environmental problems, transportation planners need a tool to get a greater visibility of current and projected condition and comparative benefit of potential system improvement alternatives. In principle, strategic transportation planning models provide the best means of satisfying these requirements. With accurate database and careful specifications, such models are capable of affording planning insights that may not be obvious to the common sense.

The standard approach to urban travel demand modeling, commonly employed by transportation planners, is embodied in a system of models generally known as urban transportation modeling system (UTMS) (Meyer and Miller, 1984). In order to determine the pros and cons of the influential factors related to travel behavior and to explore their importance and implications on strategic transportation planning for future Mega City Dhaka, the present study proposes a comprehensive modeling framework consisting of several sub-models in a comprehensive travel behavior modeling framework. This chapter describes the components of the models developed for Dhaka to investigate the influence of socioeconomic characteristics as well as spatial environments (types of urban forms) and the ways to adjust its parameters. The individual modules of the models are developed by using available data and resources and taking basic ideas and patterns followed in similar types of studies (Schwanen, 2001; Dieleman, 2002, Fillone, 2007; Srinivasan, 2005 et.) conducted different parts of the world. So the performance of the model should be carefully verified to represent the actual situation of the area of concern.

This chapter discusses the modeling issues related to Dhaka's transport environment and the proposed research design framework to handle those issues including its scopes and objectives, principles, assumptions and the limitations. The methodology followed in the research is also discussed. An introduction to the modeling tools used in this study is given. The detailed procedures for data preparation and assembly for modeling and analysis are also presented at the end of this chapter.

3.2 Modeling Issues

A critical concern in the development of travel behavior analysis model for Dhaka is how to handle the extensive growth of a mixed land use pattern, the heterogeneous socio-economic structure and travel patterns as well as the mixed transportation system. To consider the influence of non-motorized modes, especially Rickshaws and to include all possible minor modes (taxi, CNG, motor cycles etc.) in the model was a crucial task of the model. In such a complex heterogeneous environment, the reliability and predictability of a model that is developed and calibrated based on the data collected at one point in time is more limited than under normal circumstances. In this section, the various modeling issues, which need to be considered in the development of travel behavior model in Dhaka, are discussed. The issues are discussed under three following broad categories.

3.2.1 Issues Related to Data Availability and Forecasting

1. *Data Availability*: Data availability is a common major issue for transportation modeling in developing countries. The scenario is not much different for Dhaka. Sometime the reliability and extent of the available data are also limited.

2. *Demographic forecasts*: As Dhaka is the capital city of Bangladesh, every year a great number of populations come to Dhaka for employment and other purposes. There is no reliable information on the numbers of the floating population in the base year. Also, the amounts are very sensitive to demand assessment. It is thus extremely difficult to derive reliable estimates for these variables in the future.

3. *Land Use development*: The land use development greatly affects the spatial distribution of various categories of employment and population and thus the demand for transportation. Moreover there exists a rapid growth of uncontrolled mixed land use pattern in Dhaka. With such large-scale mixed land use development, it is difficult to forecast the spatial distribution of employment and population.

4. *Heterogeneous Socio-Economic Structure*: The socio-economic structure is very much heterogeneous in Dhaka. There are large differences in the income of the population. Further the income differences are distributed differently in various parts of the city making difficult to forecast the income distribution of the population of the city.

5. *Policies related to transportation*: The demand on the transportation system is greatly affected by the policies regarding motorization growth and land use development, e.g., the policy regarding owning automobiles, introducing new transport services and infrastructures, controlling land use development etc. These policies are updated, modified or changed in Dhaka without considering their effects on transport demand. However such policies should be clearly defined for developing reliable and meaningful long-term transport planning.

3.2.2 Issues Related to Transportation Supply

1. *Mixed Traffic*: Traditionally, Dhaka has been served by a wide variety of transport modes. These modes can be classified into two groups, the Motorized transport (viz. bus, mini-bus, truck, car, auto-rickshaw, human-hauler, motorcycle etc.) and Non-motorized transport (viz. rickshaw, rickshaw van, bicycle, push cart etc.). The presence of this heterogeneous mixed traffic makes it difficult to develop a reliable and practical model for Dhaka city.

2. *Uncoordinated transit service*: With the uncoordinated and schedule less individual companies or persons operated transit service being present, the operations of various transit vehicles (e.g., Volvo bus, A.C bus, Mini-bus, Human-haulers etc) are difficult to model.

3. *Emerging transit routes or services*: Every year new transit routes and services are being introduced in Dhaka. Different service characteristics and fare structures of these improved transit services would change significantly the demand of other modes. Therefore, it is hard to represent these differential service characteristics in the model and to project these services in the future.

4. *Non motorized vehicle (NMV) restrictions*: Currently, NMV is being banned on different arterial roads of Dhaka city. The planning of NMV restrictions on different arterials is not strictly followed. However with new restriction being applied the residential location, route selection and modal choice will be affected.

3.2.3 Issues Related to Travel Demand

1. *Induced Demand*: The people in Dhaka have experienced several new kinds of transportation services, infrastructures and policies, such as improved bus system, CNG auto-rickshaw, flyover, NMV restriction etc. These emerging services may induce people’s travel behavior which may not have reached into an equilibrium level in the base year. Therefore the

information collected in the base year may not be adequate enough to reflect people's travel behavior in the future.

2. *Trade-off between fare and service quality*: With more transit alternatives with different service characteristics and fare structures, the people in Dhaka now can choose among different alternatives based on the trade-off between cost and service quality which can affect the modal share.

3. *Heterogeneous demand characteristics*: The socioeconomic structure and travel behavior of the people in Dhaka are heterogeneous. For example, there are differences in the number of trips, O-D pattern and modes between low income and high income people. Moreover, there is a high incidence rate of urban poor in Dhaka who have completely different trip making pattern. Therefore it is difficult to model such heterogeneous demand characteristics under a single modeling system.

Reviewing the above issues, it is apparent that modeling travel behavior for Dhaka city is a complex as well as colossal task. However not all of them are critical for a strategic perspective; and to make such a task manageable with reasonable accuracy simplification of the problem is necessary. The proposed modeling framework attempts to address the critical issues with reasonable assumptions appropriate for a strategic level of analysis. The following section describes the framework including its scopes, principles and assumptions.

3.3 Proposed Modeling Framework

3.3.1 Scopes and Objectives

The scopes of this framework are limited to the development of a system of models which can simulate the complex travel behavior, can assess and analyze the urban travel demand situation and can evaluate the performance of the transportation system under the given travel demand. The principal objectives of the models are:

1. To develop a comprehensive modal split model that can determine the modal share of Dhaka including the dominant non-motorized mode, Rickshaw and all possible minor motorized modes of transport.
2. To develop a model that properly describes the effects of exogenous variables on mode choices.
3. To develop a trip frequency model to identify the trip making tendency of people of different levels and places.
4. To develop a model for distance traveled to estimate the influence of socioeconomic characteristics as well as spatial environments on individuals choice sets.
5. To identify group specific differences in travel behavior and their mode choices for different market segments of Dhaka City.

The developed system can be applied in various fields of transportation planning. Using this model, the performance of the existing transportation system under the present travel demand can be evaluated, the need for improvements in the urban transport infrastructure can be identified, future urban travel demand can be forecasted and the performance of the future transportation system and policies under the future travel demand can also be evaluated.

3.3.2 Modeling Principles

In order to deal with the specific modeling issues in Dhaka as discussed above, a new modeling framework has been attempted. The framework is designed in such a way that the complexity of the situation is addressed with a scope of making future enhancement. The framework is developed based on a number of principles as stated below:

1. *Strategic Model*: The model can allow changes, assess present status, analyze different future scenarios and evaluate strategic options within a specific time frame.
2. *Market Oriented*: In order to address the heterogeneity in travel market, different demand markets with minimum interaction, e.g., the personal motorized trip market and the non-personal motorized trip market are considered separately in the model framework.
3. *Heterogeneous Demand*: The heterogeneity in socio-economic structure has been addressed by segregating the households into different income groups and analyzing their travel mode choices separately. Urban poor being unable to afford to use the transport system have been excluded from the analysis.
4. *Disaggregate Model*: The model has sub-models that follow 'disaggregate' (e.g., household and even individual based) approach of calibrating and validating different parameters. Such an approach can determine parameters with greater accuracy with limited available data.
5. *Multi-Modal Model*: The model framework considers the presence of heterogeneous travel modes such as non motorized vehicles (rickshaws and also walking) and motorized vehicles (CNG, private cars, taxi, motor cycle, and buses) and provides separate information for each mode.
6. *Flexible Structure*: The relationships among the model components are established in such a way that future refinements can be made with increasing complexity of certain components.
7. *Simple Structure*: The structure of each sub-model as well as the interactions between model components is simple so that model elements can be updated, implemented and applied easily.

8. *Modularization*: The entire model set comprises a number of sub-models or model components so that each sub-model can be calibrated or updated individually.

3.3.3 Model Assumptions

Several assumptions are required in order to make the modeling process more manageable.

1. The modal choice model has been developed as a tool for strategic transportation planning and so all possible modes of travel have been carefully considered in the analysis.
2. This framework considers that hardcore urban poor have different trip pattern and they will not use any form of the vehicular transport of the system and therefore walking as a mode of transport has been considered in the analysis.
3. The intra-zonal movements (by walking and other vehicular trips within a TAZ area) have not been considered for modeling since they are insignificant as well as difficult to model.
4. The model assumes freight and through movement insignificant compared to the traffic considered.
5. The model separates travel market into several parts; firstly, motorized and non-motorized and then the motorized part divided into another two parts- personal motorized trip market (trips made by HH-owned vehicles like car and motor-cycle) and other one –trips made by those who owned no personal vehicles and assumes the later market homogeneous for the purpose of modal split.
6. Travel time for each mode is obtained from zone-to-zone distance and assumed speed based on mode-specific speed observed in STP (2005) study and other studies. Network analysis provides the zone-to-zone distance from the zone-to-zone shortest paths which are derived by assigning minimum traffic in the network.

7. The costs of travel for specific modes of transport have been derived based on mode-specific base-year fare structure and as assumed in STP (2005) study as cost-related data for different modes are not available in the data. The cost of each trip is divided by the O-D distance in order to derive the per-km cost of travel.

3.4 Methodology Development

3.4.1 Research Design

The methodology of the current study consists of three main stages: Data preparation for the model, model development, and policy analysis. Figure 3-1 ustrates the activities involved in each stage and the sequence which the activities are linked together to generate the intended outputs in each stage.

3.4.2 Modeling Framework

Considering the principles mentioned above, a comprehensive modeling framework is developed. The whole modeling framework of study consists of several sub-models which is based on relatively simple structures so that the models can be calibrated, updated, implemented and applied easily. The sequential modeling process is considered the most practical modeling approach, particularly for the developing countries, where the availability of reliable data and professionals with advanced modeling knowledge is relatively limited (Ho et al, 1999). Figure 3-2 summarizes the modeling framework for this study.

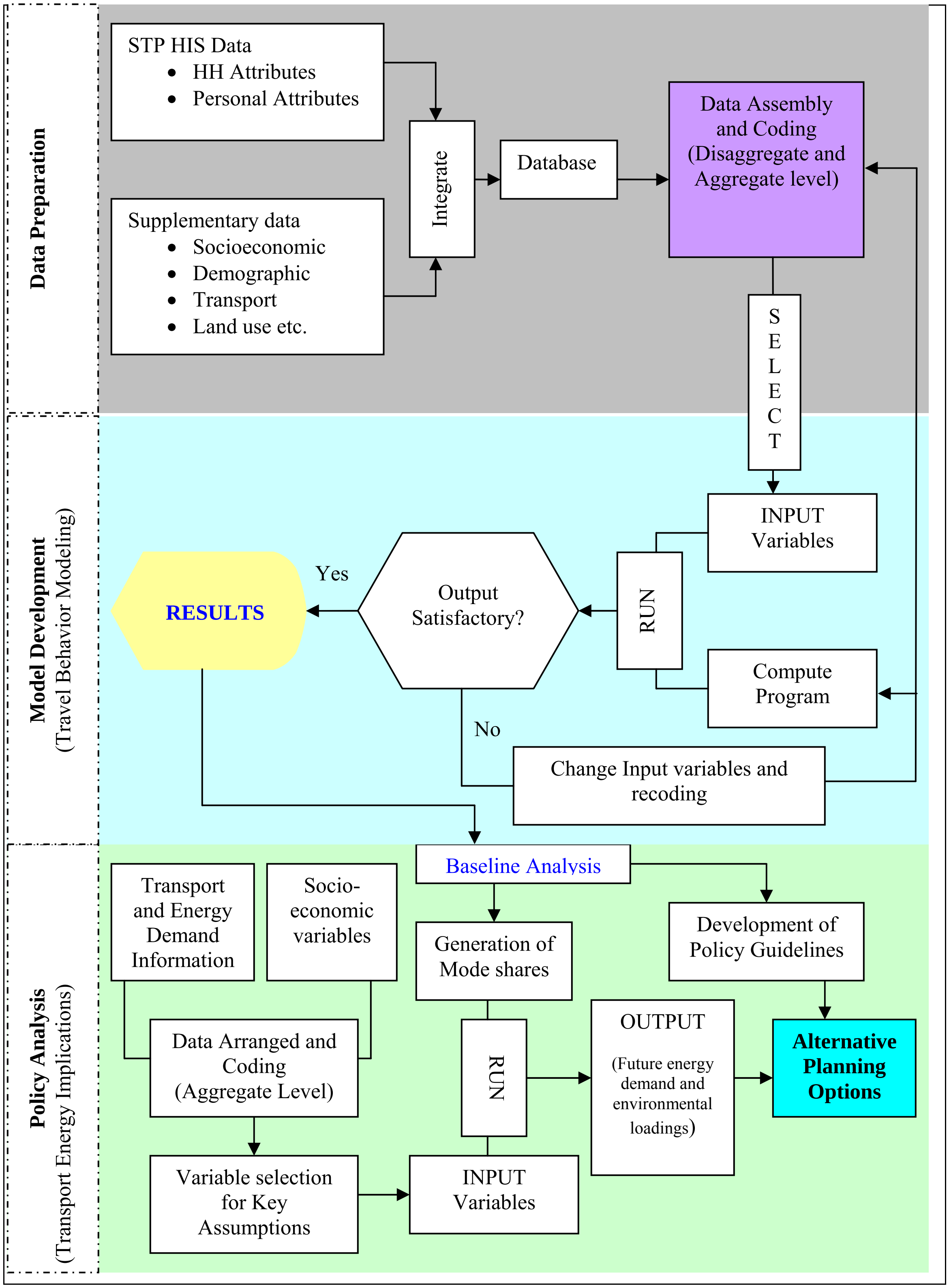


Figure 3-1 Research Design and Integrated Policy Analysis Process

For strategic modeling purpose, at first the intra-zonal trips are separated from the selected data set. Then variables are identified for each model types based on Dhaka's socioeconomic context and travel behavior. The overall modeling procedures are as follows:

Development of Mode Choice Models

- The modeling approach is a discrete choice model based on random utility maximizing principles.
- The "multi-stage" modal split procedure is applied as it is believed to be more effective for dealing with the specific situation in Dhaka, as compared with the single pre-distribution or post-distribution modal split model.
- Two types of modal split models are developed: the Multinomial Logit (MNL) and the Nested Logit (NL) model to predict the modal shares.
- Firstly, simple MNL Model are developed and calibrated for all trip purposes (based on daily travel activity) as the MNL model is the most popular form of discrete choice model in practical applications (Mohammadian, A., and S.T. Doherty, 2005).
- Secondly, NL Model will be developed and tested based on specific market segmentation in order to overcome the so-called independence of irrelevant alternatives (II A) limitation in the MNL model by modifying the choice structure into multiple tiers.
- Separate Multinomial Logistic Regression Modes are developed to show the effects of exogenous variables on alternative mode choices for different trip purposes as these (multivariate techniques) are very useful for travel studies because so many factors are at play (Boarnet, M. and Crane, R., 2001).

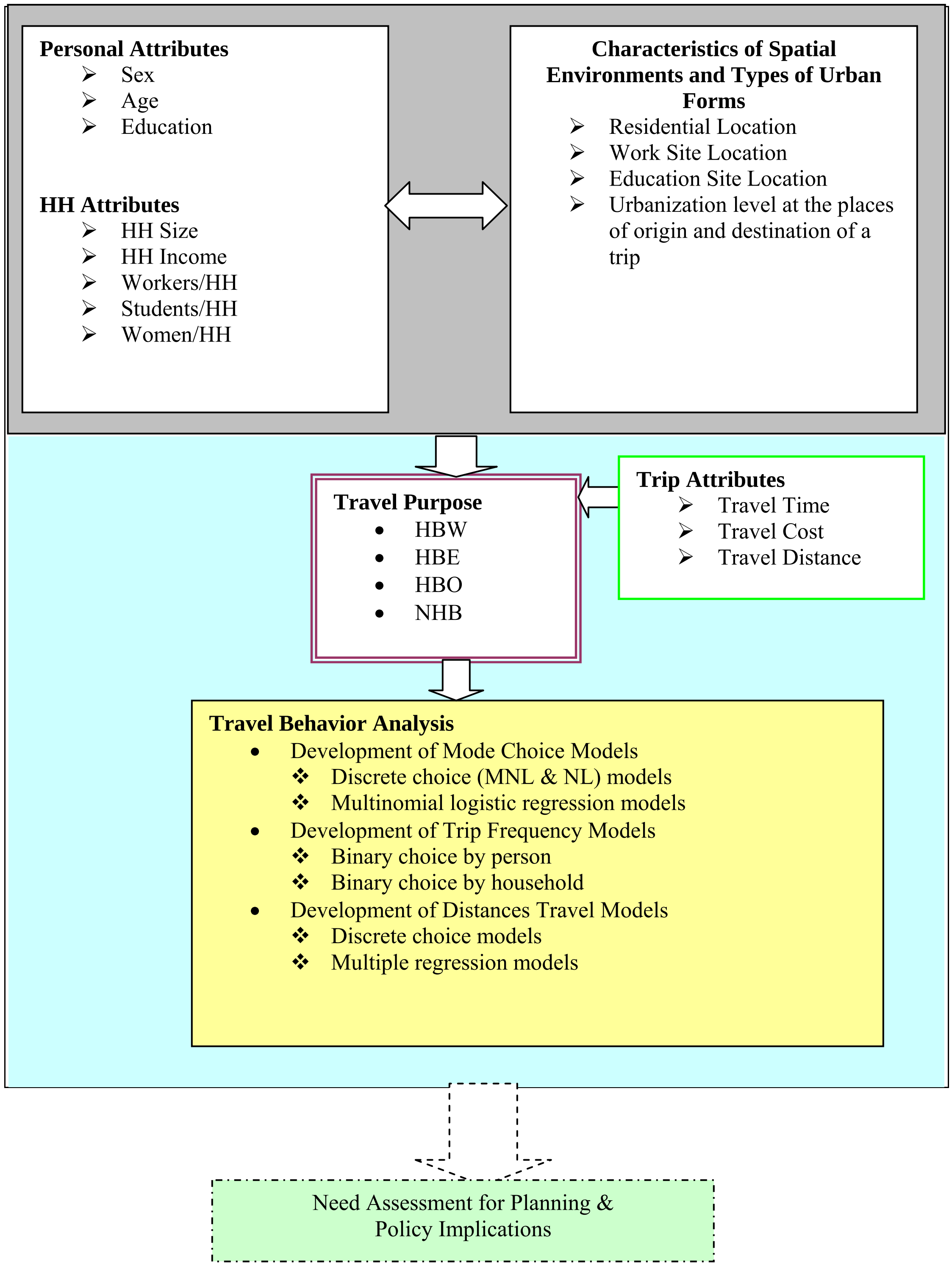


Figure 3-2: Modeling Framework and Model Variables

Development of Trip Frequency Models

- Firstly, trip rates/ frequency are analyzed by purpose-wise, location-wise, mode-wise and income-wise for different HH attributes (HH size, no. workers, no. Students, Income etc.) and personal attributes (sex, age, education, employment etc.) applying Multiple-Classifiaction Analysis (MCA) techniques to identify the relationship of travel behavior (especially the tendency of making trips) with socioeconomic and spatial characteristics.
- Then trip frequency models are estimated as a binary choice model between less than or average no. of trips vs. more than average no. of trips (per Person and per HH) to identify the trip making propensity depending on personal and HH attributes.

Development of Distance Traveled Models

- Firstly, Trip Length Frequency Distribution (TLFD) models are developed to judge the nature of trips lengths by different modes of transport for each trip purpose.
- Regression models for distance traveled are estimated to identify the influence of socioeconomic characteristics as well as origin/destination environments on individual's choice sets.

Finally, multi-stage disaggregate (MNL) models are also developed for different market segments based on Dhaka's socioeconomic characteristics to identify the group specific differences in mode choices and to estimate travel behavior stratified by residential location types and income levels.

3.4.3 Travel and Energy Demand Assessment for Policy Implications

The study estimates base level travel demand in Mega City Dhaka on the basis of vehicle population, usage rate and occupancy for passenger and loading rate for freight transportation and fuel economy. Energy demand assessment for the transport sector of Dhaka is based on Long-range Energy Alternatives Planning (LEAP) framework developed by Stockholm Environmental Institute. Because of unavailability of past travel demand information, it is estimated on the basis of reported information on vehicle stock, vehicle kilometers traveled and occupancy rate using Equation 1 and 2 as suggested by J.B. et al. (2007):

Passenger Travel Demand, $P_{TD}(t) = \sum_i V_i(t) * VKT_i(t) * OR_i(t)$

Freight Transportation Demand, $F_{TD}(t) = \sum V_i(t) * VKT_i(t) * LR_i(t)$

Where $V_i(t)$ is the vehicle population, $VKT_i(t)$ is the average annual vehicle kilometer traveled, $OR_i(t)$ is the Occupancy Rate for passenger transport and $LR_i(t)$ is the Loading Rate for freight transport by a vehicle for vehicle type i in year t.

Aggregate travel demand for calibration is estimated multiplying vehicle inventory with annual usage and occupancy data from Table B-3 (Appendix-B). Then travel demand is distributed among sub-sector level through trip-end modal share to provide estimates of aggregate demand road, rail and waterways. In the next stage, trip-interchange modal share is used to estimate travel demand among alternatives like car, bus and Non-Motorized Transport in the case of passenger movement. Subsequently at device level the amount of vehicles-kilometers for specific type of vehicle is estimated using vehicle occupancy rate which is assumed to be constant for the analysis period. Energy consumption by fuel type is estimated as follows:

Fuel Demand, $FD(t) = \sum_i TVKT_i(t) * F_{ij}(t)$

where, $TVKT_i(t)$ is the annual total vehicle kilometer traveled by i-th type of vehicle and $F_{ij}(t)$ is the fuel economy of j-type fuel for vehicle type i in year t in km/l.

Data, required for the fuel demand analysis, have been collected from various secondary sources including published journal, reports published by the Bangladesh Bureau of Statistics (BBS) and the Ministry of Communications of the Government of Bangladesh. Information on registered vehicles reported by Bangladesh Road Transport Authority (BRTA) is considered. For forecasting future population and GDP, reports published by the government and findings of different studies (STP etc.) have been used. Only limited information is available on vehicle's fuel efficiency in the country, which is shown in Table B-3 (Appendix-B). This value has been adopted in the analysis

3.4.4 Variables Selection and Their Definitions

There are different variables and categories are considered in this study considering the research objectives based on Dhaka's socioeconomic characteristics and transport environments. These variables are mainly of two broad types: socioeconomic and land use types. The socioeconomic variables include household (HH) and personal attributes. The HH attribute are namely household size, household income group, the number of employed persons per household, the number of students per household and so on. The personal attributes include sex, age and education. The land use variable refers to the level of urbanization i.e. types of urban forms.

It is necessary to mention that one important variable 'car ownership' is widely used in almost all studies related to travel behavior analysis. But this variable is not considered in the current study as the level of car ownership in Dhaka (both by HH or Personal level) is till very low and insignificant for analysis. Besides, the travel by car in Dhaka does not represent car ownership level as people in jobs who travel by car mostly use official cars.

Each variable used in this study is classified into different subgroups. Some of them are briefly described below:

❖ **Household Structure and Personal Attributes**

HH size is defined as the total number of the members in the HH. For the current study, HH size is grouped into seven groups-1, 2, 3, 4, 5, 6, and 6+ persons. Number of employed persons is the number of working persons having definite source of income in a HH, i.e who are not housewife, students and unemployed persons. Most of the HHs have single earning person. This variable is grouped into five groups: 0, 1, 2, 3 and 3+. The number of students is number of members in the HH that are admitted to any educational institution including from school level to university level. It is grouped into five categories as 0, 1, 2, 3 and 3+.

Personal attributes such as sex, age, education, occupation etc. are defined and categorized accordingly for the study. Based on years in schooling, the level of education has been defined: Low Level – less than 10 years of schooling; Lower Medium Level – 10 to 12 years of schooling; Higher Medium Level – 13 to 15 years of schooling; and Higher Level – 16 or more years of schooling. Primary occupation or profession of an individual has been categorized into any of the five groups: service (Government and Private Service), business (personal jobs), student, housewife and others.

Households consisting of extended families are common in Dhaka like many developing cities. This, with a higher birth rate, means that the average size of household in the developing world is generally higher than in the developed world. Typical average household size is around *5-6* persons, though this is dependent on the degree of economic development. Household size affects the number of trips made. A travel study. of three Indian cities (Fouracre and Maunder, .19 87) found that a 10 per cent increase in household size was associated with a 6 per cent increase in household trip making, and a 1 to 3 per cent reduction in per capita trip making. In his travel study of Kumasi, Takyi (1991) has also suggested that increasing family size is associated with a greater likelihood of using public transport, though, as he notes, this is probably because larger families have lower per capita incomes.

The sex, age and role structure of household members are also likely to have an important influence on travel characteristics; activity analysis carried out in the UK suggest that households have very different travel patterns at different life-cycle stages (Jones et al,1983). In their Indian study, Fouracre and Maunder found that an increase in the proportion of students and/or workers in the household had a positive effect on both household and per capita trip rates. The magnitude of these elasticity values was of the same order giving rise to a 1 to 4 per cent increase in trip making for a 10 per cent increase in either the proportion of students or workers in the household. Women have a lower participation rate than men in both work and education; Momnsen (1991) notes, for example, that female employment rates in urban areas of the developing world average only *25* per cent of total employed. Because of their domestic responsibilities (child-care, household upkeep, etc), women are less likely than their western counterparts (or men in general) to travel long distances for employment. Where they do travel longer distances they are very unlikely to use a bicycle or any motorized personal vehicle, except as a passenger. In some cities they travel in reserved compartments on public transport. Many women will not travel unaccompanied on any kind of business, apart from local shopping and school (accompanying young children) trips.

Age structure is important largely in respect of children and the retired. Pre-school children are unlikely to make any significant trips except in the company of elders. While all school children make school trips their mode of travel may well be influenced by their age; young children will have only a short trip to a local school which can be accomplished on foot, while older children attending secondary school and colleges will inevitably travel further, possibly using some mechanised mode. Lida Song (1989) also noted, in Beijing, a large (over two-thirds) increase in trip making as students progress from primary to secondary education age. The same study also demonstrated the rapid drop in trip making which results from old age.

❖ **Household Income Group (IG)**

Household (HH) incomes have an impact of trip generation rates, trip length, travel modes used as well as on overall travel behavior of a person or even of a HH. HHs sampled by STP (2005) Study were divided into three IGs, with household income defined as the total income of all members of the HH (in Tk/month). The HHs sampled by the STP HIS were distributed by IG as follows: Low Income Group (LIG) with less than 12,5000 Tk/month, 43.4% of all HHs; Medium Income Group (MIG) ranging from 12,500 to 55,000 Tk/month, 52.5% of all HHs; and High Income Group (HIG) with more than 55,000 Tk/month, 4.1 % of all HHs.

We find that there was a big difference in household income level of people in the classification of STP Study. In our study we have redefined the household income level and grouped it into four sub categories as follows (also shown in Table B-9 in Appendix-B) which represents the prevailing socio economic clustering pattern of the population of the city:

- Low Income Group (LIG): HH Income<Tk. 12,500/month (represents 43.97% HH)
- Lower Medium income Group (LMIG): HH Income Tk. 12,500~<25,000/month (represents 29.72% HH)
- Higher Medium Income Group (HMIG): HH Income Tk. 25,000~<55,000/month (represents 22.12% HH)
- High Income Group (HIG): HH Income>=Tk. 55,000/month (represents 4.20% HH)

From the limited evidence available, household income does not appear to play a significant part in determining household trip rates, though it is clearly a major determinant of modal choice. The study of three Indian cities (Fouracre and Maunder, 1987) indicated that income has a relatively small impact on trip frequency: a 10 per cent increase in either household or per capita income was associated with a 1 per cent increase in household and per capita trip making respectively. Much trip making must be a necessary part of life (to get to work or school) irrespective of income level; only households, made-up solely of the very poor, the unemployed or retired will not participate in these committed trips. Income is more likely to have an effect on trips associated with more leisurely pursuits, though these might account for only 20 per cent of total trip making. Even here, however, there is no strong reason to believe that higher income groups will have markedly higher activity patterns. Income clearly affects the way in which people choose to travel. It sets the limit on *5* their capacity to acquire a personal vehicle and also, given that trip mnaking is relatively inelastic to income, it sets the limit on how much of a particular mode they can 'consume' in order to achieve their desired level of travel. For example, it is quite common for low income commuters to switch their normal mode of travel from bus to walking towards the end of their pay-period as money runs out.

Not surprisingly, personal vehicle ownership is highly correlated with high income (eg. Fouracre and Maunder, 1987). Personal car ownership is largely confined to high income groups, though as Cundill (1986) noted in Kenya, the equi-probability income (ie. the income level at which the probability of car ownership is *50* per cent) seems to be falling. This would suggest that car ownership will increase regardless of any increase in household income. Perhaps as a cheaper 'second best' to car ownership, motor-cycle ownership amongst the middle income groups has increased at a very rapid pace in many cities. Bicycle ownership is high amongst low income groups in specific locations, notably Chinese and Indian cities. The reason for non-use of bicycles in other apparently 'fertile' locations is not clearly understood, although differences in attitude towards cycle use may be critical (Barrett, 1991).

Access to a personal vehicle seems to confer on households a marginally higher trip rate (per capita and per household). Again, the Indian study of Fouracre and Maunder (1987) suggests that motor-vehicle owning households make ten per cent more trips than bicycle owning households, who in turn make ten per cent more trips than non-vehicle-owning households. The same study also noted that higher trip rates were associated with access to cheap public transport: a family living in Vadodara, where average total public transport cost was estimated to be 21 paise per passenger km., was making 15 per cent more trips than a similar family in Patna, where comparative costs were 30 paise (ie. one third as much).

- **Location or Region**

A region, later referred as Specific Zone (SPZ) is defined as the combination of a number of TAZs which are similar in terms of such factors as socioeconomic conditions of the people living in that area, economic activities, planning options adopted and spatial location of the area that influence overall accessibility to and from the zones. The region is grouped into eight categories as described in Section 3.3.7.3.

A sizeable proportion of work trips in most developing cities are focused on the city centre with its commercial, service, government and retailing activities. Some light industry may also be centrally located, though main industrial sites are likely to be in the suburbs. Most people in a city live in a location which affords reasonable access, by one way or another, to both their work place and other activities. As a result, location, like income, probably has little effect on trip rate and has more influence on mode choice and travel time.

Maunder (1984) established some differences in income elasticities between communities living close to and long distance from the centre of Delhii, but he was unable to show the extent to which different levels of vehicle ownership and access to public transport may have been influencing his findings. However, it is possible that there may be some small attenuation in non-essential trip making as distances from city centre (or sub-centre) increase and that this attenuation is more marked in low-income groups. It is also the case, as already indicated, that women (who are less able to travel long distances to work) will be more affected, than men, by location.

Locational aspects are very important in mode choice. Maunder's work in Delhi, for example, showed how commuters come to rely on public transport for journeys in excess of about 10km. This characteristic is particularly marked in low-income groups who have little other travel option. (It is one of the ironies of development in Third World cities that, as already noted, it tends to be the low-income groups who live furthest from the city centre.) Where high income commuters do travel long distances, they usually have access to modes faster than public transport and will accomplish their journeys speedily.

3.4.5 Classification of Travel by Trip Purpose

In this research person trips are considered and trips have been divided into four categories based on the procedures followed by the STP (2005) Study: Home based work (HBW), Home based education (HBE), Home based other (HBO) and Non-home based (NHB) trips. A LOOKUP Table was developed to define the trip purposes for a specific trip from an origin to a destination in a single trip making process. The definitions of trip purposes used here are given below:

- Home-based Work trips (HBW) – "Trips between the trip-makers' homes and their places of work, which could be trips from home to work trips or the return trips from work to home (STP, 2005)".
- Home-based Education trips (HBE) – "Trips between the trip-makers' homes and the places where they attend an educational institution and which could be from home to the education site or the return trip from school to home, (STP, 2005)".

- Home-based Other trips (HBO) – "All other trips with either end of the trip at the trip-maker's homes. These could include travel to or from shopping, visiting, personal business or any other locations except the trip-makers' places of work or education, (STP, 2005)."
- Non-home Based trips (NHB) – "All other trips, trips having neither end of the trip at the home of the trip-maker, (STP, 2005)."

3.4.6 Mode Definition

As determined from the STP (2005) HIS, many person-trips involve the use of a series of travel modes (walk, rickshaw, auto rickshaw, bus, etc.) by the trip-maker to reach his destination. From the HIS, we find that many trips involve a number of transfers (as much as five legs or transfers make a single trip in some cases) and in these transfers different types of transport modes are used. In tabulating the HIS trip data for input to analysis and development of final data set, the travel mode for trips involving a combination of travel modes was defined as the major segment of the trip. A LOOKUP Table was also developed to define the main (major) mode of transport for a trip from a series of modes involved in that trip making. Finally, seven modes of transport considered for modeling are: Walking, Rickshaws, Private Car (PC), Transit (Bus), Taxi, Auto-rickshaw (CNG) and Motor Cycles (MC). The mode definition procedures used in the study were as follows:

- Trips that used public transit i.e. buses for any part of the journey were classified as transit trip that means the mode used for those trips are buses;
- Trips that did not use buses for any part of the trip but did use personalized vehicles like cars or motor cycles were classified as trips by private cars or by motor cycles;

- Trips that did not use buses or any personalized motorized vehicles but did use taxi or CNG for any part of the journey were classified as taxi or CNG trips;
- Trips that did not use any motorized modes but did use rickshaw for any part of the journey were classified as rickshaw trips; and
- Trips made entirely by walking were classified as walk trips.

3.3.7 Zoning and Urban Forms Classification

3.3.7.1 Overview

Although the principal data source for our study is the zonal data of STP Household Survey (2004), but in particular relation with the scope of our study some modifications have been made. Changes have been made in traffic analysis zone definitions; such as STP had 230 zones on the other hand we have 102 zones. The following sections describe the backgrounds of TAZ definition and urban forms classification for our study in details.

3.3.7.2 Traffic Analysis Zone (TAZ) Definition

We analyze the travel behavior of Dhaka City considering the movement between areas referred as Traffic Analysis Zones (TAZ). The TAZs act as the origins and destinations of all movements. Trips enter the network from the TAZs and move along link connectors. The study area is subdivided into 102 TAZs within the earlier specified eight SPZ sub-regions. In defining the TAZ boundaries, the boundaries are used as census and administrative jurisdictions referred to in Bangladesh as Wards in Dhaka City Corporation (DCC) and Union or Pourashava (Outside DCC). Of these 102 TAZs, 90 are located within the DCC, 1 under cantonment board and 11 external TAZs cover the urbanized surrounding of the study area. Among the external TAZs, 6 are located in the periphery of Dhaka city such as Uttara (West), Uttara (East), Badda, Demra, Sabujbag and Kamrangir Char and the rest 5 are located in the surrounding areas such as Keraniganj, Savar, Tongi, Gazipur, and Narayanganj. Table B-4 (Appendix-B) gives TAZ locations of the study area. The TAZ locations and their boundaries are shown in Figure A-9 (Appendix-A).

3.3.7.3 Urban Forms Classification

To assess the impact of spatial characteristics (land use patterns) on people's travel behavior and to make the analysis more comprehensive and realistic we have sub-divided the whole study area into eight broad sub-regions or Specific Zones (SPZ) shown in Figure A-10 (Appendix-A) based on the following criteria of the places where people reside and work:

- Socioeconomic characteristics of the regions
- Structures of the urban systems
- Location and urbanization level

Van der Laan (1996, 1998) constructed a typology of daily urban systems based on two dimensions: the degree to which the suburban commuters are oriented toward the central city; and the degree to which central-city commuters are oriented toward sub-urban municipalities. The scores on both dimensions are used to distinguish eight types of functional daily urban systems. For our analysis, the study area is divided into eight broad sub-regions or Specific Zones (SPZ). These are:

- Sub-Region A: Motijheel Area as Central Business District-Core (CBD-Core)
- Sub-Region B: Dhanmondi & Farmgate Area as CBD-Mixed
- Sub-Region C: Old Dhaka as Unplanned High Densely Part
- Sub-Region D: Greater Gulshan and Banani as Planned: Type I
- Sub-Region E: Uttara as Planned: Type II

- Sub-Region F: Greater Mirpur as Planned: Type III
- Sub-Region G: North-West Dhaka as Western Fringe: Mixed I
- Sub-Region H: Eastern Metropolitan as Eastern Fringe: Mixed II

Sub-Region A covers 11 DCC wards; Sub-Region B covers 9 DCC wards; Sub-Region C covers 27 DCC wards; Sub-Region D cover DCC 5 wards; Sub-Region E covers 1 DCC wards; Sub-Region F Covers 7 DCC ward, Sub-Region G covers 15 DCC wards, Sub-Region H covers 15 DCC wards. In accordance with DCC wards, all SPZs are again divided into a number of Transportation Analysis Zones (TAZ). The identification numbers of TAZs are kept same as their DCC ward number within the city corporation boundary. The total number of TAZs is 102. The physical differences of the eight regions are presented in Table B-5 (Appendix-B).

3.4 Model Types and Modeling Tools

3.4.1 Model Types

The whole modeling framework consists of various sub-models or model components as described earlier. Table 3-1 also shows the types of various model components. The structures of the most of the model elements are quite simple and widely used in travel demand models. With the data obtained from the secondary sources, these various model components are calibrated and validated.

3.4.2 Modeling Tools

In order to satisfy the objectives of study different software packages are extensively used in different parts of the modeling process. Therefore it is necessary to bring some light on these packages and their scopes to the present study. Table 3-2 summarizes various tools used in developing sub-model.

Table 3-1: Sub-Models and Their Types

Sub-Model	Model Type

Modal Split Models	Disaggregate Analysis
	• MNL Models
	• NL Models
	  • 2-Level NL Model
	  • 3-Level NL Model

Models for showing effects of exogenous variables on mode choices	Multinomial Logistic Regression
Walk & Intra-zonal Trip Split	Rate Analysis
Pre-Distribution Personal Motorized Trip Split	Rate Analysis
Trip Frequency Model	• Binary Choice Model (Binary Logit) • Multiple-Classification Analysis
Models for distance traveled	Regression models
Trip Length Frequency Distribution Model	Multiple-Classification Analysis
Multi-stage Group Specific Models	Disaggregate (MNL) Models

Table 3-2: Software Packages and Their Uses in Modeling

Software Package	Where used
SPSS	• Models for showing effects of exogenous variables on mode choices • Models for distance traveled
ArcView GIS	To generate the GIS based land use map and data
LIMDEP	• Modal Split Models • Trip Frequency Models
LEAP	Future Energy Demand Forecasting
AutoCAD	Development of network and Zonal Map

In addition to the above packages, Microsoft EXCEL is widely used to prepare data and graphical presentation. Some other packages (like Photoshop, Pain, MS Photo Editor, MS

Access etc.) are also used in various stages of this research work. A brief description of the scopes of the software used in this research is presented below:

- **SPSS**

  There are many software tools available for statistical analysis. But SPSS is an easily available, flexible and well-known package. SPSS 16.0, the latest available package, has been used in our analyses.

- **ArcView GIS**

  The land use map available for Dhaka city is prepared in ArcView GIS 3.2 platform. Hence using ArcView's tools, the land use information are collected which is required for different analyses.

- **LIMDEP**

  Various software packages such as LIMDEP, ALOGIT, ELM, TSP etc. are available for discrete choice modeling estimation. The multinomial and nested logit mode choice model estimations of DUTBM are implemented using LIMDEP 8.0 (NLogit 3.0), mainly due to its availability to us and previous experience of using it. Besides, NLogit 3.0 has been used for Binary Choice Models.

- **LEAP**

  The Long-range Energy Alternatives Planning system (LEAP) is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. With its flexible data structures, LEAP allows for analysis as rich in technological specification and end-use detail as the user chooses.

With LEAP, the user can go beyond simple accounting to build sophisticated simulations and data structures. Unlike macroeconomic models, LEAP does not attempt to estimate the impact of energy policies on employment or GDP, although such models can be run in conjunction with LEAP. Similarly, LEAP does not automatically generate optimum or market-equilibrium scenarios, although it can be used to identify least-cost scenarios. Important advantages of LEAP are its flexibility and ease-of-use, which allow decision makers to move rapidly from policy ideas to policy analysis without having to resort to more complex models.

LEAP serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables the user to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic, and environmental - of alternative energy programs, investments, and actions.

One can use LEAP to project the energy supply and demand situation in order to glimpse future patterns, identify potential problems, and assess the likely impacts of energy policies. LEAP can assist to examine a wide variety of projects, programs, technologies and other energy initiatives, and arrive at strategies that best address environmental and energy problems.

3.5 Summary

This chapter described the overall research design for the current study and reviewed the modeling issues with respect to Dhaka's transport context. Major identified issues are extensive growth of a mixed land use pattern, the heterogeneous socio-economic structure and travel behaviors, limited data availability and the presence of a mixed transportation system, which are discussed in this chapter. A modeling framework is proposed in order to handle the critical issues for a strategic perspective. The framework attempts to develop a system of models which can simulate the complex travel behavior of Dhaka city by applying a number of individual sub-models. The developed system can be applied in various fields of transportation planning such as evaluating the performance of the existing transportation system under the present travel demand, identifying the planning needs, forecasting future urban travel demand and evaluating the performance of the future transportation system and policies under the future travel demand. The framework is developed based on a number of principles such as having strategic perspective; being market oriented; addressing heterogeneous demand; following disaggregate approach and capturing the multi-modal nature of the transport system of Dhaka. The framework follows a simple modular structure so that individual model elements can be updated, implemented and applied easily. This chapter also presents a theoretical framework to assess the travel sector energy demand for policy implications.

The chapter described the variables used in the study with their definitions. Classification of travel by trip purposes and the definitions of four trip types and modes of transport considered for modeling are also discussed. The TAZ definition and urban forms classification used in this study have also been clearly discussed in this chapter.

The methodology, particularly the modeling process, followed in the research has also been discussed. An introduction to the modeling tools used in this study is given. Different software packages used include SPSS, ArcView GIS, LIMDEP, AutoCAD, LEAP etc.

CHAPTER 4

STUDY AREA AND DATA SELECTION

4.1 General

Dhaka, the largest city of Bangladesh, is the national capital. The city is one of the sixth municipalities belonging to the Dhaka Metropolitan Area (DMA) which covers an area of about 1530 square kilometer. Its share of national urban population was 25% in 1981, 31% in 1991 and 34% in 2001 respectively. Dhaka's dominance exists not only in terms of population, but also in terms of economy, trade, commerce and administration. In 1990 Dhaka ranked twenty-third among the thirty largest cities of the world having a population of more than 6.6 million, while in 2000 it ranked 14th and by the year 2025 it is anticipated to be the world's fourth largest city with an estimated population of 21.015 million (UN Population Division, World Urbanization Prospects: The 2007 Revision).

Dhaka to day is one of the most populous cities in the world with highest growth rate (Figure A-17). Any large city experiencing such phenomenal population growth would understandably face multifarious problems. If such a city happens to be the capital of a poor country and governed by inexperienced people also lacking in vision, commitment and integrity, the problems soon assume crisis proportions. This is what has been happening in the case of Dhaka, particularly in the central areas. Among the more critical problems in the city would be: problems of transportation and traffic congestion, environmental degradation, law and order situation, and problems of personal security and problems of delivery of services, including the service of solid waste disposal and management. Delivering services to the urban poor would be even more problematic.

This chapter is devoted to present a background description of Dhaka city, the study area of this research work and an overview of the selected data including their sources and types etc. Finally, data organization and assembly procedures for modeling are also discussed.

4.2 Selection of Study Area

4.2.1 Overview of the Study Area

The study area of the present research is the inner part of about 1530 sq. km. of Dhaka Statistical Metropolitan Area (DSMA) including the whole of Dhaka City Corporation (DCC) boundary, the central part of the study area and the surrounding sub-urban areas adjacent to the central city (Figure 4-1). The administrative authority of the central DCC portion is Dhaka City Corporation.

Dhaka occupies a large part of the relatively small portion of land which is considered to be “permanently” flood-free. Most of the Dhaka metropolitan area is subject to flooding of various types related to tidal and typhoon conditions, excessive rainfall, and river flooding arising from conditions in the mountains to the north outside the country (STP, 2005).

Dhaka city is more than 400 years old. Over these years the population and area of the city have increased many folds. The city is expanding in all direction in unplanned way and population is increasing in geometric progression but the civic amenities can not keep pace with the growing demand. The capacity of various utilities can no longer meet the rapidly increasing demand. Supply of pure drinking water, safe sanitation, municipal waste collection, supply of electricity and gas for about 15 million city dwellers are progressively turning into serious crisis. Hundreds of Ready Made Garments (RMG) and other small industries concentrated in Dhaka have created enormous pressure on the utility supply infrastructure.

Figure 4-1: The Map of the Study Area

Source: Banglapedia, The National Encyclopedia of Bangladesh.

Unplanned urbanization and poor transportation system are making the city progressively inhabitable. The massive traffic congestion in almost all the time of the day not only causes huge wastage of working hour, but also poses serious threats to the economic growth and development. Dhaka city air reported to containing higher proportion of lead and CO must be considered very alarming. Serious noises, inaccessible sound level is causing hearing problem. The water of rivers around the city is nothing but poison. For higher education, health care, business and job opportunities people from all over the country are flooding the city as everything in Bangladesh is Dhaka oriented. Moreover, the helpless and shelterless people from villages and rural areas are migrating to Dhaka compounding the problem still further. City dwellers are already affected with various contagious water borne disease. Dhaka has already turned into a slum of concrete.

Dhaka City is experiencing continuous deterioration of service facilities of the city. The city is growing with accelerating rate but unfortunately transport infrastructure development of the city could not keep pace with the travel and transport demand of this growing population and area.

Dhaka desperately needs massive overhauling in all sectors. It looks for well organized metropolitan governance having a visionary mission dedicated to the welfare of the city. To meet the present and emerging challenges there must be integrated planning to save the city from immense crisis that looms large for the city.

4.2.2 Urbanization of Dhaka

Dhaka City has been expanding rapidly in all directions since the independence of Bangladesh in 1971 (Pacific and Yachiyo, 2005). During the last four decades, metropolitan Dhaka has recorded a phenomenal growth in terms of population and area. Dhaka at present is the fastest (World Bank, 2007) growing metropolises in the world. After the war of independence, Dhaka's provincial capital status was raised to national capital overnight and its population increased manifold in the subsequent decades. The urbanization activities have been achieving tremendous growth for the needs of the newly independent country's capital. Figure 4-2 shows the chronological change of the expansion of Dhaka city and the neighboring area over the last four decades. The maps show that initially the development of Dhaka city started from the southern Old Dhaka area. Then the development continued through the center toward the north side. The city has been expanding over the low-lying areas on the eastern side, such as in Jurain, Goran, Badda, Khilgaon, Rampura, and in the western side, areas like Kamrangirchar, Shyamoli, Western Mohammadpur, Kallyanpur through the earth filling (DCC, 2007).

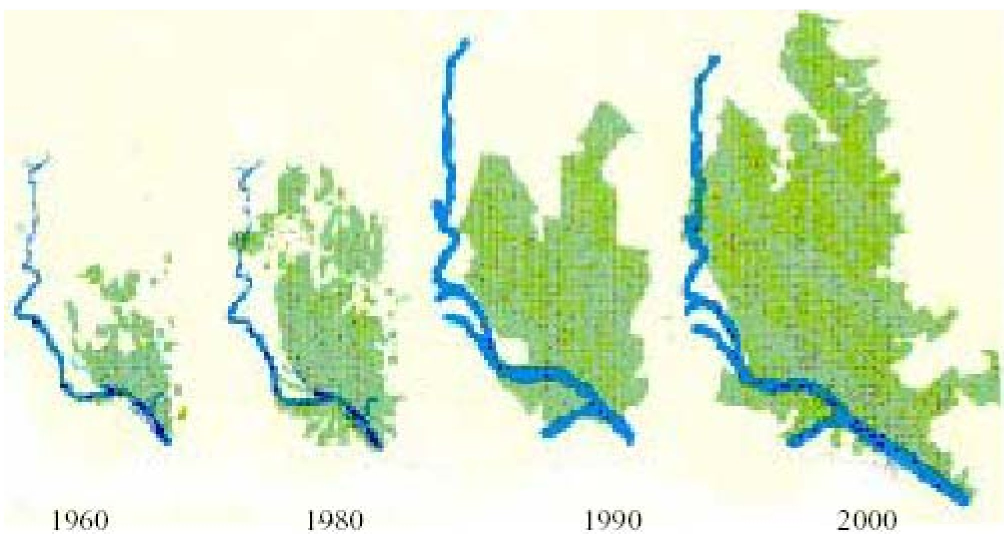


Figure 4-2: Growth of Dhaka City and Its Surrounding Area
Source: Pacific and Yachiyo, 2005

The land area of greater Dhaka is usually expressed in terms of Dhaka Statistical Metropolitan Area (DSMA) or Dhaka Megacity Region. The DSMA, however, is an extended metropolitan region, comprising the mother city Dhaka or the Dhaka City Corporation (DCC) area and six other medium and small municipal cities/towns and vast expanses of rural entities in between the urban centers (Figure A-11 in Appendix-A).

The larger boundary is under Rajdhani Unnayan Kartripakkhya (RAJUK), the Capital Development Authority. The area under the jurisdiction of DCC is about 360 square kilometer, which is referred as the central or mother city of Dhaka and this part is almost fully built-up. As the built-up area developed, DCC increased its number of wards (City Corporation's smaller administrative unit) from 50 in 1971 to 90 in 1993, but the urbanization took place in unplanned way. There was no systematic development observed in Dhaka City due to the absence of proper urban planning initiatives in the past and as a result the quality of living standard is highly questionable for its extreme population density, unbearable congestion level and environmental hazards. People do not have enough road space or open space, even other non-residential space either. Outside DCC, but within RAJUK limits, the densities vary from very high to low. In fact much of the RAJUK areas, beyond DCC, are not ready for proper urban development yet. There are low lands, liable to annual floods, and to deep flooding during abnormal floods. But urban expansion takes place even in such marginal lands through gradual earth filling. The GIS map of Figure A-12 (Appendix-A) shows more detailed information on the built-up area, DCC ward boundaries and the surrounding urbanization particularly in the east and southeast side fringe area. Keeping pace with the magnitudes of the rapid urban growth, the new urbanized areas were being encroached in the low-lying areas in the city and even in some of the adjacent distant areas.

Dhaka City is increasingly characterized by large slums, poor housing, excessively high land prices, traffic congestion, water shortages, poor sanitation and drainage, irregular electric supply, unplanned construction, increasing air pollution and poor urban governance which results in growing problems of law and order. Bangladesh State of the Environment Report, 2001 says that serious problems of environmental degradation are resulting from unplanned urbanization.

The present pattern of urbanization is leading to various problems like land use alterations; inadequate shelter, water, sanitation, and other facilities in slums and other urban poor areas; degradation of community ambient environment; little control of industrial waste emissions; and environmental pollution due to inadequate management of human and domestic wastes. According to an estimate, 700800 tons of household and commercial solid wastes are produced in the dry season, and 9001100 during the monsoon season in Dhaka city. The wastes are dumped untreated in nearby low-lying areas and water bodies, where they pollute surface water and generate a foul odor. The hazardous medical wastes from a large number of clinics and hospitals go through the same type of untreated disposal. Air pollution is a serious threat to human heath in Dhaka (Mondal, 2006).

There is no comprehensive policy on urbanization and urban poverty. There are between 16 and 40 different bodies involved in one way or another in urban matters in Dhaka with little coordination and planning. As a result, there are major gaps in services and infrastructure ranging from weak electrical supply to inadequate land and housing options, and major traffic congestion. The poor are particularly affected as they do not have the resources to find alternatives for meeting their basic needs.

4.2.3 Population

There are today 19 megacities (cities with at least 10 million inhabitants) on the earth and Dhaka ranked the 9^{th} position in 2007 with a population of about 13.5 million having the highest growth rate in the world (UN Population Division, 2007). Although Dhaka's area is less than 1% of the country's total land area, it supports about 10% of the total population and about 34% of the total urban population. After the independence of Bangladesh in 1971, the city's population increased rapidly and in 1974 it was about 1.31 million. Population of DCC increased along with the expansion of the city area as tabulated in Table B-6 (Appendix-B) which indicates that population growth of DCC area in the period of 1974-1981 was very high with the annual growth rate of about 10.9%. In the following decade, the population growth rate dropped conspicuously. Evaluation of the population increase in the period of 1991-2001 shows an annual growth rate of 3.80% within the DCC boundary.

According to the National Census 2001, the population in DCC and Dhaka mega city area was about 5.38 million and 9.91 million (BBS, 2001) respectively. In the year 2004, population of Dhaka mega city was estimated as 11.3 million while that of DCC area was 5.94 million (SDNP, 2005). According to UN Population Report 2007, among the largest 30 cities of the world, Dhaka ranked the 23^{rd}, 20^{th}, 14^{th} and 9^{th} position in the years of 1990, 1995, 2000 and 2005 respectively and expected to be the 4^{th} largest city of the world with a population of 22.015 million by 2015 (UN Population Division, World Urbanization Prospects: The 2007 Revision). The changes of population in Mega City Dhaka are shown in Figures A-15 and A-16.

Population density of Dhaka megacity was found to be 5,059 persons/sq. km in 1991 while 7,918 persons/sq. km in 2001. In the year 2004, density is estimated at approximately 8,352 persons/sq. km. However, the population density of DCC area is much higher than that of the megacity area, as in 1991 it was 16,255 persons/sq. km and in 2001 it was 19,485 persons/sq. km. The estimated population density of DCC in 2004 was 21,521 persons/sq. km. In some parts of the old Dhaka, the density is even over 100,000 persons per square kilometer (Census, 2001). With limited availability of flood-free land, further densification of population along with haphazard encroachment of peripheral land of Dhaka seems inevitable. Table B-7 (Appendix-B) summarizes the population density figures of Dhaka mega city and Dhaka City Corporation in 1991, 2001 and 2004.

Rapid population growth in the face of finite environmental resources will have catastrophic effect on human well being (Ehrlich and Ehrlich, 1970). Dhaka is the fastest growing mega-city in the world, with an estimated 300,000 to 400,000 new migrants, mostly poor, arriving to the city annually. Most migrants come from rural areas in search of opportunities which can provide new livelihood options for millions, translating to improvements in living standards. This migration, however, also adds tremendous strain on an already crowded city with limited inhabitable land due to the city's topography, limited infrastructure, and a low level of public services although their contribution to Dhaka's economic growth is significant, as they provide much needed labor to manufacturing, services, and other sectors.

4.2.4 Socioeconomic Characteristics of the Study Area

Except for the relative affluence of some part of Dhaka, the macro-economic characteristics of the study area are generally reflective of, and are largely pre-determined by, the marco-economic characteristics of the country as a whole. The GDP of Bangladesh in 2002 was approximately US$ 44 billion and that was US$ 63.4 billion in the 2004-05 financial year (BBS, 2005). By way of comparison, the Bangladesh economy is more than twice as large as Sri Lanka's, approximately three-fourths the size of Pakistan's and less than one tenth the size of India's. Its Gross National Income (GNI) per capita was approximately US$ 400 in 2003 – compared to US$ 930, 470 and 530 for Sri Lanka, Pakistan and India, respectively. As a benchmark Hong Kong has a per capita GNI of over US$ 25,000 and Singapore is over US$ 21,000. Thailand's per capita GNI of over US$ 2,190 is more than five times that of Bangladesh. Bangladesh ranks 174th position in the World Bank's listing of 208 countries in 2004 (STP, 2005). Measured in terms of employment, agriculture is the largest segment of the economy, followed by services, manufacturing and construction in that order. The formal and informal sectors currently account for one-fourth and three-fourths of urban employment, respectively- a ratio which is expected to remain relatively constant for the foreseeable future (World Bank, 1997). Garments account for more than three-quarters of all exports, dwarfing the country's historic cash crop- jute for last couple of years.

Dhaka is the economic, as well as the political capital of Bangladesh and by far the dominant economic feature in the country. Its importance in the overall economy of the country has increased as the role of industry and other non-agricultural activities in the national economy have declined. Most of jobs in the area's basic industries are in manufacturing. As of the mid-1990s approximately 60% of its manufacturing jobs were in broad "textile" category, more than one-third in garment sector and remainder generally in jute and cotton textiles. The garment industry has been the source of much of Dhaka's economic growth in the last 15 years employing nearly 570,000 in Dhaka in 2003 and nearly 700,000 in Dhaka Metropolitan Area (BGMEA Member's Directory 2003-04). Some 80% of the workers are females between the ages of 14 and 29. Other significant industrial activities include frozen fish, leather and leather products, tea, urea fertilizer and ceramic tableware, sugar, newsprint, pharmaceuticals and fertilizer productions.

Dhaka is the commercial heart of Bangladesh and it accounts for much of Bangladesh's net GDP growth. Many skilled workers are employed in the businesses and industries located in the Dhaka metropolitan area. The city has historically attracted large number of migrant workers. Hawkers, peddlers, small shops, rickshaws, transport, roadside vendors and stalls employ a large segment of the population — rickshaw - drivers alone number as many as 400,000. Half the workforce is employed in household and unorganized labor, while about 800,000 work in the textile industry. Even so, unemployment remains high at 23%. According to *City Mayors Statistics*, Dhaka's GDP registered at $5.2 billion in 2005 with an annual growth rate of 6.1%. Its estimated GDP in the year 2020 is $12.6 billion. The annual per capita income of Dhaka is estimated at $550, although a large segment of the population lives below the poverty line, with many surviving on less than $3 a day. The facts of Dhaka are given in Table 4-1.

Table 4-1: Facts about Dhaka City

Global Location	Latitude : $23^0 30' - 25^0 05'$ N Longitude : $90^0 15' - 90^0 35'$ E
Area	Metropolitan Area: 1,529 sq. km DCC boundary: 360 sq. km
Population	10.0 million
Density	6,545 persons/km^2
Sex Ratio	127
Household Size	4.12
Population Growth Rate	4.2
GDP	US $ 4.8 Billion
Per Capita Income	US $ 500
Literacy Rate (Adult)	62.3
Employment	Employed : 77% • Informal activities : 24% • Household work : 28% • Other services : 25% Unemployed : 23%
Child Mortality	96.2
Piped Water	70%
Electricity (% HH)	90
Crime Rate	2.03/1000 POPULATION
Informal Settlement	30%
Homeless People	112.5 thousand (1991)
Tenure Type	Owned – 32.0% Rented – 54.0% Rent Free – 6.5% Others – 7.5%
Land Phone	20/ 1000 population
HH below poverty line	48%
School enrolment at reaching grade 5	60%

Sources:

1. Bangladesh Country Report, National Habitat Committee, Ministry of Housing & Public Health, Government of Bangladesh, May 2000.
2. World Population Day 2007, The World Bank in South Asia, On-line Resources.
3. Asian City Development Strategies: Fukuoka Conference, 2000

Although average income is higher in Dhaka, in absolute terms, a large number of people remain poor. About 28% of the population of Dhaka is poor which accounts about 5% of the country’s total population. 70% of the urban poor have access to 20% of land. 80% of residential land is occupied by the 30% population. 5% households is at high income level share 37% of total income while 50% of households is at low income level sharing 12% of total income. Some 3.4 million live in slums. There are about 3000 slums and squatters in the city. Average floor size 1.2 to 1.5 square meters and 30% population live in the slum. 30% population has no access to piped water. Close to one third don’t have access to sanitation. There are about 3,200 metric tons of solid waste produced per day and only about 50% are collected by service authority for proper disposal. Dhaka’s groundwater level is rapidly declining due to over-use, dropped 20 meters in last decades. Future development of surface water is in danger because of industrial pollution. Informal sector employment is high at 63% of total employment (South Asia Population, World Bank, 2007).

Dhaka has also led the country's rise in the global IT industry, with a massive expansion in wireless communications, and the proliferation of electronics across the population. Since 1996, the Bangladeshi government has steadily moved away from socialism and adopted free-market reforms. Dhaka has been the recipient of the boom in foreign investment, service industries and information technology. Dhaka gives the lead to economic growth to the rest of the country. Most of foreign trade and investment is conducted with companies based here. Urban developments have sparked a widespread construction boom, causing new high-rise buildings and skyscrapers to change the city landscape. Growth has been especially strong in the finance, banking, manufacturing, telecommunications and services sectors, while tourism, hotels and restaurants continue as important elements of the Dhaka economy. However, poverty, lack of basic services, illiteracy and poor sanitation are still serious problems for the city, as they are for the rest of Bangladesh. Torrential rains and floods cause terrible damage to the city's infrastructure and economy, and most seriously to the population, reducing any benefits of previous improvements and growths. Because of the high rate of population growth, access to basic necessaries seems to be decreasing. However, a potential strength of Dhaka is its relatively rich human resources.

4.2.5 Land Use Pattern

Historically, the land use development of the city started from the old town and along the bank of Buriganga River. Later it expanded towards the north, and the expansion was more or less continued in most of the city areas though the remarkable growth was observed after the independence. In fact, after the liberation war, the physical feature of the main city has changed and covered by rapid development both by the government and private sectors. These include development of commercial, industrial, educational, health, communication and residential sectors. Most of the government and non-government administrative headquarters, centers to control regional, national and international business and trade, industries, housing have been formally and informally established within the DCC area.

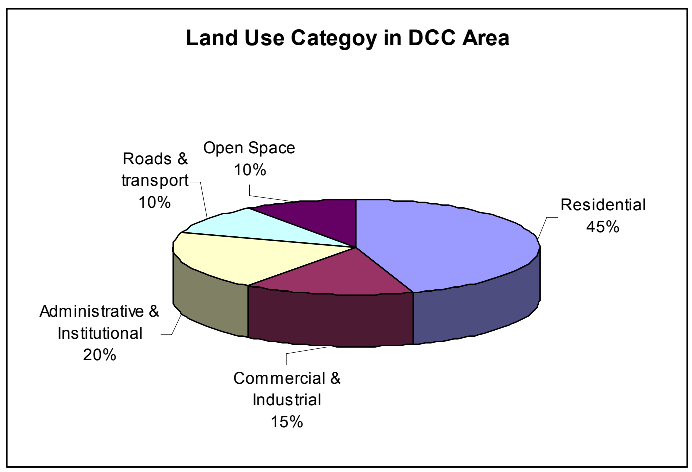


Figure 4-3: Land Use Distribution of Dhaka City Corporation

Source: STP, 2005

The DCC area presently covers more than 25 percent of the total land area of the mega city (BCAS, 2005). Land area under different categories of use is reported differently in various sources. The Figure 4-3 shows the category wise land use of DCC area. Presently, the city development activities spread over approximately 40 km from north to south and 14 km from the east to the west (DCC, 2007). The land use types within the built-p area (the DCC boundary and the surrounding urbanization particularly in the east and southeast side fringe area) of Dhaka City are shown in Figure A-13 (Appendix-A). Figure 4-8 shows more detailed information on the generalized land use patterns of greater Dhaka City.

4.3 Selection of Data

4.3.1 Overview

Numerous types of data are used in this study. Major portion of the data are on household and person travel information based on Household Interview Survey (includes travel mode choices, household socioeconomic characteristics and person's attributes etc.) and Person Trips Survey of Dhaka City, collected from secondary sources based on input data requirements for the study. Other types of data include population and household data, travel demand and traffic data, energy data, land use data, road network data, socioeconomic data of Dhaka City. The data collection procedure of the present study consists of the following stages:

- Assessment of the input data requirements
- Collection of data from the available sources.
- Identification of data deficits and recollection from available alternatives sources.

4.3.2 Sources of Data

Various data have been collected from different agencies and reviewed to assess their usefulness in different sub-models used in the study. Secondary data such as population, household trip data, road network map, transit route, traffic counts, school and college enrollment and land use details were collected from various agencies. Table 4-4 summarizes the collected data and their sources.

Table 4-2: Available Data and Their Sources

Data	Source
Network Inventory	STP Study
Household Interview Survey	STP Study
Road Capacity Survey	STP Study
Traffic Volume Count	STP Study
GIS Land Use Data	Asia Air Survey Co. Ltd. and JICA
Other Land Use Data	RAJUK
Transit Route Data	BRTA
Other Transport Data (No. of registered vehicles etc.)	BRTA
School and College Enrollment Data	BANBEIS
Population and Household Data	Bangladesh Census 2001
Data on DCC	Dhaka City Corporation
Socioeconomic Data	Various printed media and offices
Energy Data	BBS
Others	Government Offices Published Reports/Documents Literature Reviews

4.3.3 Brief Description of STP Household Interview Survey

The STP Household Interview Survey (HIS) 2004, conducted by the Consultants, The Louis Berger Group, Inc, an United States based international consultant, and Bangladesh Consultants Ltd. (BCL), a local consultant at Dhaka, was comprehensive and had large number of samples which aimed at determining how the population, socioeconomic and travel characteristics of the STP study area residents affect their demand for personal travel (STP, 2005). The field survey activities started in early May and continued through September 2004. Supplementary surveys on NMT and HIS were undertaken in September. The HIS collected adequate data and information based on interviews at sampled households (HHs) of 6035 (5,000+1,035) within the DCC area to make a comprehensive analysis of travel demand characteristics by well trained Survey Enumerators. The information included number of members in household, their sex, age, education level, occupation, income, household ownership of transport vehicles, patterns of travel, purpose of travel, average trip per day, preference for modal choice and the reasons for such choices, etc. This also included options about the appropriate future public transport system in the city. The information has great value in terms of providing a basis for future transportation planning for Dhaka. A brief note on the sampling procedures of the HIS followed is given below:

Stage 1: The HIS was planned to cover the households within the DCC. There are 90 Wards in the metropolitan city of Dhaka. The Consultants collected, tabulated and analyzed the demographic data relating to these Wards.

Stage2: To conduct the HIS sample, starting from Ward 1, every 5^{th} Ward was selected except for last two, resulting in the selection of 20 Wards. Based on the percentage share of each Ward in the total number of HHs in 20 Wards, the Ward-wise sample size was determined up to a total of 5,000 HHs. For example, Ward No. 1 (Uttara) with 12,652 HHs constitutes 4.8 % of the total number of HHs for 20 Wards. Hence, 4.8% of 5,000 (total sample size), i.e. 239 HHs were selected for survey in Ward No. 1 and so on.

Stage 3: To assist in selecting the specific HHs for the survey, the designated Survey Supervisors visited the respective Ward Commissioners to facilitate the survey and help with the sampling of the HHs. For the purpose of income group representation, approximately 45%, 50% and 5% of the HHs were selected in the Wards for HIG, MIG and LIG respectively.

Stage 4: Based on the outcome of Stage 3, the specific HHs were selected on a random basis in all the selected Wards. These HHs were then interviewed for 5,000 samples. Later on as per suggestion of the Steering Committee on the initial results in mid-term review a purposive sample of 1035 HHs were interviewed to include the representation of slum areas.

4.3.4 Characteristics of Data

The data source of our study is STP (2005) HIS as mentioned earlier. For the current study, a total number of 4,906 valid samples (out of 6,035 HH samples), representing approximately 20,150 people have been taken into consideration for the analysis. Some specific characteristics of the data set (including intra & inter-zonal data) are presented in Tables B-8 & B-9 and Figures 4-5 to 4-9.

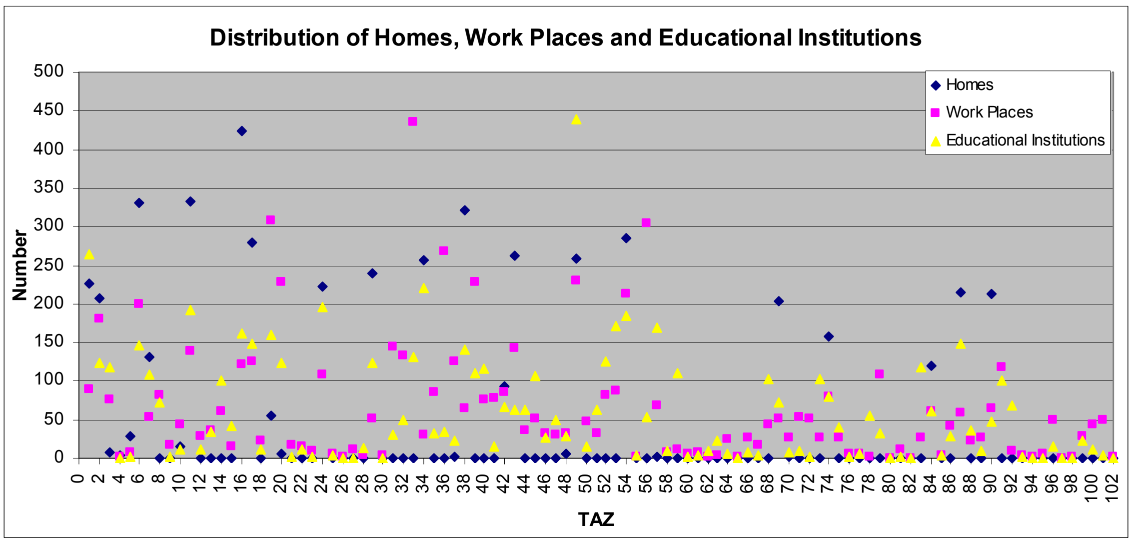


Figure 4-4: Distribution of Residential Locations, Work Places and Educational Institutions over TAZs

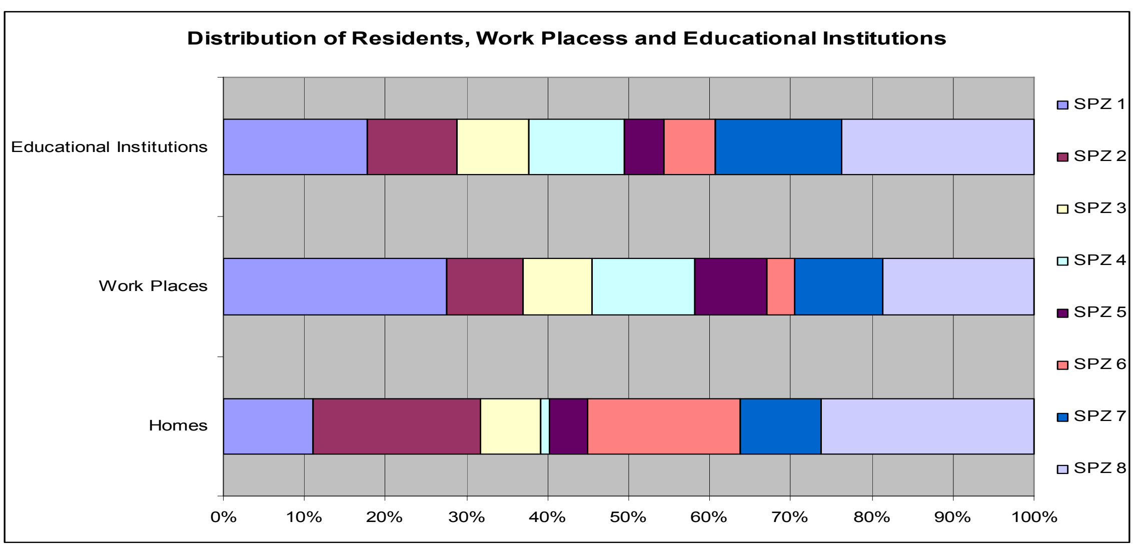


Figure 4-5: Distribution of Residential Locations, Work Places and Educational Institutions over SPZs

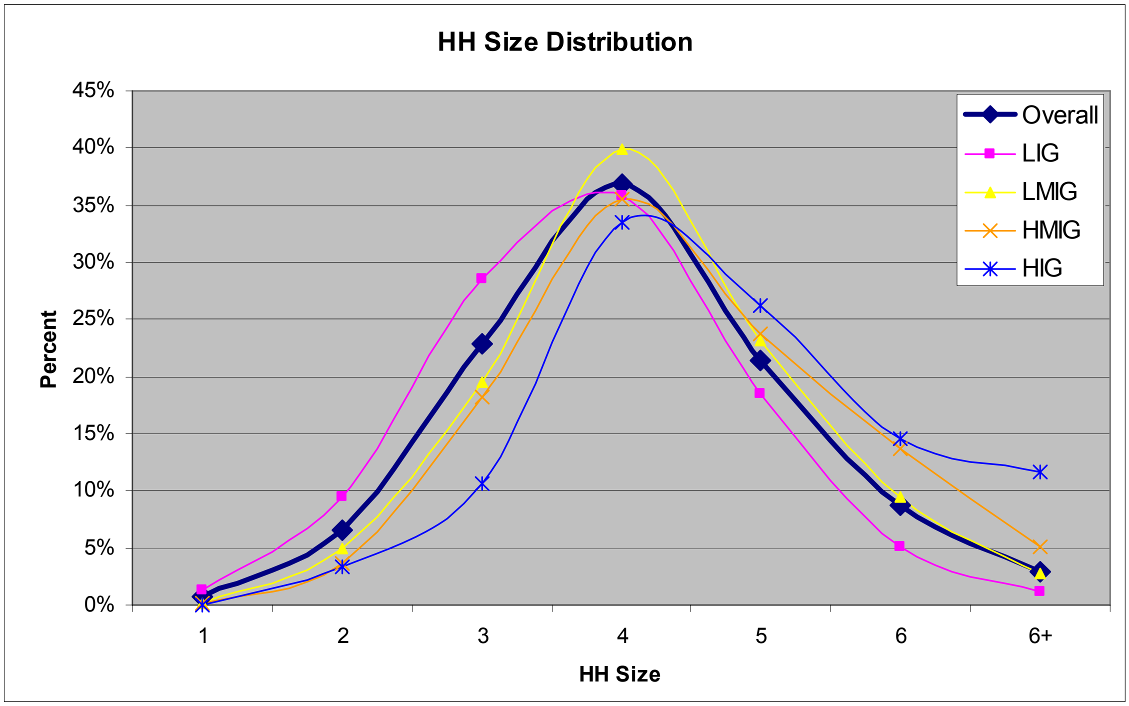


Figure 4-6: Distribution of HH Size by Income Groups

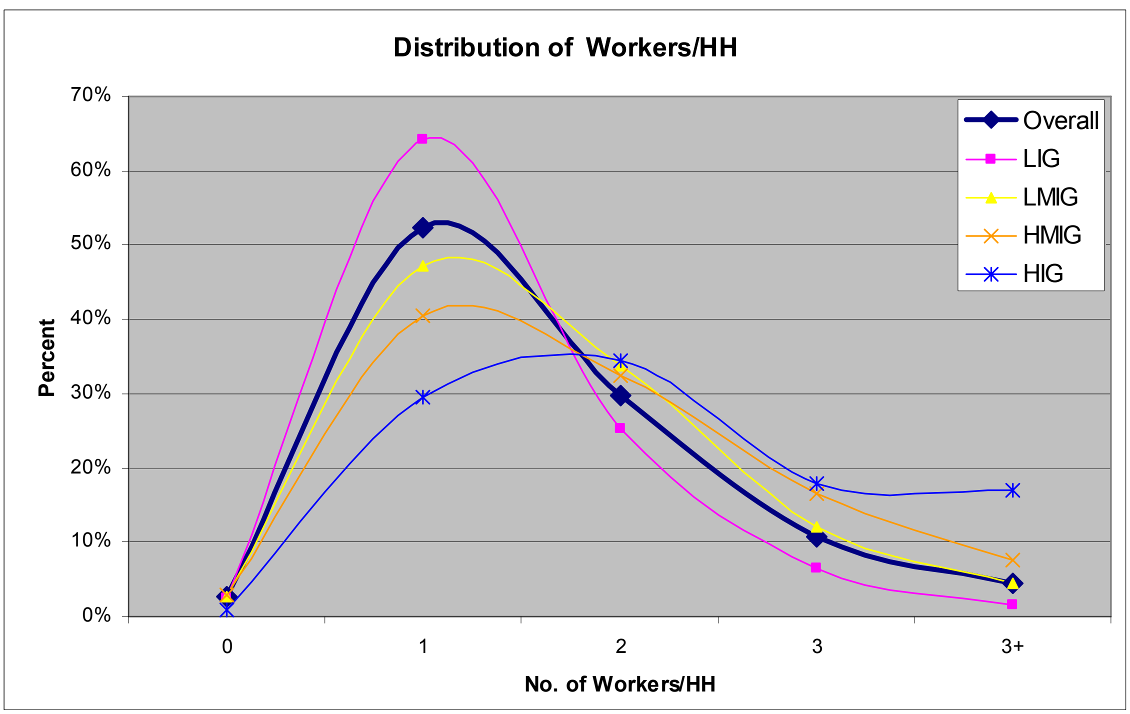


Figure 4-7: Distribution of Workers per HH by Income Groups

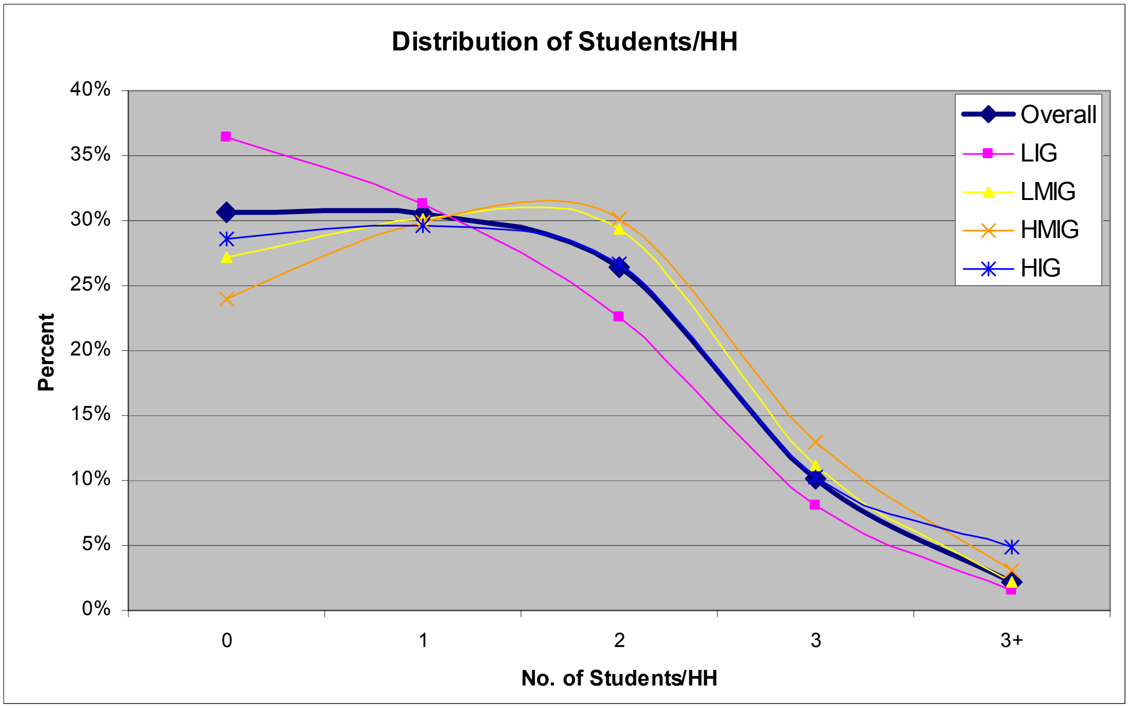


Figure 4-8: Distribution of Students per HH by Income Groups

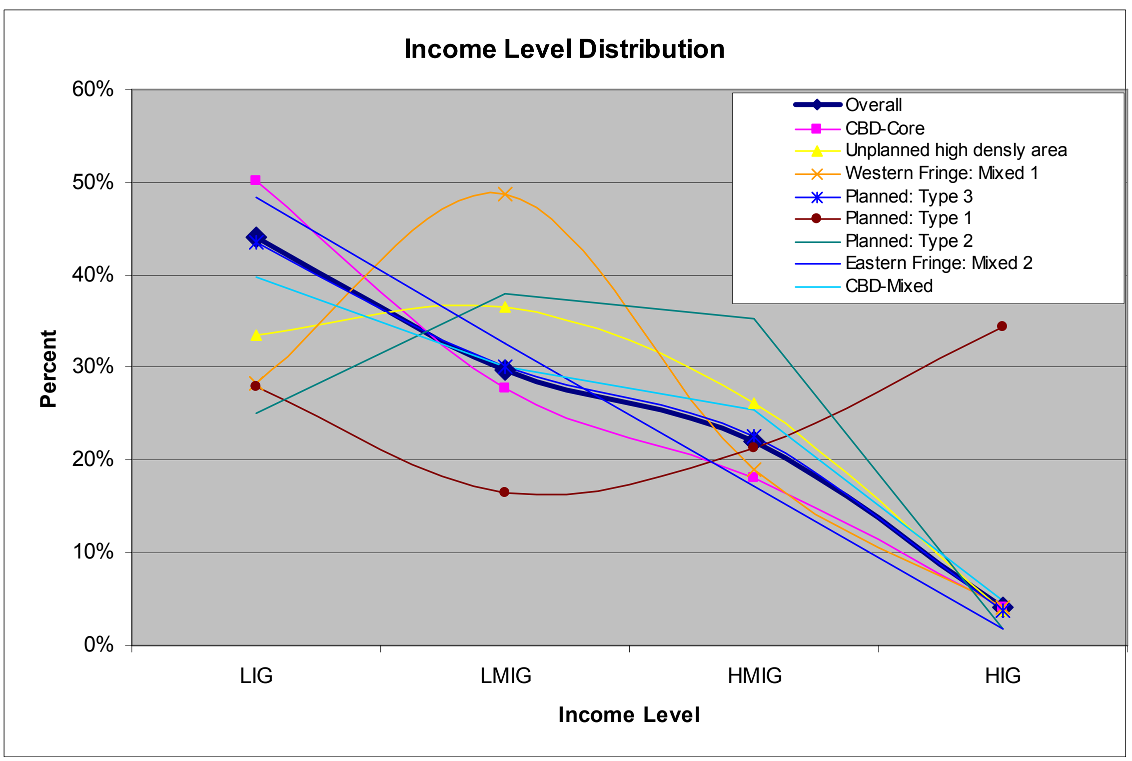


Figure 4-9: Distribution of Income Level over SPZs

4.3.5 Data Organization and Assembly for Modeling

4.3.5.1 Overview

Data analyzed in this study are mainly collected from STP (2005) Household Interview Survey conducted in 2004 which are described in next chapter. The final sample used in this study slightly differs from the sample used in STP (2005) Study. For the current study, the TAZs of the Study area as well as some other variables have been redefined and from the original data set (6035 samples/households) a total number of 4,906 valid samples (households), representing approximately 20,150 people have been taken into consideration for the analysis. The detailed procedures for data preparation and assembly for final analysis are described briefly in the following sections.

4.3.5.2 Data Organization

It was a very big task to organize the raw data in a specific format as required for our study. The original data set of STP (2005) Household Interview Survey was collected based on a set of specific questionnaires developed in accordance with the requirements of their study with particular emphasis on the needs of the EMME/2 Model. The questionnaire was divided into five sections covering different sets of information: Section-1 deals with introducing the dwelling unit, address and location, respondent identification, family size, etc.; Section-2 describes the household, relationships of members, their age, education level, employment status, occupations by sector, income level and monthly expenditure on transport; Section-3 describes the ownership of household vehicles and their utilization; Section-4 describes the most important information, the trip reports for household members including personal ID, trip number, place of origin and destination, purpose and transport mode used; and Section-5 deals with the attitudinal questions regarding the existing public transport system and future preferences. The raw data collected by us was organized in the same formats described above in separate 5 sections. To combine the data in a comprehensive single data set/format for the purpose of our analyses, we have to use a number of mathematical, statistical, logical and other types of functional arguments like VLOOKUP, SUMIF and so on. It was very time consuming and cumbersome task.

4.3.5.3 Intra-zonal trip Separation

The total number of trips made by the selected of 4,906 HHs is 42,688, of which 346 trips are beyond the selected study area. Finally, 42,342 trips, which are within the study area, have been considered. But it is necessary to separate the intra-zonal trips from the total zonal trips since these trips are insignificant for a model developed with a strategic perspective.

For this reason, at first the whole trip data has been divided into four parts based on four trip purposes as described earlier and organized them by modes used for specific trip purposes. Then the intra-zonal trips of each trip purpose have been separated by mode-wise from the inter zonal trips as presented in the Table B-11(Appendix-B). Administrative boundaries have been selected as TAZ boundaries in order to find other variables easily. It shows that nearly 19% of the total trips are intra-zonal trips. The separated inter zonal trips (total 34,262 trips) are finally considered for modeling and other analyses. Table 4-3 summarizes the data selected for modeling in this study.

Table 4-3: Inter zonal Trips Selected for Modeling by Purposes and Travel Modes

Mode	HBW	HBE	HBO	NHB	All
Walk	6.22%	6.86%	1.50%	2.07%	4.11%
Rickshaw	23.83%	41.02%	31.23%	22.39%	29.95%
PC	6.28%	4.95%	4.26%	10.78%	5.70%
Tran	53.96%	40.55%	37.36%	46.12%	44.11%
CNG	5.42%	5.14%	19.60%	11.47%	11.43%
Taxi	1.65%	0.75%	5.63%	3.76%	3.21%
MC	2.64%	0.73%	0.41%	3.42%	1.48%
Total Data	**10790**	**6826**	**13166**	**3480**	**34262**
% of Total Trips	**31.49**	**19.92**	**38.43**	**10.16**	**100.00**

In case of intra-zonal trips, especially for home-based trips, walking and rickshaw play very significant role as medium of travel. Over 77% HBE trips, 62.64% HBW trips and 63.54% HBO trips are conducted by walking. Rickshaws also have quite large shares for intra-zonal HBE and HBW trips. However, walk and intra-zonal trip depends on many variables such as population density, employment density, land use density, land use mix etc (Eric et al, 1999).

4.4 Summary

This chapter presented an overview on the background of the study area, the Dhaka City, in brief, including its urbanization, population growth, motorization growth and existing land use pattern. The chapter carefully described the data used in the study including the sources of data, data type and presented a brief description of the STP household interview survey. Characteristics of the data and its organization and assembly for modeling are also discussed.

Data collection procedure of this study includes assessment of the input data requirements, collection of data from the available sources are discussed accordingly. Various data have been collected from different agencies such as population, household trip data, road network map, transit route, traffic counts, school and college enrollment and land use details. A brief description on the survey procedures of the collected HIS data has also been discussed.

CHAPTER 5

DEVELOPMENT AND CALIBRATION OF TRAVEL BEHAVIOR MODELS

5.1 General

Transportation planning uses the term 'models' extensively. The term ‘model’ is used to refer to a series of mathematical equations that are used to represent how people travel. Travel demand occurs as a result of thousands of individual travelers making individual decisions on how, where and when to travel. These decisions are affected by many factors such as family situations, characteristics of the person making the trip, and the choices (destination, route and mode) available for the trip. Mathematical relationships are used to represent (model) human behavior in making these choices. Models require a series of assumptions in order to work and are limited by the data available to make forecasts. The terms in the model are set (calibrated) to match existing data. Normally, these relationships are assumed to be valid and to remain constant in the future.

Models are important because future transportation plans are based on what the models say will happen rather than on what individual people may think will happen. Models provide forecasts only for those factors and alternatives which are explicitly included in the equations of the models. If the models are not sensitive to certain polices or programs (i.e. policy sensitive), they will not affect the process or results. A consequence of this may be that a conclusion could be drawn that such polices are ineffective. This would be wrong because the models were not capable of testing the policy. For example, travel forecasting models usually exclude pedestrian and bicycle trips. Plans that include bicycle or pedestrian system improvements will not show any impact in the conventional modeling procedure since the models typically ignore these types of trips. It is not correct to conclude that pedestrian or bicycle improvements are ineffective. The actual impact is unknown. Models are used in a sequence of steps to answer a series of questions about future travel patterns. These basic questions asked in each modeling step are as follows:

1. What will our community look like in the future?
   - A. How many people will their be? (population forecasts)
   - B. What will they be doing? (economic forecasts)
   - C. Where will activities take place? (land use)
2. What are the travel patterns in the future?
   - A. How many trips will be made? (trip generation)
   - B. Where will the trips be? (trip distribution)
   - C. What modes will be used? (mode split)
   - D. What routes will be used? (traffic assignment)
   - E. What will be the effects of this travel? (impact analysis)

The general approach of travel demand modeling is conventionally known as the sequential four-step model consisting of trip generation, trip distribution, modal split and trip assignment. The principal goal of travel demand modeling is to accurately predict the behavioral responses to changes in the relevant policy variables affected by applications such as congestion management, travel demand management, congestion pricing, and environmental sustainability. This process is used to estimate the number of trips that will be made on a transportation systems alternative at some future date. It involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given system of highways, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react a particular transportation alternative.

The basic purpose of transportation planning and management is to match transportation supply with travel demand, which represents 'need'. A thorough understanding of existing travel pattern is necessary for identifying and analyzing existing traffic related problems (Chatterjee, A. and Venigalla, M.M., 2004). Considering this importance, understanding and modeling traveler behavior in a variety of situations has been a major area of emphasis for this current study as 'traveler behavior lies at the core of procedures for analysis and evaluation of transportation-related measures aimed at improving urban mobility, environmental quality and a wide variety of social objectives (ICRA Project Report, 2001)'. With an identifiable area of scholarly research, and of practical application to policy and planning questions, travel behavior analysis has established itself as a central area of fundamental intellectual significance in transportation area and in the social science.

Greig Harvey noted in the 1993 *NARC Manual of Regional Transportation Modeling Practice for Air Quality Analysis*: "For some time the travel behavior research community has recognized a need to rethink the basic paradigm of travel demand analysis in light of three decades of advances in the cognitive sciences, in economics, and in computational capabilities." His research direction has led to Urban Transportation Planning models that more realistically represent travel and activity patterns, and therefore provide greater insight into current policy debates. Our present study is an attempt to explore the insight of travel behavior and its relationship with socioeconomic characteristics and spatial urban forms in a first growing developing city like Dhaka. The chronological steps of the modeling processes and the variables used in the models are described in Figure 3-2 (Chapter 3). Conventional four steps modeling processes are beyond the scope of this research work. This study undoubtedly investigate the complex nature of travel behavior of Dhaka City by exploring the heterogeneous effects of different influential factors on daily travel activities and thus provide basic information needed for a strategic transportation planning process. Improvement to transportation planning models must be a continual process involving honest assessment of the profession's skills and shortcomings. Harvey (1985) asserts that most of the fundamental statistical tools have been developed, and that thought must be given to prioritizing the aspects of traveler behavior needed to evaluate future policy and investment options.

This chapter starts with a brief review of the transportation modeling system and sequentially describe the development and calibration process of some specific models (a series of models to describe travel behavior patterns) used in this study namely, discrete choice models for modal split analysis, multinomial logistic regression models for assessing the influence of exogenous variables on modal choices, binary choice models for trip frequency analysis and finally regression models for distance traveled. Besides a number of descriptive analyses are presented to clarify the model estimations.

5.2 Development of Mode Choice Models

5.2.1 Overview

One of the main purposes of this study was to develop a comprehensive mode choice model for Dhaka City which will be capable to predict the diversified modal shares of different modes of transport including the dominant non-motorized mode Rickshaw and all possible minor modes available in city with an attempt to provide background information for the strategic urban transportation planning process. The choice of a transport mode by the individual during the morning home-to-work trip or even in case of other home-based trips or non-home-based trips could involve complex decision making processes largely influenced by the attributes of the person and the characteristics of the urban transport system available. For a traveler in Metropolitan Dhaka City, the available modes and route choices for a trip are sometimes numerous. Figure 5-1 shows the universal choice set of urban travelers from home-to-work. In most of the cases, there are a number of alternatives modes are available to travelers in Dhaka

City and many trips are combination of a series of legs or transfers (as per the STP Study, as many as five legs or transfers make a full one-way trip in some cases) and travelers may have to use different types of modes in each leg. We have considered seven modes for our current study: walking, rickshaws, car, transit (buses), taxi, CNG and motor cycle. The bicycle and other minor modes were excluded from the study because of the limited number of samples who used them for trips, which do show that there are still quite a few people who use these modes. Although, taxi and motor cycles represent very low shares for some trip purposes (HBE, HBO etc.) in the data set, these two modes of transport have been considered in this study as in recent years the increasing number of motor cycles and taxi have significant roles on modal choices analysis especially studies for strategic planning purposes.

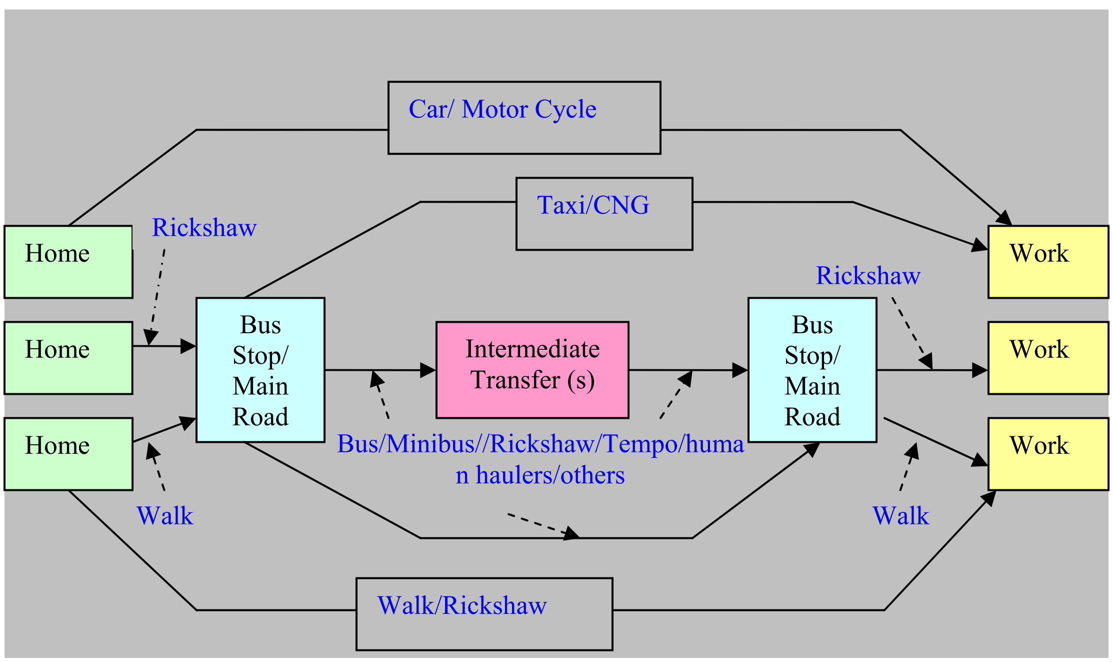


Figure 5-1: The Universal Mode Choice Set of Individuals during Morning Trip to Work in Dhaka City

An urban traveler in Dhaka City could have an infinite number of choices or mode choice combinations if the universal choice set available is directly considered. The modes could be basically divided into two types, the primary modes and the auxiliary modes. In order to simplify the mode and route combinations and further limit the elements of the choice set, the concept of the dominant mode was used where the primary mode used for the longest time or distance is the chosen dominant mode. But how most commuters decide to use only a few of the several modes and routes are not well understood. With regards to choosing a mode from the reduced choice set, the most common assumption is that a public transport commuter chooses his travel itinerary in order to maximize his utility of travel. The utility of a mode can be expressed in terms of the deterministic component and the unobservable component where the latter is usually lumped into what is called the error component.

In this section, we describe the modeling details of modal choice models and analyze the effects of exogenous variables (individual/personal characteristics, household attributes, residential/work or destination place environments) on modal choice for different trip purposes. First of all, we present modal split models in details and then we develop separate models (multivariate techniques) to examine the effects of exogenous variables on modal choices for each of the trip purposes distinguished (HBW, HBE, HBO and NHB) as these multivariate techniques are very useful for travel studies because so many factors are at play (Boarnet, M., Crane, R., 2001).

5.2.3 Theoretical Framework of Modal Split Models

The modeling approach presented here is a discrete choice model based on the random utility maximizing principles as the research direction currently being pursued in discrete choice modeling is the merging of behavioral models and predictive choice models. This incorporation is termed by Walker and Ben-Akiva (2001) as Hybrid Choice Modeling or by Walker (2001) as a Generalized Discrete Choice Framework and Figure 5-2 presents the model framework. The traditional random utility model (RUM) model is what occurs along the middle vertical axis where explanatory variables are used to make the decision and the choice indicators are revealed. The multinomial (MNL) and nested logit (NL) models are considered the traditional approaches of discrete choice modeling which is the backbone (in the middle portion) of the hybrid model shown in Figure 5-2.

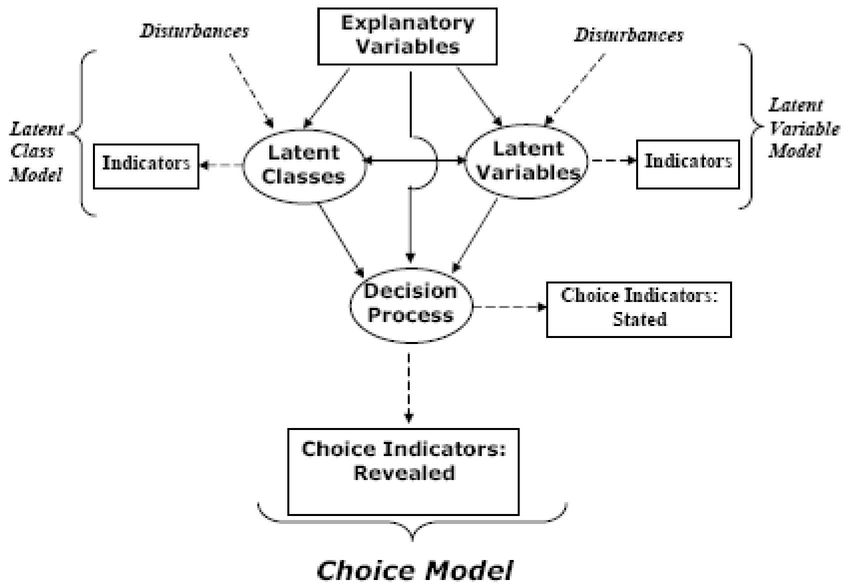


Figure 5-2: Hybrid Choice Model (Generalized Discrete Choice Model) Framework
Source: Walker and Ben-Akiva, (2001)

This study focused on these traditional approaches of discrete choice modeling; because, these models can already provide answers to the objectives being put forward. Moreover, there are still quite a few studies of this nature in developing countries and these closed form models are still very popular when used in transport policy applications.

Marschak (1960) was the first to derive random utility models (RUMs). But it was McFadden (1974) who developed the utility equation as a function of the attributes of the alternatives and the characteristics of the decision maker. The following RUMs derivations were obtained from Train (2002). The traveler, n, would obtain from each alternative, k, a certain level of utility U_{nk}, $k = 1, \ldots, K$. The alternatives being considered here are the dominant transport modes, say, when going to work in the morning which include the rickshaws, buses, CNG, private car, the regular taxi, motor cycle and walking. Hence, in this study $K = 7$.

The traveler chooses the alternative that provides the greatest utility but the reasons of how the choice is made by the traveler may not be fully known to the modeler. So, in this case, the utility equation is given by:

$$U_{nk} = V_{nk} + \varepsilon_{nk} \quad \text{………………………………….. (5-1)}$$

Where, V_{nk} is the part of utility that can be measured by the modeler, also called systematic, deterministic, representative, or observable component, and ε_{nk} represents those components hidden or unobservable to the modeler

Since εnk is unknown to the modeler, this is also called the random component of the utility. Since $\varepsilon_{nk} = U_{nk} - V_{nk}$, the V_{nk} is highly dependent on how the modeler would represent this observed utility in the equation. Hence, one can develop several utility equations, which may or may not result to the same choice probabilities. Ben-Akiva, et al. (1999) provides a comprehensive summary of the logit family of models as used in travel demand analysis.

Following the notation by Hensher and Greene (2000), a summary of the developed equations using the random utility model for which μ is set to one as applied to the determination of the probability of choosing a model is presented later in the following sections. Initially, the MNL model was developed. This model assumes that individual utility is calculated for all possible alternatives; then the alternative with the highest utility is chosen (Meyer and Miller, 2001). Later, Nested logit (NL) model, which has been utilized in this study, is a model that has been developed in order to overcome the so called independence of irrelevant alternatives (IIA) limitation in the multinomial model by modifying the choice structure into multiple tiers.

Nested logit models are very commonly used for modeling mode choice, permitting covariance in random components among nests of alternatives. Alternatives in a nest exhibit an identical degree of increased sensitivity relative to alternatives in the nest (McFadden, D.,1978). A nested logit model has a log-sum or expected maximum utility associated with the lower-tier decision process. The parameter of the log-sum determines the correlation in unobserved components among alternatives in the nest (Daganzo, C.F., and M. Kusnic, 1993). The range of this parameter should be between 0 and 1 for all nests if the nested logit model is to remain globally consistent with the random utility maximizing principle.

5.2.3.1 Multinomial Logit (MNL) Model

The logit model allocates person trips to alternative modes. It does so by comparing the utilities of all alternative modes. The hypothesis underlying discrete choice models is that when faced with a choice situation, an individual's preferences toward each alternative can be described by an "attractiveness" or utility measure associated with each alternative. This utility function incorporates the attributes of the alternatives as well as the decision maker characteristics. The decision-maker is assumed to choose the alternative that yields the highest utility. Utilities, however, cannot be observed or measured directly. Furthermore, many of the attributes that influence individual's utilities cannot be observed and must therefore be treated as random. Consequently, the utilities themselves in models are random, meaning that choice models can give only the probability with which alternatives are chosen, not the choice itself (Mohammed, A.A., and Hassan, A., 2001). It has been shown that the multinomial logit (MNL) model is the most popular form of discrete choice model in practical applications (Mohammadian, A., and S.T. Doherty, 2005).

The utility associated with any given mode choice, k, is given as a linear, additive function of the independent variables (Southworth, 1981). That is,

$$U_k^r = \sum_{q=1}^{Q} X_{kq}^r \theta_q \qquad \text{(5-2)}$$

where, $U_k^r =$ the utility associated with mode choice k by observation (trip maker) r; $\sum_{q=1}^{Q} X_{kq}^r =$ a set of variables describing mode choice k, for observation r, for variables q=1,……,Q; $\sum_{q=1}^{Q} \theta_q =$ a set of model parameters q=1,….,Q associated with mode choice k.

The multinomial logit model has the form,

$$P(k:K') = \frac{\exp(U_k^r)}{\sum_{k'=1}^{K} \exp(U_k^r)} \qquad \text{(5-3)}$$

where, $P(k:K') =$ the probability that observation (trip maker) r will select mode k from the set (k′=1,…..,K) available to him.

The dependent variable for this model is the observed choice from a set of mode alternatives. The probabilities of choice are not observed, only the actual choices, and hence the observed dependent variable takes a value of either 0 or 1.

One of the most widely discussed aspects of the multinomial logit model is the independence from irrelevant alternatives property, or IIA. The IIA property holds that for a specific driver the ratio of the choice probabilities of any two modes is entirely unaffected by any other alternatives. The IIA property is a result of the assumption that the disturbance terms are mutually independent. The IIA can be easily shown to hold in the case of MNL as follows (Mohammed, A.A., and Hassan, A., 2001):

$$P_n(i)/P_N(j) = (\frac{e^{\beta_i X_n}}{\sum_I e^{\beta_i X_n}})/(\frac{e^{\beta_j X_n}}{\sum_I e^{\beta_i X_n}}) = \frac{e^{\beta_i X_N}}{e^{\beta_j X_N}} = e^{(\beta_i - \beta_j)X_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(5-4)}$$

McFadden and Hausman (1984) investigated a wide range of computationally feasible tests to detect violations of the IIA assumption. This involves comparisons of logit models estimated with subsets of alternatives from the universal choice set. If the IIA assumption holds for the full choice set, then the logit model also applies to a choice from any subset of alternatives. Thus, if the logit model is correctly specified, we can obtain consistent coefficient estimates of the same sub-vector of parameters from a logit model estimated with the full choice set and from a logit model estimated with a restricted choice set.

5.2.3.2 Nested Logit (NL) Model

The Multinomial Logit Model (MNL) structure has been widely used for both urban and intercity mode choice models primarily due to its simple mathematical form, ease of estimation and interpretation, and the ability to add or remove choice alternatives. However, the MNL model has been widely criticized for its Independence of Irrelevant Alternatives (IIA) property as described earlier. The IIA property of the MNL restricts the ratio of the choice probabilities for any pair of alternatives to be independent of the existence and characteristics of other alternatives in the choice set. This restriction implies that introduction of a new mode or improvements to any existing mode will reduce the probability of existing modes in proportion to their probabilities before the change. The IIA property is a major limitation of the MNL model as it implies equal competition between all pairs of alternatives, an inappropriate assumption in many choice situations. For example, in the case of urban mode choice among drive alone, shared ride, bus and light rail; the bus and light rail alternatives are likely to be more similar to each other than they are to either of the other alternatives due to shared attributes which are not included in the measured portion of the utility function; for example, bus and light rail may have the same fare structure and operating policies, the same lack of privacy, control of the environment, and so on. Such similarities, if not included in the measured portion of the utility function, lead to correlation between the errors associated with these alternatives, a violation of the assumptions which underlie the derivation of the MNL (Koppelman, F.S., and Bhat, C., 2006).

One way to relax the homoscedastiticy assumption (i.e., equal variances of distributions of errors) in the multinomial logit model that provides an intuitively appealing structure is to group the alternatives into subgroups that allow the variance to differ across the groups while maintaining the IIA assumption within the group. This specification defines a nested logit (NL) model. The NL model is currently the preferred extension to the simple multinomial logit discrete choice model. The appeal of the NL model is its ability to accommodate differential degrees of interdependence (i.e. similarity) between subsets of alternatives in a choice set. In this section, we will demonstrate a general outline of nested logit models.

A nested logit (NL) structure allows estimation of proportions among selected sub-modes, prior to the estimation of proportions between modes (Mohammed, A.A., and Hassan, A., 2001). For examples, a nested logit model might estimate the proportions between car occupancies, such as 2 persons per car and 3 persons per car, prior to estimating the proportions between the drive alone mode and the shared ride mode. This ability of the NL model reduces some of the limitations of the MNL model, specially the independence from irrelevant alternatives (IIA) limitation. It has also been found that the selection between sub-modes may be more sensitive to travel times and costs than the selection between modes. For examples, fairly small travel time changes can shift trips between the shared ride sub-modes (i.e., 2, 3, and 4+ persons per car) much more than it can shift the trips to or from the drive alone mode or the transit mode. The NL structure accounts for these differences in sub-mode sensitivities to a far greater extent than a multinomial logit model. Each nest within the choice set is associated with a pseudo-utility, called composite utility, expected maximum utility, inclusive value or accessibility in the literature.

The nested logit model, first derived by Ben-Akiva (1973), is an extension of the multinomial logit model designed to capture correlation among alternatives. It is based on the partitioning of the choice set C into several nests C_K. Where, for each pair $C_k \cap C_j = 0$. The utility function of each alternative is composed of a term specific to the alternative, and a term associated with the nest. If $i \in C_K$, we have

$$U = V_i + \varepsilon_i + V_{CK} + \varepsilon_{CK} \qquad (5\text{-}5)$$

The error terms ε_i and ε_{CK} are supposed to be independent. As for the multinomial logit model, error terms (ε_i's) are supposed to be independent and identically Gumbel distributed, with scale parameter σ_k. The distribution of ε_{CK} is such that the random variable max $j \in C_K U_j$ is Gumbel distributed with scale parameter μ.

In the nested logit model the correlated alternatives are placed in a "nest", which partly removes the IIA property. By laws of probability, the unconditional probability of the observed choice made by an individual is given as

$$P(k, j, i) = P(k \mid j, i).P(j \mid i).P(i) \qquad (5\text{-}6)$$

where, *P(k,j,i)* stands for the probability of choosing a mode *k* (*k* □ number of alternative modes available to choose) in branch j in limb i.

• The choice probability for the mode k alternatives is:

$$P(k \mid j, i) = \frac{e^{[\mu_{(j|i)}[\alpha_{k|ji} + \beta' x_{(k|ji)}]}}{e^{[IV_{(j|i)}]}} \qquad (5\text{-}7)$$

where, the $IV_{(j|i)} = \ln \sum_{k=1}^{K|ji} e^{\{\mu(j|i)[\alpha_{k|ji} + \beta' x_{(k|ji)}]}$

• The probability of choosing a particular branch j in limb i would be:

$$P(j \mid i) = \frac{e^{\{\rho_{(i)}[\gamma' y_{(j|i)} + (1/\mu_{(j|i)} IV_{(j|i)}]\}}}{e^{[IV_{(i)}]} } \text{..................................} (5-8)$$

where, the $IV_{(i)} = \ln \sum_{j=1}^{j|i} e^{\{\rho_{(i)}[\gamma' y_{(j|i)} + (1/\mu_{(j|i)} IV_{(j|i)}]\}}$

• Lastly, to obtain the probability of choosing the general mode classification *i* would be:

$$P(i) = \frac{e^{[\delta' z_{(i)} + (1/\rho_{(i)} IV_{(i)}]}}{e^{IV}} \text{..................................} (5-9)$$

where, the

$$IV = \ln \sum_{i=1}^{I} e^{[\delta' z_{(i)} + (1/\rho_{(i)}) IV_{(i)}]}$$

There is a vector of `shallow'" parameters, [β, α, γ] at each level, which multiplies the attributes (at the lowest level), or, e.g., demographics, at a higher level. There are also two vectors of `deep' parameters, which multiply the inclusive values at the middle and high levels. In principle, there is one free inclusive value parameter for each branch in the model and one for each limb. But, some may have to be restricted to equal 1.0 for identification purposes.

For the nested logit models, there are two ways to estimate the parameters of the nested logit model. 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 (Mohammed, A.A., and Hassan, A., 2001). Therefore, the models presented in this study are all calibrated using the FIML estimation approach.

5.2.4 Data Requirement and Assembly for Mode Choice Model Calibration

It is intended to make the modal split model simple with limited data requirement since there is lack of data availability. The model developed here for mode choices use only two variables to avoid difficulties due to appropriate data constraints: Total Travel Time (in minutes) and Travel Cost (2004 taka).

Total travel time and travel cost represent mode related attributes; all other things being equal, a faster mode of travel is more likely to be chosen than a slower mode and a less expensive mode is more likely to be chosen than a costlier mode. The travel time and travel cost variables are specified as generic in this model. This implies that an increase of one unit of travel time or travel cost has the same impact on modal utility for all modes.

The trip records of 2004 STP Household Interview Survey (HIS) are used to derive the trip purpose and mode choice of trip makers. Modal data (travel time and travel cost) is generated from simulation of network analysis. Network analysis provides the zone-to-zone distance from the zone-to-zone shortest paths which are derived by assigning minimum traffic in the network. A per-kilometer travel cost is applied to obtain zone-to-zone travel costs for each mode. As the cost related data for different modes are not available in HIS data of STP, two separate small-scale person trip interview surveys of 210 (77+133) persons were conducted by this author in February 2007 and August 2007 in Dhaka City especially in some office premises including Government Offices (Sarak Bhaban, Public Works Department, Bangladesh Railway), Private Offices (real estate companies such as Sheltech (Pvt.) Ltd. and RAMS Holdings Ltd. at Panthapath, McDonald (Pvt.) Ltd. at Sonargaon Road, different banking institutions namely Jamuna Bank at Sonargaon Road, National Bank and National Credit and Commerce Bank Limited (NCCBL) at Motijheel, etc. and National Housing Finance and Investments Limited, a financial institution, at Sonargaon road) and also in Dhaka City Corporation office and in REHAB (Real Estate and Housing Association of Bangladesh) office at Sonargaon Road to get an clear idea on travel cost especially for rickshaws and motor cycle. Travel costs for transit (buses) and auto (private car) are used as STP Study.

The fixed fares for CNG and Taxi set by the Government are taken as their cost of travel. The cost of each trip is divided by the O-D distance in order to derive the per-kilometer cost of the trip. The average per-kilometer cost for each mode is obtained from survey data analysis and converted into the taka value of 2004. The travel time for each mode is obtained from the zone-to-zone distance and an assumed speed based on survey and STP Study. Finally, the appropriate travel times and cost between zones is appended to each trip in the trip file based on the origin and destination zones of the trip. The travel time (in terms of travel speed) and travel cost (Taka 2004) for different modes of transport considered for this study are mentioned in Table B-10 (Appendix-B).

Table 5-1: Data Structure for Mode Choice Model Estimation

Alternative Number	Income	Time	Cost	Alternative Chosen
1	75,000	40	50	1
2	75,000	20	40	0
3	75,000	30	20	0
4	30,000	50	30	1
5	30,000	40	40	0
6	20,000	60	20	1

The selected data are assembled into a single data set to support model estimation. The structure of the resultant data file satisfies the format requirements of the selected software package, in this case LIMDEP, designed for choice model estimation. The software packages for discrete choice model estimation require the data to be structured in one of two formats: a) the trip format or b) the trip alternative format. The data structure of model estimation, presented in Table 5-1, follows the trip alternative format.

5.2.5 Calibration of Mode Choice Models

5.2.5.1 Overview

We use the STP (2005) data to estimate mode choices models using a basic specification which includes travel time and travel cost as the explanatory variables. Travel time and travel cost represent mode related attributes; all other things being equal, a faster mode of travel is more likely to be chosen than a slower mode and a less expensive mode is more likely to be chosen than a costlier mode.

Both for MNL and NL models, four separate modal split models have been calibrated of the form provided by in the equations described in the earlier sections considering four trip purposes. Trip purposes are: Home based work (HBW), Home based education (HBE), Home based other (HBO) and Non-home based (NHB). Mode alternatives available to trip makers to make choice include: walking, rickshaw, private car (auto), transit (bus), CNG (auto-rickshaw), taxi and motor cycle. Auto i.e. Private car is considered as the base mode for all cases.

The estimation results, both the MNL and NL Models, reported in this study are obtained from using LIMDEP (NLOGIT 3.0) software package. The outputs from the software package typically include, at least, the following estimation results:

- Parameter20 names, parameter estimates, standard errors of these estimates and the corresponding t-statistics for each variable/parameter;

- Log-likelihood values at zero (equal probability model), constants only (market shares model) and at convergence and
- Rho-Squared and other indicators of goodness of fit.

In addition, a variety of other information either as part of the default output or as a user selected option are reported. These include:

- The number of observations,
- The number of cases for which each alternative is available,
- The number of cases for which each alternative is chosen,
- The number of iterations required to obtain convergence, and
- The status of the convergence process at each iteration.

The value for the log-likelihood at zero and constants can be obtained for either software by estimating models without (zero) and with (constants) alternative specific constants and no other variables. Further, the log-likelihood at zero can be calculated directly as:

$$\sum_t \ln(1/Number\_of\_Alternative_t)$$

The estimation results for the developed models are justified using the following different tests as suggested by Koppelman and Bhat (2006) which provide a basis to evaluate each model and to compare models with different specifications:

- Informal judgment tests
- Goodness-of-fit measures
- Statistical tests

Informal judgment tests: A variety of informal tests can be applied to an estimated model. These tests are designed to assess the reasonableness of the implications of estimated parameters. The most common tests concern:

- The sign of parameters (do the associated variables have a positive or negative effect on the alternatives with which they are associated);
- The difference (positive or negative) within sets of alternative specific variables (does the inclusion of this variable have a more or less positive effect on one alternative relative to another?); and
- The ratio of pairs of parameters (is the ratio between the parameters of the correct sign and in a reasonable range).

Goodness-of-fit measures: The rho-squared value ($\rho 2$) which can be used to describe the overall goodness of fit of the model. The rho-squared (ρ_0^2) value is based on the relationship among the log-likelihood values: LL(0) represents the log-likelihood with zero coefficients (which results in equal likelihood of choosing each available alternative), *LL*(C) represents the log-likelihood for the constants only model, $LL(\beta\hat{})$ represents the log-likelihood for the estimated model and LL(*) = 0 is the log-likelihood for the perfect prediction model. It is simply the ratio of the distance between the reference model and the estimated model divided by the difference between the reference model and a perfect model. If the reference model is the equally likely model, the rho-square with respect to zero, ρ_0^2, is:

$$\rho_0{}^2 = \frac{LL(\hat{\beta}) - LL(0)}{LL(*) - LL(0)}$$

Since the log-likelihood value for the perfect model is zero, the ρ_0^2 measure reduces to:

$$\rho_0{}^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)}$$

Similarly, the rho-square with respect to the constants only model is:

$$\rho_c{}^2 = \frac{LL(\hat{\beta}) - LL(c)}{LL(*) - LL(c)} = 1 - \frac{LL(\hat{\beta})}{LL(c)}$$

By definition, the values of both rho-squared measures lie between 0 and 1 (this is similar to the R^2 measure for linear regression models). A value of zero implies that the model is no better than the reference model, whereas a value of one implies a perfect model; that is, every choice is predicted correctly.

The rho-squared measures are widely used to describe the goodness of fit for choice models because of their intuitive formulation. The ρ_0^2 measures the improvement due to all elements of the model, including the fit to market shares, which is not very interesting for disaggregate analysis so it should not be used to assess models in which the sample shares are very unequal. The rho-squared measure with respect to the constant only model, ρ_c^2, controls for the choice proportions in the estimation sample and is therefore a better measure to use for evaluating models.

A problem with both rho-squared measures is that there are no guidelines for a "good" rho-squared value. Consequently, the measures are of limited value in assessing the quality of an estimated model and should be used with caution even in assessing the relative fit among alternative specifications. It is preferable to use the log-likelihood statistic (which has a formal and convenient mechanism to test among alternative model specifications) to support the selection of a preferred specification among alternative specifications. Another problem with the rho-squared measures is that they improve no matter what variable is added to the model independent of its importance. This directly results from the fact that the objective function of the model is being modeled with one or more additional degrees of freedom and that the same data that is used for estimation is used to assess the goodness of fit of the model. One approach to this problem is to replace the rho-squared measure with an adjusted rho-square measure which is designed to take account of these factors. The adjusted rho-squared for the zero model is given by:

$$\bar{\rho}_0^{\,2} = 1 - \frac{LL(\hat{\beta}) - K}{LL(0)}$$

where K is the number of degrees of freedom (parameters) used in the model.

The corresponding adjusted rho-squared for the constants only model is given by:

$$\bar{\rho}_c^{\,2} = 1 - \frac{LL(\hat{\beta}) - K}{LL(c) - K_{MS}}$$

where K_{MS} is the number of degrees of freedom (parameters) used in the constant only model.

Statistical tests: t-statistic of an estimated parameter is an important statistical test. The t-statistic presented here tests the hypothesis that the true value is zero i.e. the variable has no effect on modal utilities. The rejection of this null hypothesis implies that the corresponding variable has a significant impact on the modal utilities and suggests that the variable should be retained in the model. Low absolute values of the t-statistic imply that the variable does not contribute significantly to the explanatory power of the model and can be considered for exclusion. The statistic used for testing the null hypothesis that a parameter $\hat{\beta}_k$ is equal to some hypothesized value, $\beta_k^{\,*}$, is the asymptotic t-statistic, which takes the following form:

$$t - statistic = \frac{\hat{\beta}_k - \beta_k^{\,*}}{S_k}$$

where, $\hat{\beta}_k$ is the estimate for the k^{th} parameter, $\beta_k^{\,*}$ is the hypothesized value for the k^{th} parameter and S_k is the standard error of the estimate.

In order to evaluate the models, the estimation results of the all models, presented below are analyzed based on the above tests where they can be applied.

5.2.5.2 MNL Models

For the multinomial logit model (Figure 5-3), the following choices were considered in the universal choice set: private car, rickshaw, bus, taxi, CNG, motor cycle and walking. Since logit choice modeling allow for differences in the number and type of mode choices per commuter, it was expected that most commuters will have different individual choices given their origin and destination and the available transport mode service in the area of his origin and destination.

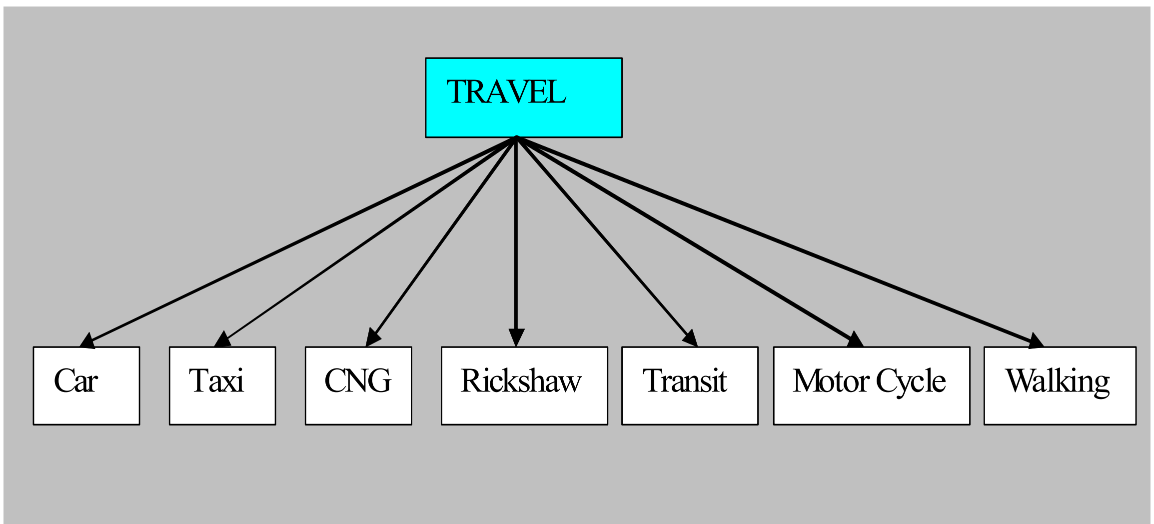


Figure 5-3: The Multinomial Logit Model

The full data set have been divided into four sub-sets based on trip purposes (HBW, HBE, HBO and NHB) as described earlier. The NLOGIT 3.0 software was used in discrete choice analysis starting with the multinomial logit model. The resulting MNL models developed are shown in through Tables 5-2 to 5-5. For each of the four models, TIME (total travel time in Minutes) and COST (total travel cost in 2004 Taka) were the obtained deterministic variables in addition to the alternative specific constants (ASC) for each of the seven modes.

Table 5-2: The MNL Models for HBW Trips

Variables	**Coefficient**	**t-value**
TIME	-0.09496***	-37.215
COST	-0.00813***	-14.244
Mode Constants		
Auto/Private Car (Base)	0	
Transit (Bus)	1.77996***	26.572
Rickshaw	2.18344***	34.091
Taxi	-1.88066***	-21.016
CNG (Auto-rickshaw)	-0.77397***	-11.587
Motor Cycle	-1.96277***	-23.580
Walk	2.53182***	28.358
Goodness of Fit Measures		
LL(0)	-20996.371	
LL(c)	-14491.048	
LL(β)	-13188.370	
ρ^2	0.3719	
$\bar{\rho}^2$	0.3715	
χ^2	2605.354	
2[LL(β)-LL(0)]	15616.002	
2[LL(β)-LL(c)]	2605.356	

*** passed the .01 level of significance

Table 5-2 presents the estimation results of simple MNL model for HBW Trips. Going over the parameters of the model, the estimated coefficients on the TIME and COST variables have the expected negative signs since the utility of a mode decrease as the mode becomes slower and/or more expensive and are considered as disutility and they satisfactorily passed the 0.01 level of significance. The expected negative signs of these two variables, in turn, imply that this will reduce the choice probability of the corresponding mode. The statistical measures (Goodness of fit measures) of all four models show good performance.

For the alternative specific constants of the modes developed for HBW trips, all mode constants passed the 0.01 level of significance. Considering the t-values of the individual variables, we find satisfactory results in all cases.

Considering the statistical measures of the model for HBW Trips, the obtained log likelihood functions: Log-likelihood at Convergence, *LL(*β*)* is -13188.370, Log-likelihood at Constant, *LL(*c*)* is -14491.048 and Log-likelihood at Zero, *LL(0)* is -20996.37; all present reasonable results in terms of magnitude and signs. The value of Likelihood Ratio, 2[LL(β)-LL(0)], is 15616.002, which indicates that we can reject the null hypothesis that all the parameters are zero at the 0.001 level of significance; a 2[LL(β)-LL(c)] value of 2605.356, indicating that the null hypothesis can also be rejected at the 0.01 level of significance, the value of a Rho-squared, ρ^2 is 0.3719 and an Adjusted Rho-squared, $\overline{\rho}^2$ is 0.3715. The Chi-squared, χ^2 value is 2605.354.

Model Estimations for HBE, HBO and NHB trips are presented in tables 5-3, 5-4 and 5-5 respectively. In all cases of these MNL models, TIME (total travel time in Minutes) and COST (total travel cost) were also the obtained deterministic variables in addition to the alternative specific constants (ASC) for each of the seven modes as well. In all model estimation, the obtained deterministic variables (TIME and COST) have the expected negative signs and they satisfactorily passed the 0.01 level of significance. For the alternative specific constants of the modes developed for HBE, HBO and NHB trips, all mode constants passed the 0.01 level of

Table 5-3: The MNL Model for HBE Trips

Variables	Coefficient	t-value
TIME	-0.08287***	-26.473
COST	-0.01460***	-12.437
Mode Constants		
Auto/Private Car (Base)	0	
Transit (Bus)	1.30509***	13.602
Rickshaw	2.35756***	27.645
Taxi	-2.52905***	-16.340
CNG (Auto-rickshaw)	-0.70923***	-8.006
Motor Cycle	-2.95642***	-18.509
Walk	1.94948***	16.057
Goodness of Fit Measures		
LL(0)	-13282.783	
LL(c)	-8800.882	
LL(β)	-8186.990	
ρ^2	0.3836	
$\bar{\rho}^2$	0.3830	
χ^2	1227.785	
2[LL(β)-LL(0)]	10191.586	
2[LL(β)-LL(c)]	1227.784	

*** passed the .01 level of significance

significance. Considering the t-values of the individual variables of each model, we also find satisfactory results in all cases. Considering the statistical measures (the goodness of fit measures) we obtain log-likelihood ratios and other measures in acceptable level as shown in the corresponding tables.

Table 5-4: The MNL Model for HBO Trips

Variables	Coefficient	t-value
TIME	-0.14355***	-47.475
COST	-0.01419***	-20.777
Mode Constants		
Auto/Private Car (Base)	0	
Transit (Bus)	1.42818***	19.114
Rickshaw	3.06679***	46.435
Taxi	-0.64680***	-9.900
CNG (Auto-rickshaw)	0.45152***	7.313
Motor Cycle	-4.17642***	-27.441
Walk	2.22371***	20.471
Goodness of Fit Measures		
LL(0)	-25619.853	
LL(c)	-18864.121	
LL(β)	-16795.150	
ρ^2	0.3445	
$\bar{\rho}^2$	0.3441	
χ^2	4137.950	
2[LL(β)-LL(0)]	17649.406	
2[LL(β)-LL(c)]	4137.942	

*** passed the .01 level of significance

Table 5-5: The MNL Model for NHB Trips

Variables	Coefficient	t-value
TIME	-0.08828***	-17.165
COST	-0.00545***	-6.258
Mode Constants		
Auto/Private Car (Base)	0	
Transit (Bus)	1.33919***	14.150
Rickshaw	1.60720***	16.892
Taxi	-1.38686***	-12.383
CNG (Auto-rickshaw)	-0.32292***	-3.560
Motor Cycle	-1.91145***	-14.953
Walk	0.84981***	4.831
Goodness of Fit Measures		
LL(0)	-6771.767	
LL(c)	-5218.280	
LL(β)	-4989.763	
ρ^2	0.2632	
$\bar{\rho}^2$	0.2620	
χ^2	457.034	
2[LL(β)-LL(0)]	3564.008	
2[LL(β)-LL(c)]	457.034	

*** passed the .01 level of significance

5.2.5.3 NL Models

As mentioned by Hensher and Greene (2000), one justification for moving from the MNL model to an NL model is to recognize the possibility that the standard deviations (or variances) of the random error components in the utility expressions are different across groups of alternatives in the choice set. This is more likely to occur because the utility of alternatives cannot be fully captured by the expressions used. The part of the utility not captured may then have some effect on the random components across alternatives that would result to different variances. The scale parameters are then used into each of the utility expressions to accommodate these differential variances.

There are different formulations of the NL model as described earlier. They are not simple reparameterizations of the model, so they will not give identical results in a finite sample. Which is the appropriate to use is up to the analyst. There are also different ways to normalize the variances in the NL model. Following the approach being put forward by Hensher and Greene (2000), when the μ is being normalized, the model being referred to is the Random Utility Model 1 (RUM1) and when the λ is being normalized, this refers to the Random Utility Model 2 (RUM2).

The assumptions underlying the nested logit model results in two types of Nested Logit (NL) structure for all four trip purposes: the Two-Level NL models and the Three-Level NL models based on specific market segments of Dhaka City for the seven alternative modes of transport. This nesting structure is one of many possible two or three-level nested logit models which can be constructed for a choice set with seven alternatives. The possible set of all nesting structures are examined with the obtained dataset, but some of these nesting structures are likely to be behaviorally unreasonable and two-level nested structures perform better over MNL and also three-level NL model structures. In case of two-level nested logit model, there are also many possible alternative structures which can be developed. So, we have selected the best nest for two-level nested logit models for each of the four trip purposes examining the log-likelihood value, $\overline{\rho}^2$ value, and values of inclusive value parameters of all possible and behaviorally reasonable nested structures for representing the travel market of Dhaka City.

- **NL Model for Home-Based Work (HBW) Trips**

For HBW Trips, we examined different Two-Level NL model structures based on all possible market segments. Here we present the best fitted model only which is shown in Figure 5-4. People in Dhaka City going to work in the morning were grouped into three parts– (1) those who own private personalized vehicles like a car or a motor cycle in the household; (2) those who have no private vehicles but travel by other available motorized vehicles ; and (3) those who are users of non-motorized modes like rickshaws or walking. However, the people of second group who have no personalized motorized vehicles like car or motor cycle, the expensive modes of motorized transport like regular taxi and CNG are available to them in addition of transit or buses.

Hence, three subsets of mode choices were developed with the first subset termed as the private motorized vehicles (PMV) with elements - private car and motor cycle, and the second subset termed as the hired motorized mode of transport (HMV) with elements – taxi, CNG and transit and these modes of transport often compete each other among the majority of people live in Dhaka especially for long distance travel or where non-motorized mode rickshaws are not available. The third group represents the non-motorized modes of transport (NMV) namely very popular mode rickshaws and least popular mode walking. Figure 5-4 describes this nested logit model structure.

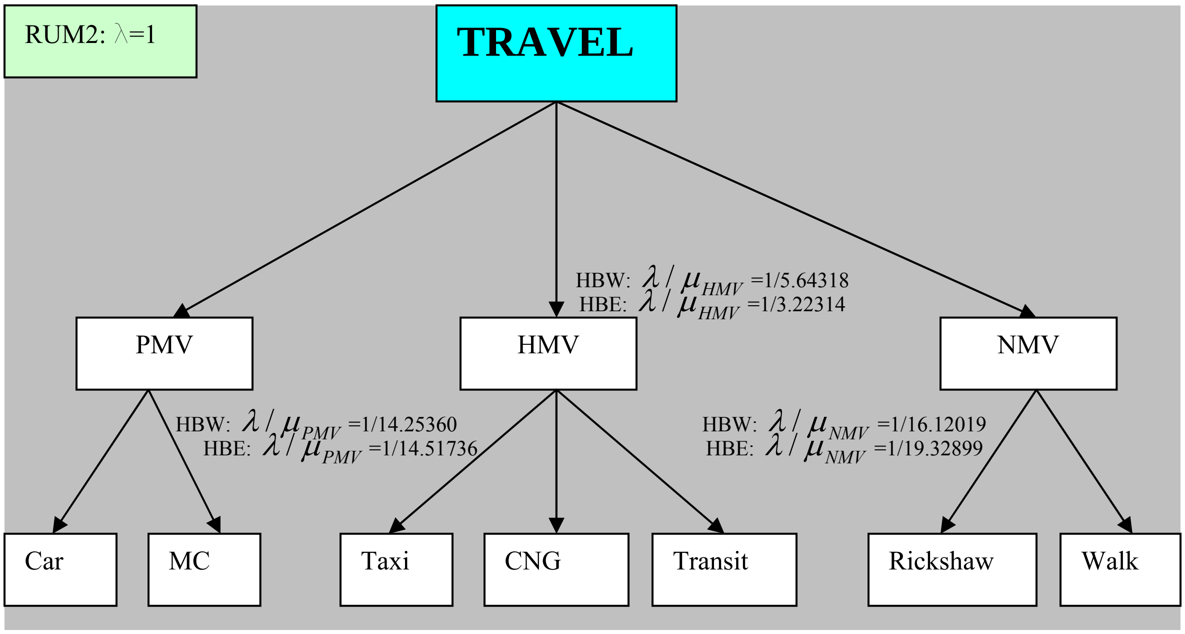


Figure 5-4: The Structure of NL Model for HBW and HBE Trips with IV Parameters

Table 5-6 presents the estimated parameters of NL model for HBW Trips. Going over the parameters of the model, the estimated coefficients on the TIME and COST variables have the expected negative signs as well and they satisfactorily passed the 0.01 level of significance. The statistical measures (Goodness of fit measures) of the models show good performance over MNL model developed for HBW trips.

For the alternative specific constants of the modes, mode constants for walk only passed the 0.05 level of significance. The t-values of the NL model (HBW trips) for deterministic variables TIME and COST are higher than that of MNL model, but the t-values for mode constants are smaller.

Considering the statistical measures of the model for HBW Trips, the obtained Log-likelihood at Convergence, *LL(β)* is -12503.520 shows better performance over that of MNL model. The value of a Rho-squared, ρ^2 is 0.4045 and an Adjusted Rho-squared, $\bar{\rho}^2$ is 0.4041 are also better than that of MNL model for HBW Trips.

Table 5-6: The Estimated Parameters of NL Model for HBW Trips

Variables	RUM2	
	Coefficient	t-value
TIME	-.14822***	-46.608
COST	-.01197***	-19.007
Mode Constants		
Auto/ Private car (Base)	0	
Transit (Buses)	5.79697	1.161
Rickshaws	3.92212	.788
Taxi	-14.22810	-690
CNG (Auto-rickshaw)	-7.46245	.522
Motor Cycle	-2.21836	-18.876
Walk	-15.11651**	-2.249
IV Parameter, μ (j|i), γ(i)		
PMV	14.25360	1.036
HMV	5.64318	1.019
NMV	16.12019***	5.644
Goodness of Fit Measures		
LL(0)	-20996.371	
LL(c)	-14491.048	
LL(β)	-12503.520	
ρ^2	0.4045	
$\bar{\rho}^2$	0.4041	
2[LL(β)-LL(0)]	16985.702	
2[LL(β)-LL(c)]	3975.056	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

The Log-likelihood at Constant, *LL(*c*)* and Log-likelihood at Zero, *LL(0)* also present reasonable results in terms of magnitude and signs. The value of Likelihood Ratio, 2[LL(β)-LL(0)], is 16985.702, which indicates that we can reject the null hypothesis that all the parameters are zero at the 0.01 level of significance; a 2[LL(β)-LL(c)] value of 3975.056, indicating that the null hypothesis can also be rejected at the 0.01 level of significance.

As expected the *LL(0) and LL(c)* are similar for that of MNL model (for HBW trips) presented earlier since same data set was used for both of the analyses.

❖ **NL Model for Home-Based Education (HBE) Trips**

The same model structure like HBW trips are developed and accepted for HBE trips as this structure (Figure 5-4) suited the model best for the said trip purposes. The estimated results are presented in Table 5-7. Going over the parameters of the model, the estimated coefficients on the TIME and COST variables have the expected negative signs as well and they satisfactorily passed the 0.01 level of significance. The statistical measures (Goodness of fit measures) of the models show good performance over MNL model developed for HBW trips.

For the alternative specific constants of the modes, the mode constants for walk only passed the 0.01 level of significance. The t-values of NL model for HBE trips are smaller than that of MNL model.

Considering the statistical measures of the model for HBE Trips, the obtained Log-likelihood at Convergence, *LL(*β*)* is -7665.632 shows better performance over that of MNL model. The value of a Rho-squared, ρ^2 is 0.4229 and an Adjusted Rho-squared, $\overline{\rho}^2$ is 0.4223 are also better than that of MNL model for HBW Trips. The Log-likelihood at Constant, *LL(*c*)* and Log-likelihood at Zero, *LL(0)* also present reasonable results in terms of magnitude and signs. The corresponding values of Likelihood Ratios, 2[LL(β)-LL(0)] and 2[LL(β)-LL(c)] indicate that the null hypothesis can also be rejected at the 0.01 level of significance.

Table 5-7: The Estimated Parameters of NL Model for HBE Trips

Variables	RUM2	
	Coefficient	t-value
TIME	-.16653***	-24.716
COST	-.01603***	-11.779
Mode Constants		
Auto/ Private car (Base)	0	
Transit (Buses)	3.07375	.530
Rickshaws	1.92797	.333
Taxi	-9.16494	-.730
CNG (Auto-rickshaw)	-3.47489	-.417
Motor Cycle	-27.99720	-.385
Walk	-27.11387***	-4.077
IV Parameter, μ (j|i), γ(i)		
PMV	14.51736	0.369
HMV	3.22314	1.130
NMV	19.32899***	12.233
Goodness of Fit Measures		
LL(0)	-13282.783	
LL(c)	-8800.882	
LL(β)	-7665.632	
ρ^2	0.4229	
$\bar{\rho}^2$	0.4223	
2[LL(β)-LL(0)]	11234.302	
2[LL(β)-LL(c)]	2270.500	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

As expected the *LL(0) and LL(c)* are similar for that of MNL model (for HBE trips) presented earlier since same data set was used for both of the analyses.

❖ NL Model for Home-Based Others (HBO) Trips

The tree structure for home-based others trips are shown in Figure 5-5. In this case, the travel market of Dhaka has been segmented into four parts: (1) people who have household-owned private vehicles such as private car and motor cycle; (2) people who travel by motorized vehicles but have no household-owned private vehicles and they travel mainly by taxi, CNG and transit/buses; (3) people who use non-motorized modes rickshaws; and (4) people of who live below poverty line and have no access to any sorts of vehicles and mainly travel by walking. The estimated model parameters for HBO trips are shown in Table 5-8.

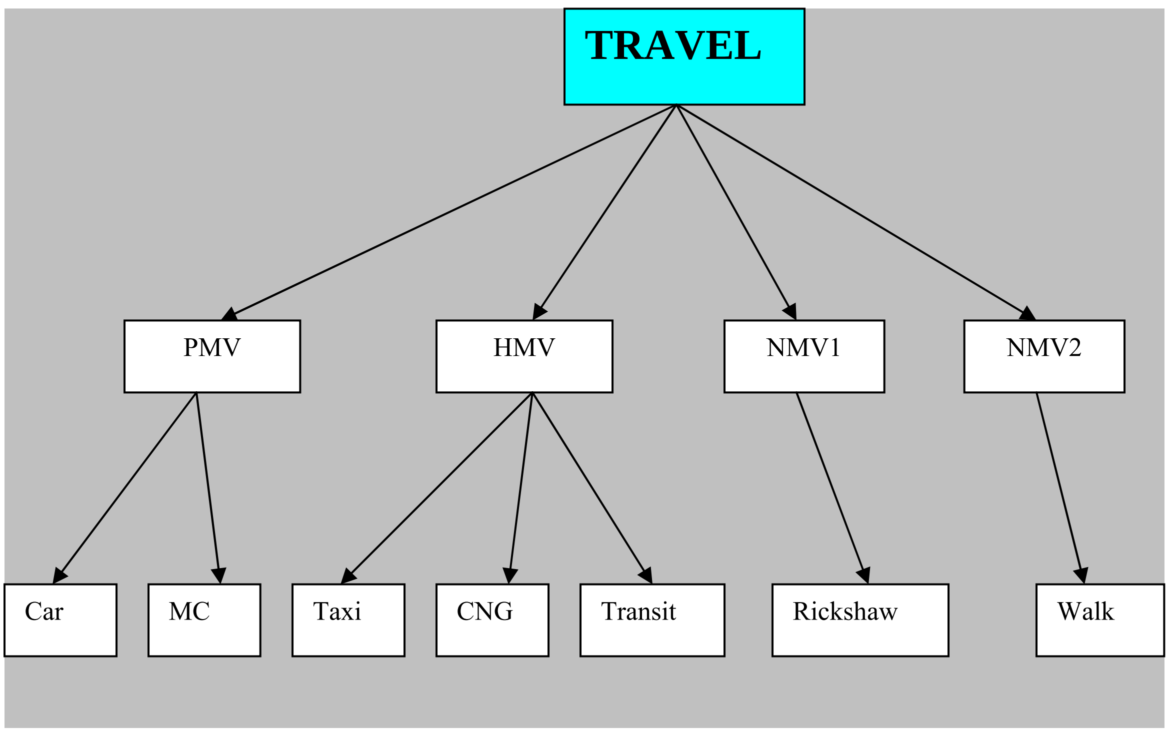


Figure 5-5: The Structure of NL Model for HBO Trips

Table 5-8: The Estimated Parameters of NL Model for HBO Trips

Variables	RUM2	
	Coefficient	t-value
TIME	-.16094***	-105.375
COST	-01127***	-20.608
Mode Constants		
Auto/ Private Car (Base)	0	
Transit (Buses)	-1.966783	-.679
Rickshaws	4.44104***	3.832
Taxi	-21.25598*	-1.733
CNG (Auto-rickshaw)	-8.90471*	-1.477
Motor Cycle	-23.95641	-.935
Walk	3.78653***	3.256
IV Parameter, μ (j|i), γ(i)		
PMV	10.11418	.886
HMV	10.04782**	1.966
NMV1	1 (degenerated)	
NMV2	1 (degenerated)	
Goodness of Fit Measures		
LL(0)	-25619.853	
LL(c)	-18864.121	
LL(β)	-16656.240	
ρ^2	.3499	
$\bar{\rho}^2$	.3496	
2[LL(β)-LL(0)]	17927.226	
2[LL(β)-LL(c)]	4415.762	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

- **NL Model for Non-Home-Based (NHB) Trips**

The non-home-based trips (mainly from office to some non-home destinations) of Dhaka city may be represented by Figure 5-6 which segments the NHB travel market of Dhaka City into three parts: (1) people those who use motorized modes (MV) of transports for their trip making mainly for distance travel; (2) people who use non-motorized mode rickshaws; and (3) those who prefer to travel nearby places on foot or who are compelled to walk for some constraints. The first subset combines different motorized transport of Dhaka, namely car, motor cycle, taxi, CNG and transit or buses.

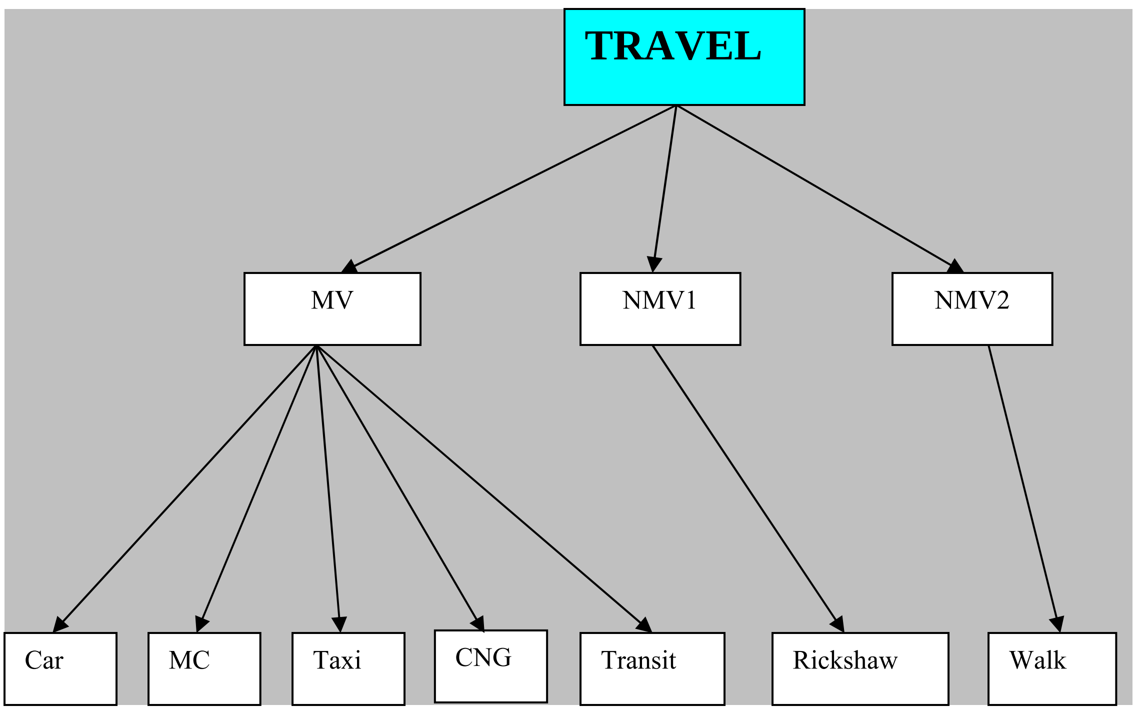


Figure 5-6: The Structure of NL Model for NHB Trips

The important variables of the utility equations as well as the statistical measures of the model developed for NHB trips are given in Table 5-9.

Table 5-9: The Estimated Parameters of NL Model for NHB Trips

Variables	RUM 2	
	Coefficient	t-value
TIME	-0.11757***	-18.233
COST	-0.06328***	-3.690
Mode Constants		
Auto/ Private Car (Base)	0	
Transit (Buses)	22.41737***	2.639
Rickshaws	32.17632***	2.737
Taxi	-20.70532***	-2.908
CNG (Auto-rickshaw)	-1.54163	-1.010
Motor Cycle	-23.08691***	-2.979
Walk	31.23681***	2.679
IV Parameter, μ (j|i), γ(i)		
MV	17.93712***	2.860
NMV1	1 (degenerated)	
NMV2	1 (degenerated)	
Goodness of Fit Measures		
LL(0)	-6771.767	
LL(c)	-5218.280	
LL(β)	-4933.779	
ρ^2	0.2714	
$\bar{\rho}^2$	0.2702	
2[LL(β)-LL(0)]	3675.976	
2[LL(β)-LL(c)]	569.002	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

5.2.6 Modeling the Effects of Exogenous Variables on Mode Choice

5.2.6.1 Overview

From the review of the literature, it is evident that personal characteristics, household attributes and the characteristics of the places where people live, work and travel have a strong relationship with modal choice. The purpose of the trip undertaken also influences modal choice. We decided to estimate separate four multinomial logistic regression models for the four trip purposes distinguished. But at the very beginning, we present some cross-tabulations of modal choice with each of the determinants considered.

Figure 3-2 described in Section 3.4.2 of Chapter 3 summarizes the factors in this analysis which are related to travel behavior and the selection of variables used. In this analysis, we use seven main transport modes (private car, motor cycle, taxi, CNG, transit/buses, rickshaws and walking) for trips undertaken as well. The personal/household attributes are operationalized first by the HH type to which a person belongs. This typology of HH is based on four characteristics: the size of the HH, the number of workers in the HH, the number of students in the HH and finally the HH Income level. One of the most important variable in travel behavior analysis studies, the car ownership, has not been considered in this current study as the level of car ownership in Dhaka is very low and many car users use official cars which does not stand for the actual representation.

5.2.6.2 Descriptive Analysis

There are clear relationship of modal split with personal attributes (such as sex, age, education etc.), type of household (HH Size, number of workers and students in the HH, HH Income etc.) and places of origin and destination. In Dhaka city, considering the inter-zonal trips, majority of person trips (especially for HBW, HBO and NHB Trips) are carried out by buses followed by rickshaws and buses provide basic transport services for over 44% of all trip purposes. Private cars have around 6% shares of all trips, whereas walking shares around 4% of all inter zonal trips. Rickshaws have maximum shares for HBE trips and they shares around 30% of total trips (Table B-12 in Appendix-B).

Residential environment also seems to influence the use of the different travel modes (Table B-12 in Appendix-B). Income level has always very strong influence on modal choices and also the choices of residential locations. Although the car ownership rate is very low in Dhaka City comparatively other big cities of the world, people of affluent society and living in well-planned areas have great tendency (as high as 76%) in using private car for all trip purposes. Relatively few trips by private car are undertaken by those living in CBD areas although having high level of income. People of higher income groups who live in CBD and older Dhaka prefer rickshaws than those of other areas. Affluent people of sub-urban areas (say, Uttara) have higher inclination to use public transit (buses) for their trips as the existing road-networks and public transport facilities of these areas are comparatively better.

In Dhaka city, people have very low access to private car as mentioned earlier, and majority of people are captive users to public transit, rickshaws or other transports although the level of service of these conventional modes of transport is highly questionable. Majority of people (except those who have high level of income) have to prefer either buses or rickshaws for their travel for all trip purposes. People living in suburban areas prefer buses over people of other residential areas irrespective of income level. Rickshaws are highly popular in high densely older part of the city and also around CBD areas. The observed shares of travel by different modes of transport are shown in Figure A-20 (Appendix-A).

5.2.6.3 Multinomial Logistic Regression

The Multinomial Logistic Regression (MLR) is the extension for the Logistic (binomial) Regression. Binomial (or binary) logistic regression is a form of regression which is used when the dependent is a dichotomy and the independents are of any type. MLR exists to handle the case of dependents with more classes than two, though it is sometimes used for binary dependents also since it generates somewhat different output. The most statistical output for multinomial logistic regression, the "parameter estimate" is the 'b' coefficient used to predict the log odds (logit) of the dependent variable. Let z be the logit for a dependent variable, then the logistic prediction equation is:

$$z = \ln(odds(event)) = \ln\frac{prob(event)}{prob(nonevent)} = \ln\frac{prob(event)}{1 - prob(event)}$$
$$= b_0 + b_1 X_1 + b_2 X_2 + \dots\dots\dots\dots\dots\dots + b_k X_k$$

where b_0 is the constant and there are k independent (X) variables.

In contrast to exp(z), exp(b) is the odds ratio. The odds ratio is the natural log base, e, to the exponent, b, where b = the parameter estimate. The b coefficients vary between plus and minus infinity, with 0 indicating the given explanatory variable does not affect the logit (that is, makes no difference in the probability of the dependent value equaling the value of the event, usually 1); positive or negative b coefficients indicate the explanatory variable increases or decreases the logit of the dependent. An Exp(b)>1 means the independent variable increases the logit and therefore increases odds(event). If Exp(b) = 1.0, the independent variable has no effect. If Exp(b) is less than 1.0, then the independent variable decreases the logit and decreases odds(event).

5.2.6.4 Model Estimation

Up to this point in the analysis, we considered all possible exogenous variables described earlier to examine their effects on modal choices. The dependent variable 'main travel mode' consists of seven categories: private car, motor cycle, taxi, CNG, transit/buses, rickshaws and walking. In case of urban form measures, we took the place of origin of a trip as variable to measure spatial environments for each model instead of residential environments to understand the influence of urban forms of both ends of a trip. Because, one way journey was considered here as a trip and thus the variable 'origin' represent the spatial characteristics of both end places of a journey (as for example, it represent residential environment in case of the journey from home to office and consequently represent the characteristics of work place for return journey from office to home). The set of independent variables in each of the models is the same, permitting comparisons across the models.

In that light, we now present four multinomial logistic regression models, one for each trip purpose (Tables 5-10 to 5-13). In each of the models, we took the use of private car as the reference category; the parameters estimated here express all modes relative to the use of private car. For example, in the first model for walking (Table 5-10), the parameter B of 4.593 (LIG in HH Income sub-group) indicates a sharp increase in the likelihood of using that mode relative to private car of the people of that sub-group than those of HIG. In case of Transit of the same model (Table 5-10), the parameter B of -0.421 for female (sex) indicates that female are relatively reluctant in using public transit buses for their HBW trips than those of male. The odds ratio expresses the effect of the independent variable on the likelihood of using that mode of transport in comparison to the likelihood of using the reference transport mode. For instant, the ratio of 1.172 for unplanned high densely older part (in spatial environments sub-group) in case of rickshaws of the same model (Table 5-10) indicates that people at that place of origin are 1.172 times more likely to use Rickshaws than people of CBD-Core relative to private car. The chi-squared statistics provides an indication of the relative weight of that variable in the model. Because this is a regression model, in the comparison, the influences of income, household size, person's age, education, number of workers and students in household are also taken into account for each of the four cases.

Among the household attributes, household income has the strongest relationship with modal choice. Having higher income strongly reduces the propensity to use public transport. Household size and number of workers as well as students in household are also important determinant of modal choice although household size and level of education show somewhat ambiguous relationship with modal choice in some cases. Those with a lower level of education are more likely to use public transport buses, rickshaws and walking, while personalized motorized vehicles are more likely among those with a higher education (Table 5-10). The personal attribute, sex has also very strong influence on modal choices. Women are likely to avoid public transport buses for their lower standard service level. Women also strongly disagree in using motor cycle for making trips (Table 5-10).

Even after compensating for personal and household attributes (as in Table 5-10), the influence of spatial environments at origin (either residential location or workplace/destination place) on modal choice for all trip purposes remains high. In fact, after income level, this variable shows the highest correlation with modal choice. Evidently, the properties of the spatial environment, especially the residential environment (density, diversity, provision of suitable public transport services, all linked to the categories distinguished) have an independent effect on modal choice. Car use is fairly low with respect to public transport in sub-urban areas (like Planned: Type 2) although having high income of those people.

In all four models, the independent variables have a clear and (fairly) strong relationship to modal choice (Tables 5-10 to 5-13). As indicated by the pseudo R-square statistics- Nagelkerke's ρ^2- the models explain a fair share of the variation in mode choice, although the largest part remains unexplained. Almost all important parameters for each of the four models (except the cases of Taxi for each model) are significant.

Table 5-10: Multinomial Logistic Regression Model for HBW Trips

Parameter Estimates	Walk		Rickshaw		Transit		CNG		Taxi		Motor Cycle		Chi-Square
	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	
Individual Sociodemographics													
Female (Ref.=Male)	0.055	0.947	0.079	1.083	-0.421***	0.656	0.01	1.01	-0.552**	0.576	-1.603***	0.201	83.37***
Age	-0.058***	0.944	-0.045***	0.956	-0.04***	0.96	-0.039***	0.962	-0.024***	0.976	-0.055***	0.946	146.86***
Education (Ref.=Higher Level)													514.62***
Lower Level	2.812***	16.647	1.446***	4.246	1.401***	4.059	-0.16	0.852	0.127	1.135	0.091	1.096	
Medium, Lower	1.887***	6.599	1.538***	4.653	1.335***	3.799	0.826***	2.285	0.531**	1.7	0.741***	2.099	
Medium, Higher	0.882***	2.415	0.871***	2.388	0.935***	2.547	0.586***	1.796	0.712***	2.038	0.819***	2.268	
HH Size (Ref.<=2)													62.56***
HH_Size=3.00	0.813***	2.255	0.608**	1.837	0.541**	1.718	0.192	1.212	0.388	1.474	0.365	1.44	
HH_Size=4.00	0.421	1.523	0.258	1.294	0.071	1.073	-0.529*	0.589	-0.703*	0.495	-0.145	0.865	
HH_Size=5.00	0.527*	1.694	0.427*	1.533	0.111	1.117	-0.272	0.762	-0.359	0.699	-0.48	0.619	
HH_Size >= 6	0.517	1.678	0.343	1.409	-0.062	0.94	-0.407	0.665	-0.938*	0.392	-0.012	0.988	
# workers in HH	0.554***	1.741	0.129**	1.138	0.273***	1.314	0.058	1.06	0.082	1.085	0.287***	1.332	92.25***
# students in HH	0.005	1.005	0.055	1.056	0.071	1.074	0.106	1.112	0.08	1.083	-0.053	0.949	5.25
HH Income (Ref.=HIG)													1238.83***
LIG	4.593***	98.836	3.091***	21.997	3.664***	39.031	1.083***	2.952	-0.545*	0.58	3.52***	33.78	
LMIG	3.058***	21.28	2.744***	15.542	3.134***	22.956	1.031***	2.803	-0.478*	0.62	3.348***	28.433	
HMIG	1.064***	2.897	1.331***	3.786	1.594***	4.926	0.768***	2.155	-0.22	0.803	2.55***	12.809	
Types of Urban Forms													
Spatial Environments at Origin (Ref.=CBD-Core)													1096.67***
CBD-Mixed	0.35*	1.42	-0.281**	0.755	-0.076	0.927	0.259*	1.295	0.021	1.022	0.174	1.191	
Unplanned High Densely Older Part	0.386	1.471	1.172***	3.229	0.205	1.227	0.915***	2.497	-0.205	0.815	1.203***	3.33	
Planned: Type 1	-1.392***	0.249	-1.943***	0.143	-0.357**	0.699	0.07	1.073	0.65**	1.916	-0.723**	0.485	
Planned: Type 2	-1.846***	0.158	-3.543***	0.029	0.107	1.113	-1.414***	0.243	0.328	1.388	-0.431	0.65	
Planned: Type 3	0.591***	1.806	-0.171	0.843	0.489***	1.631	0.378*	1.46	0.67**	1.954	0.265	1.303	
Western Fringe: Unplanned Mixed 1	1.059***	2.884	-0.021	0.979	-0.209	0.812	0.076	1.079	-0.105	0.9	0.115	1.122	
Eastern Fringe: Unplanned Mixed 2	0.193	1.212	0.609***	1.838	0.897***	2.452	0.533**	1.704	0.308	1.361	1.044***	2.841	
Constant	-3.784***		-0.14		-0.081		0.304		-0.393		-2.235***		

*α = 0.1
**α = 0.05
***α = 0.01

The reference category : Private Car

-2 Log Likelihood

Null Model	:	27528.29
Final Model	:	23451.59
Chi-square	:	4076.69***
Nagelkerke R-Square	:	0.338

Table 5-11: Multinomial Logistic Regression Model for HBE Trips

Parameter Estimates	Walk		Rickshaw		Transit		CNG		Taxi		Motor Cycle		Chi-Square
	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	
Individual Sociodemographics													
Female (Ref.=Male)	-0.447***	0.639	-0.08	0.923	-0.908***	0.403	-0.082	0.922	-0.085	0.918	-1.861***	0.156	253.62***
Age	-0.034***	0.967	-0.019***	0.981	-0.03***	0.97	-0.014**	0.986	-0.036*	0.965	0.055***	1.057	57.16***
Education (Ref.=Higher Level)													368.69***
Lower Level	0.268	1.308	0.032	1.032	-0.624**	0.536	-1.293***	0.274	-1.977***	0.139	-0.421	0.656	
Medium, Lower	0.053	1.054	0.444*	1.559	0.725***	2.065	-0.617**	0.54	-1.176**	0.309	-0.463	0.63	
Medium, Higher	-0.593	0.552	0.24	1.271	0.846***	2.331	0.076	1.079	-1.174*	0.309	0.436	1.547	
Household Sociodemographics													
HH Size (Ref.<=3)													75.75***
HH_Size=4.00	0.691**	1.995	0.428*	1.534	0.227	1.254	0.19	1.209	0.44	1.553	1.531*	4.625	
HH_Size=5.00	0.657**	1.929	0.274	1.315	-0.047	0.954	-0.449	0.638	-0.715	0.489	0.743	2.102	
HH_Size>=6	1.461***	4.31	0.706**	2.026	0.206	1.229	-0.283	0.753	-1.269	0.281	-1.217	0.296	
# workers in HH	0.092	1.096	-0.106	0.899	0.156*	1.169	0.177*	1.194	-0.538**	0.584	-0.022	0.978	50.11***
# students in HH	0.021	1.021	0.047	1.048	0.185**	1.203	0.228**	1.257	-0.2	0.819	0.403*	1.496	19.68***
HH Income (Ref.=HIG)													768.26***
LIG	5.439***	230.106	3.478***	32.411	3.815***	45.37	1.432***	4.186	-0.204	0.816	2.254***	9.527	
LMIG	4.165***	64.397	2.911***	18.381	3.267***	26.221	1.471***	4.352	-1.836*	0.159	2.263***	9.616	
HMIG	1.556***	4.742	1.38***	3.975	1.736***	5.672	0.978***	2.66	0.491	1.634	0.849	2.338	
Types of Urban Forms													
Spatial Environments at Origin (Ref.=CBD-Core)													471.54***
CBD-Mixed	-0.849***	0.428	-0.713***	0.49	-0.298	0.742	-0.16	0.852	-0.011	0.989	-0.315	0.73	
Unplanned High Densely Older Part	-0.472	0.624	0.134	1.144	-0.045	0.956	-0.254	0.776	0.278	1.32	0.251	1.286	
Planned: Type 1	-2.838***	0.059	-2.28***	0.102	-0.627**	0.534	-0.503*	0.604	0.45	1.569	-1.427	0.24	
Planned: Type 2	0.043	1.044	-0.984*	0.374	0.904*	2.47	0.156	1.169	1.411*	4.101	0.025	1.025	
Planned: Type 3	-0.276	0.759	-0.778***	0.459	-0.081	0.923	-0.318	0.728	0.571	1.771	0.108	1.114	
Western Fringe: Unplanned Mixed 1	-0.18	0.836	-0.611***	0.543	-1.024***	0.359	-0.716**	0.489	-1.071	0.343	0.319	1.375	
Eastern Fringe: Unplanned Mixed 2	-0.057	0.945	0.203	1.226	0.667**	1.948	-0.136	0.873	-1.162	0.313	-0.119	0.888	
Constant	-2.706***		0.574		0.175		-0.151		1.268		-5.018***		

*α = 0.1
**α = 0.05
***α = 0.01

The reference category : Private Car

-2 Log Likelihood		
Null Model	:	16692.73
Final Model	:	14369.25
Chi-square	:	2323.48***
Nagelkerke R-Square	:	0.312

Table 5-12: Multinomial Logistic Regression Model for HBO Trips

Parameter Estimates	Walk		Rickshaw		Transit		CNG		Taxi		Motor Cycle		Chi-Square
	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	
Individual Sociodemographics													
Female (Ref.=Male)	-1.377***	0.252	-0.294***	0.745	-1.117***	0.327	0.23**	1.259	0.194*	1.215	-2.216***	0.109	795.73***
Age	-0.023***	0.977	-0.023***	0.977	-0.032***	0.969	-0.013***	0.987	-0.01**	0.99	-0.031***	0.97	165.68***
Education (Ref.=Higher Level)													243.40***
Lower Level	1.588***	4.892	1.172***	3.227	1.452***	4.272	0.947***	2.578	0.435**	1.545	-1.665**	0.189	
Medium, Lower	1.125***	3.081	1.018***	2.768	1.053***	2.866	0.951***	2.589	0.682***	1.977	-0.473	0.623	
Medium, Higher	0.482	1.619	0.726***	2.067	0.626***	1.871	0.757***	2.132	0.545***	1.725	0.591*	1.806	
Household Sociodemographics													
HH Size (Ref.<=2)													111.70***
HH_Size=3.00	0.023	1.023	0.248	1.281	0.191	1.21	0.243	1.276	0.557*	1.746	0.364	1.44	
HH_Size=4.00	-1.248***	0.287	-0.61**	0.543	-0.479*	0.62	-0.603**	0.547	-0.543*	0.581	-1.608**	0.2	
HH_Size=5.00	-1.214***	0.297	-0.322	0.725	-0.284	0.753	-0.374	0.688	-0.066	0.937	-1.463**	0.231	
HH_Size >= 6	-0.111	0.895	0.274	1.315	0.239	1.27	0.151	1.163	-0.04	0.961	-1.254	0.285	
# workers in HH	0.273***	1.314	0.248***	1.282	0.286***	1.33	0.112*	1.118	0.01	1.01	0.235	1.264	55.91***
# students in HH	0.14	1.151	-0.104*	0.901	-0.126**	0.881	-0.129**	0.879	-0.223***	0.8	-0.005	0.995	20.00***
HH Income (Ref.=HIG)													1409.75***
LIG	5.667***	289.128	4.517***	91.573	5.367***	214.157	3.634***	37.849	2.317***	10.148	3.484***	32.579	
LMIG	3.888***	48.79	3.54***	34.48	4.019***	55.649	2.694***	14.793	1.899***	6.68	1.39*	4.014	
HMIG	1.536**	4.645	1.602***	4.964	1.966***	7.144	1.316***	3.727	0.897***	2.452	2.179***	8.834	
Types of Urban Forms													
Spatial Environments at Origin (Ref.=CBD-Core)													1031.92****
CBD-Mixed	-0.266	0.767	-0.823***	0.439	-0.214	0.807	0.082	1.085	0.072	1.075	-0.392	0.676	
Unplanned High Densely Older Part	-0.291	0.748	0.202	1.224	-0.008	0.992	-0.058	0.944	-0.506*	0.603	0.58	1.785	
Planned: Type 1	-1.16**	0.313	-2.047***	0.129	-0.761***	0.467	-0.312	0.732	-0.563**	0.569	-0.328	0.72	
Planned: Type 2	-0.795*	0.452	-2.29***	0.101	0.009	1.009	-0.511**	0.6	0.918***	2.505	-0.422	0.655	
Planned: Type 3	0.573*	1.774	-0.06	0.942	0.741***	2.097	0.398**	1.489	0.611***	1.842	1.279**	3.593	
Western Fringe: Unplanned Mixed 1	1.192***	3.295	-0.256	0.774	-0.222	0.801	0.163	1.178	-0.107	0.898	0.123	1.131	
Eastern Fringe: Unplanned Mixed 2	0.008	1.008	0.326*	1.386	0.895***	2.447	0.329*	1.39	0.449*	1.567	0.564	1.758	
Constant	-3.626***		-0.021		-0.355		-0.559		-0.817*		-1.739*		

*α = 0.1
**α = 0.05
***α = 0.01

The reference category : Private Car

-2 Log Likelihood		
Null Model	:	35806.56
Final Model	:	31581.89
Chi-square	:	4224.67
Nagelkerke R-Square	:	0.291

Table 5-13: Multinomial Logistic Regression Model for NHB Trips

Parameter Estimates	Walk		Rickshaw		Transit		CNG		Taxi		Motor Cycle		Chi-Square
	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	B	Odds ratio	
Individual Sociodemographics													
Female (Ref.=Male)	-0.297	0.743	0.517***	1.678	-0.762***	0.467	0.408**	1.504	0.035	1.036	-1.467***	0.231	132.96***
Age	-0.037***	0.963	-0.037***	0.963	-0.036***	0.965	-0.018***	0.982	-0.029***	0.971	-0.024***	0.976	58.19***
Education (Ref.=Higher Level)													81.17***
Lower Level	0.83**	2.294	0.466**	1.594	0.837***	2.308	0.333	1.395	-0.464	0.629	-1.031**	0.357	
Medium, Lower	0.401	1.493	0.708***	2.03	0.788***	2.199	0.56***	1.75	-0.254	0.776	0.402	1.494	
Medium, Higher	0.136	1.145	0.488***	1.629	0.601***	1.825	0.532***	1.702	0.379*	1.461	0.557**	1.745	
Household Sociodemographics													
HH Size (Ref.<=2)													28.64
HH_Size=3.00	0.718	2.051	0.065	1.067	0.399	1.49	0.432	1.54	0.426	1.531	-0.29	0.748	
HH_Size=4.00	0.236	1.266	0.063	1.065	0.16	1.174	0.371	1.449	0.287	1.333	-0.234	0.791	
HH_Size=5.00	0.18	1.198	-0.234	0.791	0.058	1.06	0.436	1.547	0.826*	2.283	0.167	1.182	
HH_Size >= 6	-0.262	0.769	-0.028	0.972	0.213	1.237	0.506	1.658	0.927*	2.526	0.115	1.122	
# workers in HH	0.34**	1.405	0.087	1.09	0.061	1.063	-0.118	0.889	-0.543***	0.581	-0.137	0.872	36.53***
# students in HH	0.137	1.147	-0.061	0.941	-0.101	0.904	-0.259***	0.772	-0.377***	0.686	-0.347**	0.707	19.46***
HH Income (Ref.=HIG)													351.78***
LIG	2.958***	19.26	1.796***	6.027	2.619***	13.717	0.3	1.35	-1.446***	0.235	1.586***	4.884	
LMIG	2.443***	11.509	2.171***	8.767	2.624***	13.789	0.912***	2.489	-0.99***	0.371	1.488***	4.43	
HMIG	1.341*	3.822	1.238***	3.449	1.618***	5.045	0.684***	1.982	-0.028	0.972	1.235***	3.438	
Types of Urban Forms													
Spatial Environments at Origin (Ref.=CBD-Core)													269.68***
CBD-Mixed	0.022	1.022	-0.493***	0.611	-0.294*	0.745	0.045	1.046	0.079	1.082	-0.157	0.855	
Unplanned High Densely Older Part	0.792*	2.208	1.123***	3.073	0.437	1.549	0.846***	2.331	-0.935	0.392	0.29	1.337	
Planned: Type 1	-1.35**	0.259	-2.32***	0.098	-0.557***	0.573	-0.542**	0.581	-0.256	0.774	-0.428	0.652	
Planned: Type 2	-1.611*	0.2	-2.735***	0.065	-0.425*	0.654	-2.74***	0.065	-0.299	0.741	-0.394	0.674	
Planned: Type 3	0.306	1.358	-0.607**	0.545	-0.11	0.896	-0.019	0.981	-0.313	0.731	-0.188	0.829	
Western Fringe: Unplanned Mixed 1	0.494	1.639	-0.392*	0.676	-0.372*	0.69	-0.232	0.793	-0.528	0.59	0.156	1.169	
Eastern Fringe: Unplanned Mixed 2	-1.996*	0.136	-0.39	0.677	0.077	1.08	-0.111	0.895	-0.091	0.913	0.36	1.434	
Constant	-3.55***		0.459		0.322		0.046		1.461**		-0.646		

*α = 0.1
**α = 0.05
***α = 0.01

The reference category : Private Car

-2 Log Likelihood		
Null Model	:	10174.15
Final Model	:	9066.41
Chi-square	:	1107.75***
Nagelkerke R-Square	:	0.287

5.3 Development of Trip Frequency Model

5.3.1 Overview

Measures of travel behavior that have been studied in the US and other developed countries include trip time, trip length, mode choice, trip frequency and route choice (Srinivasan, 2005). To understand the determinants of travel behavior, like mode choice models, discrete choice models were estimated for trip frequency models. The trip frequency model is estimated as a binary choice model between less than or average number of trips versus more than average number of trips (per person and per household). In this section, we analyze the number of trips or frequency of trips made by individual or household under existing socioeconomic and spatial characteristics of Dhaka City. But first of all, we present some figures based on Multiple-Classification Analysis (MCA) to describe the trip rates against some important variables used in the trip frequency model; and then we give four binary choice models, one for each of the trip purposes as mentioned earlier.

5.3.2 Descriptive Analyses

According to the STP HIS (2005) report, each household makes 8.5 trips per day for all purposes. HBW constitutes 2.74 trips whereas HBE 1.11 trips, HBO (including shopping, medical and social) 3.9 trips and NHB travel 0.75 trips. The rate of trips varies according to the income classification of people. The low-income group generally makes lesser trip than high-income groups. Modal distribution of HH trips shows that 1.22 trips are made by walking, 2.90 trips are made by rickshaw, 3.71 trips are made by transit and 0.67 trips are made by non-transit modes. We now present some travel trip information (by graphical presentation) based on full data set (including intra & inter-zonal data).

Trip frequency or the number of trips per person (or per household) per day is highly influenced by the socioeconomic characteristics and spatial environments. Personal attributes like sex, age, education and profession have fairly strong relationship in making the number of trips per day. Women are likely to make fewer trips (especially work trips and non-home based trips) than men. But they have a tendency to make higher number of home-based other types of trips (mainly shopping trips) and also higher number of education trips (Figure 5-7).

Household attributes like household size, income and number of women, workers or students in household have strong influence on making total number of trips per household (Figures 5-8 to 5-13). Household size has certainly positive correlation with HH trip rates. Household with higher number of workers and students have very strong positive relationship of making higher number of HBW or HBE trips respectively (Figures 5-9 and 5-10). If the number of women/household decreases, the trip rates also decreases except the cases of HBO and NHB trips (Figures 5-11). People with higher income make more trips with some variations in the cases of HBE and HBO trips as well (Figures 5-12). Residential location has very strong influence on trip rates per household in all trip purposes (Figure 5-13).

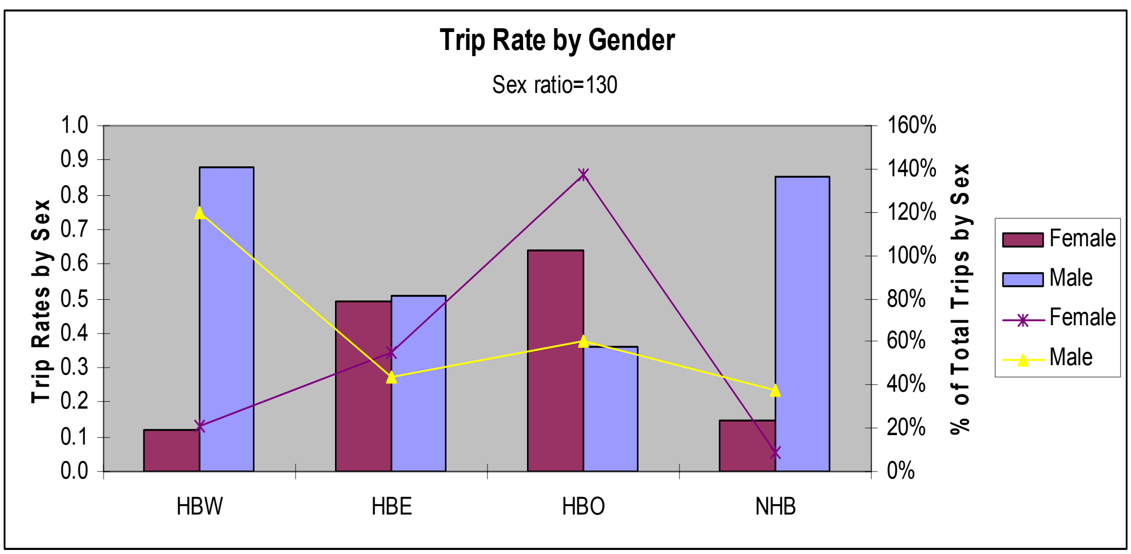
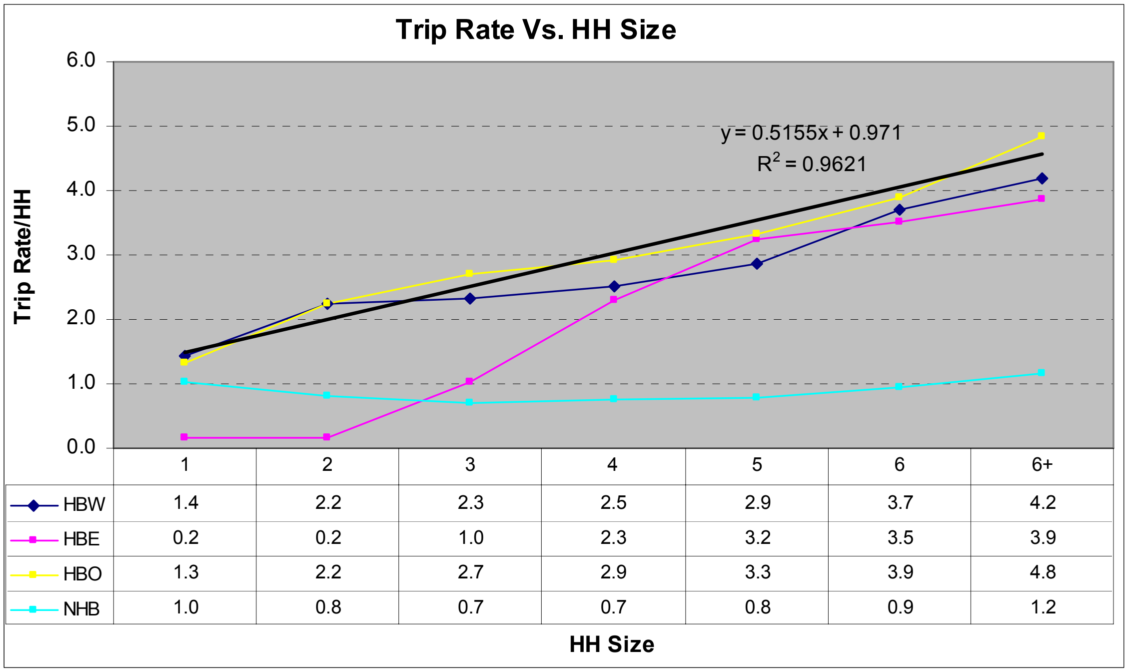
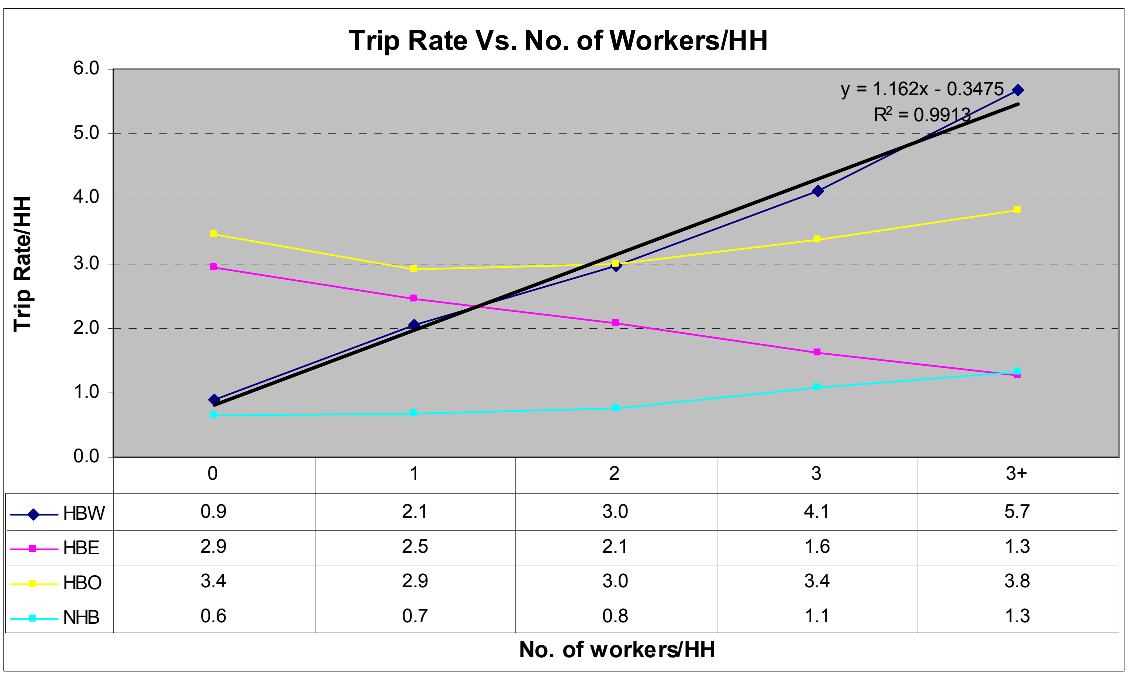


Figure 5-7: Variation of Person Trips by Gender



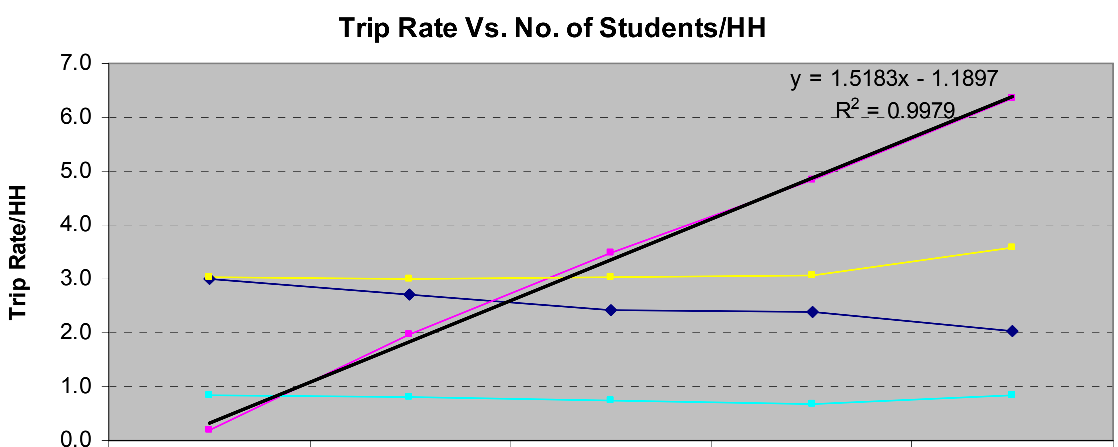
	1	2	3	4	5	6	6+
HBW	1.4	2.2	2.3	2.5	2.9	3.7	4.2
HBE	0.2	0.2	1.0	2.3	3.2	3.5	3.9
HBO	1.3	2.2	2.7	2.9	3.3	3.9	4.8
NHB	1.0	0.8	0.7	0.7	0.8	0.9	1.2

Figure 5-8: Variation of HH Trip Rates by HH Size



	0	1	2	3	3+
HBW	0.9	2.1	3.0	4.1	5.7
HBE	2.9	2.5	2.1	1.6	1.3
HBO	3.4	2.9	3.0	3.4	3.8
NHB	0.6	0.7	0.8	1.1	1.3

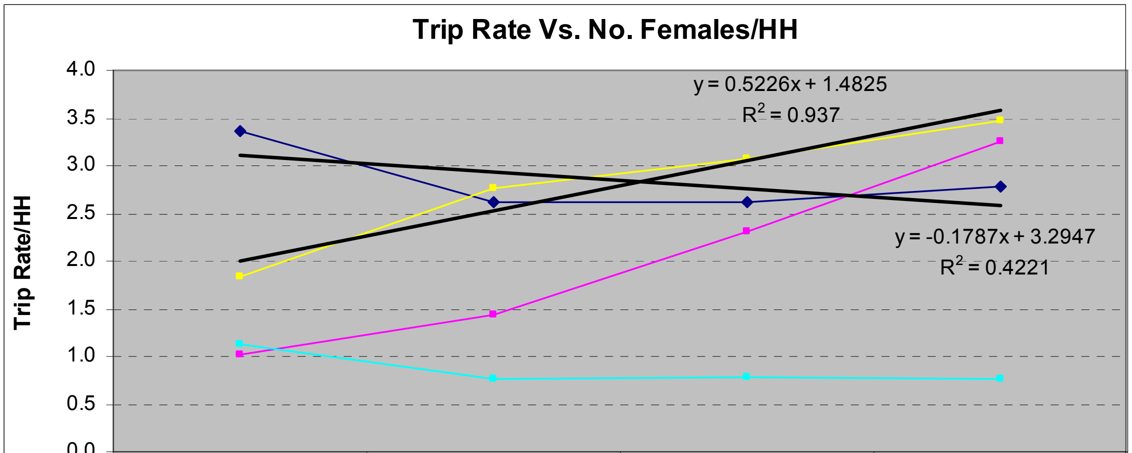
Figure 5-9: Variation of HH Trip Rates by No. of Workers in the HH



	0	1	2	3	3+
HBW	3.0	2.7	2.4	2.4	2.0
HBE	0.2	2.0	3.5	4.8	6.3
HBO	3.0	3.0	3.0	3.1	3.6
NHB	0.8	0.8	0.7	0.7	0.8

No. of students/HH

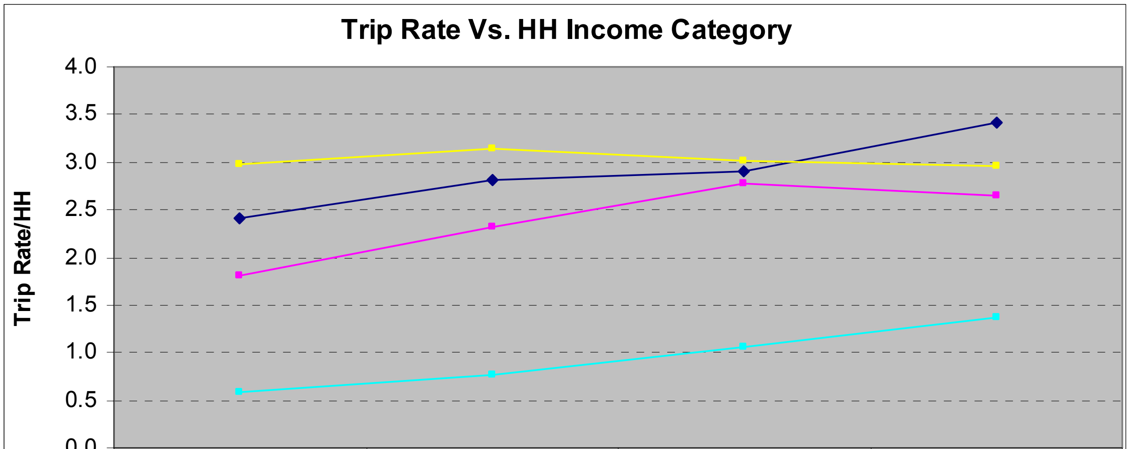
Figure 5-10: Variation of HH Trip Rates by No. of Students in the HH



	1	2	3	4
HBW	3.4	2.6	2.6	2.8
HBE	1.0	1.4	2.3	3.3
HBO	1.8	2.8	3.1	3.5
NHB	1.1	0.8	0.8	0.8

No. of Female/HH

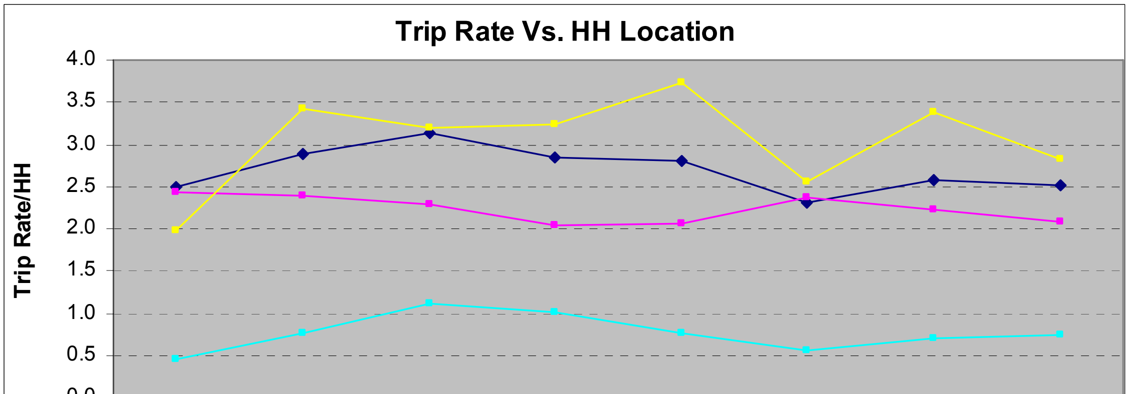
Figure 5-11: Variation of HH Trip Rates by No. of Women in the HH



	LIG	LMIG	HMIG	HIG
HBW	2.4	2.8	2.9	3.4
HBE	1.8	2.3	2.8	2.6
HBO	3.0	3.1	3.0	3.0
NHB	0.6	0.8	1.1	1.4

Income Group

Figure 5-12: Variation of HH Trip Rates by HH Income Level



	CBD-Core	Unplanned high densely older part	Western Fringe: Mixed 1	Planned: Type 3	Planned: Type 1	Planned: Type 2	Eastern Fringe: Mixed 2	CBD-Mixed
HBW	2.5	2.9	3.1	2.8	2.8	2.3	2.6	2.5
HBE	2.4	2.4	2.3	2.0	2.1	2.4	2.2	2.1
HBO	2.0	3.4	3.2	3.2	3.7	2.6	3.4	2.8
NHB	0.4	0.8	1.1	1.0	0.8	0.6	0.7	0.7

HH Region

Figure 5-13: Variation of HH Trip Rates by Residential Location

5.3.3 Binary Choice Models

A binary choice model is a regression model in which the dependent variable *Y* is a binary random variable that takes on only the values zero and one. In many economic applications of this model, an agent makes a choice between two alternatives: for example, a commuter chooses to drive a car to work or to take public transport. Another example is the choice of a worker between taking a job or not. Driving to work and taking a job are choices that correspond to $Y = 1$, and taking public transport and not taking a job to $Y = 0$. The model gives the probability that $Y = 1$ is chosen conditional on a set of explanatory variables. In the transportation example, common explanatory variables include the time and the cost of travel; in the worker example, common explanatory variables include age, education and experience. The econometric problem is to estimate the conditional probability that $Y = 1$ considered as a function of the explanatory variables. The most commonly used approach, notably logit and probit models, assumes that the functional form of the dependence on the explanatory variables is known. The logit and probit models have been used almost exclusively in econometric applications in the leading journals (Joel L. Horowitz and N.E. Savin , 2001).

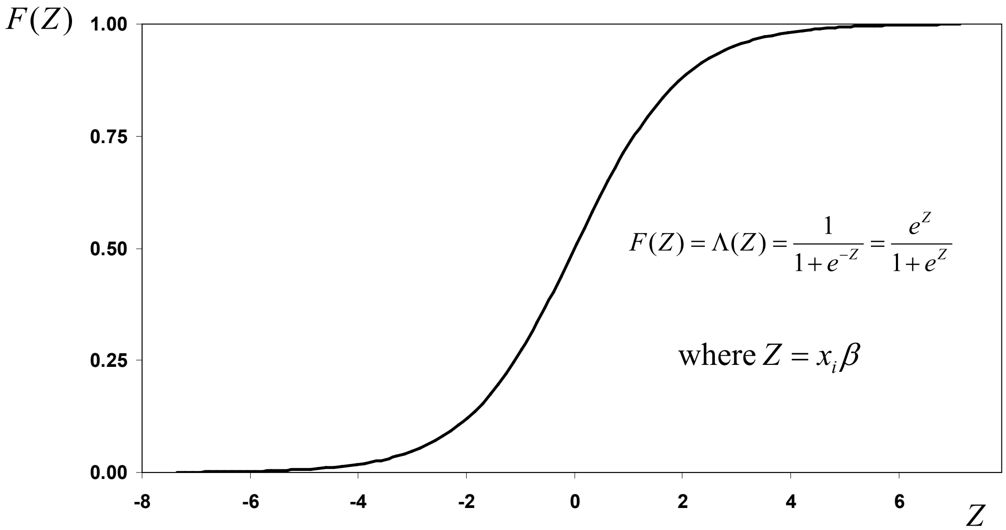
Discrete choice models (including binary models) are often expressed in terms of a latent variable approach. For example, consider the decision of an individual to vote. We can express this in terms of utility differences (y*): $y_i^* = x_i\beta + u$

where y* is an unobserved (latent) variable. Although we do not observe y*, we quite often observe a binary outcome: $y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \text{ if } y_i^* \leq 0 \end{cases}$

$$\begin{aligned} &P(y_i = 1) = P(y_i^* > 0) = P(x_i\beta + u > 0) \\ &\Rightarrow P(u > -x_i\beta) \\ &\Rightarrow 1 - F(-x_i\beta) \\ &\Rightarrow F(x_i\beta) \end{aligned}$$

This last step follows because we are assuming the distribution of u is symmetric. It also follows that

$$P(y_i = 0) = 1 - P(y_i = 1) = 1 - F(x_i\beta)$$



The usual way of avoiding this problem is to hypothesize that the probability is a sigmoid (*S*-shaped) function of *Z*, *F*(*Z*), where *Z* is a function of the explanatory variables. Several mathematical functions are sigmoid in character. One is the logistic function shown here. As *Z* goes to infinity, *e*-*Z* goes to 0 and *p* goes to 1 (but cannot exceed 1). As *Z* goes to minus infinity, *e*-*Z* goes to infinity and *p* goes to 0 (but cannot be below 0).

$$F(Z) = \Lambda(Z) = \frac{e^Z}{1+e^Z}$$

$$Z = x_i\beta$$

$$f(Z) = F'(Z) = \lambda(Z) = \frac{e^Z}{(1+e^Z)^2}$$

$$\frac{\partial P(y_i = 1)}{\partial x_j} = f(Z)\beta_j = \frac{e^Z}{(1+e^Z)^2}\beta_j$$

The marginal effect is not constant because it depends on the value of *Z*, which in turn depends on the values of the explanatory variables. A common procedure is to evaluate it for the sample means of the explanatory variables.

In addition to the logit another commonly used distribution is the probit. In the case of probit analysis, the sigmoid function is the cumulative standardized normal distribution.

$$F(Z) = \Phi(Z) = \int_{-\infty}^{Z} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}Z^2}$$

$$f(Z) = \phi(Z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}Z^2}$$

$$\frac{\partial P(y_i = 1)}{\partial x_j} = f(Z)\beta_j = \phi(Z)\beta_j$$

As with logit analysis, the marginal effects vary with *Z*.

Results are quite similar for both the logit and probit models although the logistic distribution has slightly fatter tails. Variance of the probit is 1 (standard normal distribution) and for the logit it is $\frac{\pi}{\sqrt{3}}$. Amemiya (1981) suggests the relationship between probit and logit models is as follows: $\beta_{probit} = 0.625\beta_{logit}$ and $\beta_{logit} = 1.6\beta_{probit}$

The logit and probit are non-linear and we will use logit for our analysis. Parameters can be estimated by maximum likelihood. To set this up suppose we have a random sample of n observations of the binary variable y. If the probability of success is the same for all observations, P(yi = 1) = p, then the probability distribution of the i-th observation is given by:

$$p^{y_i}(1-p)^{1-y_i}$$

If the observations are mutually independent, then the likelihood function is given by:

$$L(p) = \prod_{i=1}^{n} p^{y_i}(1-p)^{1-y_i}$$

The corresponding log-likelihood function is:

$$\log(L(p)) = \sum_{\{i;y_i=1\}} \log(p) + \sum_{\{i;y_i=0\}} \log(1-p)$$

$$= \sum_{i=1}^{n} y_i \log(p) + \sum_{i=1}^{n} (1-y_i)\log(1-p)$$

Now we assume the y observations are mutually independent but allow the probability of success to differ among the observations. Earlier we denoted that $F(x_i,\beta)$ using the latent variable framework. Clearly all observations follow the same function but there are differences in the values of the explanatory variables. In this case y_i follows a Bernoulli distribution with probability,

$$p_i = P[y_i = 1] = F(x_i\beta)$$

The probability distribution is given by:

$$p(y_i) = p_i^{y_i}(1-p_i)^{1-y_i}$$

The log-likelihood function is:

$$\begin{aligned}
\log(L(\beta)) &= \sum_{i=1}^{n} y_i \log(p_i) + \sum_{i=1}^{n}(1-y_i)\log(1-p_i) \\
&= \sum_{i=1}^{n} y_i \log(F(x_i\beta)) + \sum_{i=1}^{n}(1-y_i)\log(1-F(x_i\beta)) \\
&= \sum_{\{i;y_i=1\}} \log(F(x_i\beta)) + \sum_{\{i;y_i=0\}} \log(1-F(x_i\beta))
\end{aligned}$$

For the case of the logit, with F = Λ, we know from earlier:

$$F(Z) = \Lambda(Z) = \frac{e^Z}{1+e^Z}$$

Therefore the log-likelihood function for the logit is:

$$\begin{aligned}
\log(L(\beta)) &= \sum_{i=1}^{n} y_i \log(\Lambda(Z)) + \sum_{i=1}^{n}(1-y_i)\log(1-\Lambda(Z)) \\
&= \sum_{i=1}^{n} y_i \log\left(\frac{e^Z}{1+e^Z}\right) + \sum_{i=1}^{n}(1-y_i)\log\left(1-\frac{e^Z}{1+e^Z}\right) \\
&= \sum_{\{i;y_i=1\}} \log\left(\frac{e^Z}{1+e^Z}\right) + \sum_{\{i;y_i=0\}} \log\left(1-\frac{e^Z}{1+e^Z}\right)
\end{aligned}$$

5.3.4 Model Estimation

The four frequency models, one for each of the four trip purposes, are estimated as binary choice models between less than or average number of trips versus more than average number of trips (per person and per household) as described earlier. The estimates of these models are sequentially presented in Tables .All models are analyzed in two separate sets of data: first one (panel A) with person level and second one (panel B) with household level trip information. Some specific determinants are used for each case.

In case of the first model developed for HBW trips (Table 5-14), the positive sign of the estimated coefficient for attribute 'Female' indicates that women are likely to make fewer than average number of trips. But in case of HBE and HBO (Tables 5-15 and 5-16), this parameter shows negative signs which indicate that women are more likely to make higher than average number of these trips. Women in Dhaka city tend to conduct most of the non-work activities in the household including drop-off and pick-up of children at school and shopping. A higher trip frequency is to be expected for this reason. The number of women in household however, also appear to affect trip making in household. Location is significant for both the models that were estimated for each trip purposes: by person and by household (Tables 5-14 to 5-17).

The estimated coefficients and their corresponding t-statistics of the four models are presented below from tables 5-14 to 5-17. Important statistical measures for each of the models are also shown in these Tables.

Table 5-14: Trip Frequency Model for HBW Trips

Independent variables (all on less than average trips)	Estimated Coefficient	t-statistic
Panel A (By Person)		
Constant	2.35124***	11.5201
Female (Ref.=Male)	0.493007***	2.80628
AGE	0.00892758**	2.05791
Education Level (Ref.=Higher Level)		
Lower Level	-0.740863***	-4.98627
Medium, Lower Level	-0.513291***	-3.53515
Medium, Higher Level	-0.0883719	-0.546067
Other Statistics		
LL (B)	-1528.554	
LL ®	-1554.169	
McFadden R-squared	0.0165	
Adjusted R-squared	0.0163	
Chi squared	51.23	
Percent correctly predicted	91.39%	
Panel B (By Household)		
Constant	3.27753***	18.326
HHSIZE	-0.399449***	-7.76224
No. of workers in HH	-1.04881***	-19.3179
No. of students in HH	0.296507***	6.2705
No. of female in HH	0.225932***	4.5349
Income	-3.7E-06**	-2.21546
Residential Location (Ref.=CBD-Core)		
CBD-Mixed	0.316491**	2.33186
Unplanned high densely older part	-0.347568**	-2.03143
Planned: Type1	0.58164*	1.6372
Planned: Type2	0.296454	1.37033
Planned: Type 3	0.293949**	2.09647
Western Fringe: Mixed 1	0.0689024	0.432249
Eastern Fringe: Mixed 2	0.0740042	0.574282
Other Statistics		
LL (B)	-2282.204	
LL ®	-2827.74	
McFadden R-squared	0.19292	
Adjusted R-squared	0.19211	
Chi squared	1091.072	
Percent correctly predicted	74.54%	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

Table 5-15: Trip Frequency Model for HBE Trips

Independent variables (all on less than average trips)	Estimated Coefficient	t-statistic
Panel A (By Person)		
Constant	-2.45605***	-8.08927
Female (Ref.=Male)	-0.669755***	-5.06208
AGE	0.0505207***	7.46289
Education Level (Ref.=Higher Level)		
Lower Level	-0.752892***	-2.80205
Medium, Lower Level	-0.766129***	-3.17076
Medium, Higher Level	-0.628468**	-2.41146
Other Statistics		
LL (B)	-926.932	
LL ®	-986.118	
McFadden R-squared	0.0600	
Adjusted R-squared	0.0591	
Chi squared	118.37	
Percent correctly predicted	91.44%	
Panel B (By Household)		
Constant	2.23999***	10.0854
HHSIZE	-0.148385**	-2.41313
No. of workers in HH	0.373565***	5.95999
No. of students in HH	-1.30106***	-18.4722
No. of female in HH	-0.070014	-1.2562
Income	-2.7E-06*	-1.70874
Residential Location (Ref.=CBD-Core)		
CBD-Mixed	0.410643***	2.65982
Unplanned high densely older part	0.0256424	0.132205
Planned: Type1	0.547185	1.42835
Planned: Type2	-0.08029	-0.357648
Planned: Type 3	0.169922	1.05903
Western Fringe: Mixed 1	-0.13571	-0.727886
Eastern Fringe: Mixed 2	0.113158	0.773941
Other Statistics		
LL (B)	-1648.983	
LL ®	-2064.781	
McFadden R-squared	.20138	
Adjusted R-squared	0.20021	
Chi squared	831.60	
Percent correctly predicted	76.36%	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

Table 5-16: Trip Frequency Model for HBO Trips

Independent variables (all on less than average trips)	Estimated Coefficient	t-statistic
Panel A (By Person)		
Constant	-0.951986***	-6.24261
Female (Ref.=Male)	-1.31997***	-15.4992
AGE	-0.00552506**	-1.9697
Education Level (Ref.=Higher Level)		
Lower Level	-0.487821***	-3.67906
Medium, Lower Level	-0.371848***	-2.88744
Medium, Higher Level	-0.114401	-0.801096
Other Statistics		
LL (B)	-2117.519	
LL ®	-2270.756	
McFadden R-squared	0.0675	
Adjusted R-squared	0.0670	
Chi squared	306.47	
Percent correctly predicted	89.26%	
Panel B (By Household)		
Constant	2.13553***	12.9685
HHSIZE	-0.407757***	-8.58103
No. of workers in HH	0.0615496	1.38814
No. of students in HH	0.254843***	6.04469
No. of female in HH	-0.08897**	-2.02866
Income	1.07E-06	0.74504
Residential Location (Ref.=CBD-Core)		
CBD-Mixed	-0.629882***	-4.74596
Unplanned high densely older part	-0.798101***	-4.99154
Planned: Type1	-0.778266***	-2.61746
Planned: Type2	-0.0668511	-0.351603
Planned: Type 3	-0.729883***	-5.42707
Western Fringe: Mixed 1	-0.796569***	-5.22481
Eastern Fringe: Mixed 2	-0.854045***	-6.71723
Other Statistics		
LL (B)	-2737.400	
LL ®	-2861.337	
McFadden R-squared	0.043	
Adjusted R-squared	0.043	
Chi squared	247.875	
Percent correctly predicted	58.60%	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

Table 5-17: Trip Frequency Model for NHB Trips

Independent variables (all on less than average trips)	Estimated Coefficient	t-statistic
Panel A (By Person)		
Constant	0.251358*	1.44936
Female (Ref.=Male)	1.49246***	10.7482
AGE	-0.00376971	-1.01376
Education Level (Ref.=Higher Level)		
Lower Level	-0.0362915	-0.269082
Medium, Lower Level	0.0709433	0.557515
Medium, Higher Level	0.00339908	0.0254204
Other Statistics		
LL (B)	-1437.432	
LL ®	-1512.970	
McFadden R-squared	0.0499	
Adjusted R-squared	0.0494	
Chi squared	151.08	
Percent correctly predicted	58.78%	
Panel B (By Household)		
Constant	1.98043***	6.7109
HHSIZE	-0.070287	-0.932077
No. of workers in HH	-0.0710281	-1.01593
No. of students in HH	0.117855*	1.61453
No. of female in HH	0.095016	1.28655
Income	-8.8E-06***	-3.94259
Residential Location (Ref.=CBD-Core)		
CBD-Mixed	-0.278345	-1.04124
Unplanned high densely older part	-0.366645	-1.16909
Planned: Type1	-0.575818	-1.13935
Planned: Type2	-0.170527	-0.436569
Planned: Type 3	-0.43967*	-1.67457
Western Fringe: Mixed 1	-0.955922***	-3.44269
Eastern Fringe: Mixed 2	-0.330423	-1.25525
Other Statistics		
LL (B)	-995.248	
LL ®	-1025.224	
McFadden R-squared	0.029	
Adjusted R-squared	0.029	
Chi squared	59.951	
Percent correctly predicted	77.63%	

*** passed the .01 level of significance ** passed the .05 level of significance * passed the .10 level of significance

5.4 Model Development for Distance Traveled

5.4.1 Overview

As in the discussion in Section, we first present some cross-tabulations of distance traveled against three important dimensions: trip purpose, household type, and type of urban system and level of urbanization within this system. We then present regression models for all four trip purposes as mentioned earlier. These models also include all explanatory variables shown in Figure 3-2 in Chapter 3. The results of discrete choice models for distance traveled are shown in Section 6.2.4 of Chapter 6 for all for trip purposes.

5.4.2 Descriptive Analyses

The STP HIS indicates that average length of trips (including intra and inter zonal trips) for all purposes is 5.51 km, of which length of trips from home to works is 5.77 km, from home to education is 4.09 km, while home to other is 6.46 km and non-home based trip is longer at 5.87 km. the average length of trips across the income levels was found to be 5.51 km. the middle income group travel more (5.98 km) than other income groups. The length of trips varies according to the type of modes used. The average length by walk mode constituted 2.85 km, while rickshaw constitutes 3.81 km, bus transit 8.89 km and for non-transit travel 8.26 km.

As for mode choice with respect to distance traveled, some graphical presentation of the selected data (inter zonal trips only) based on cross-tabulations of distance traveled against four important factors: sex, HH income level, residential environment and purposes of trips are shown in Figures A-21 to A-24 (Appendix-A). From these graphical presentations, we can see that women are very much competitive in terms of distance traveled for different trip purposes irrespective of modes used in Dhaka City. In some cases they have to travel longer distances for various reasons (Figure A-21). People of high income group are likely to travel less distances in Dhaka City as they live closely to all available services (Figure A-22).

Residential locations have strong influences on distance traveled by different modes of transport. Those who live in suburban areas have to travel longer distances irrespective of modes (Figure A-23). For all trip purposes, distances traveled by taxi are comparatively longer (Figure A-24).

Here we now give four graphical presentations (Figures 5-14 to 5-17) of trip length frequency distribution (TLFD) for four trip purposes to describe the characteristics of distances traveled by different modes of transport. To analyze and develop the TLFD for all trip purposes, both the intra and inter-zonal trips data are used. In case of HBW Trips, around 43% trips within 2 kilometer. Rickshaws have over 25% shares of all HBW trips within 3 kilometers of travel distances. CNG is also a prime mode of transport for distance traveled. Both of transit (buses) and cars have 5 to 10% of all HBW trips within the ranges of 2 to 10 kilometers of distances.

In case of HBE trips, rickshaws plays vital role. Interestingly, a certain distance lies between 7 to 8 kilometers have high shares of all HBE trips made by taxi. This represent that some popular schools (especially English medium schools) are situated in the ranges where taxi services are highly popular. For HBO trips, private car represent significant shares for distance traveled which indicate that people with higher income are likely to travel longer distances for home based non-work trips especially for shopping, recreation etc. In case of NHB trips, walking and rickshaws are also prominent within shorter distances traveled.

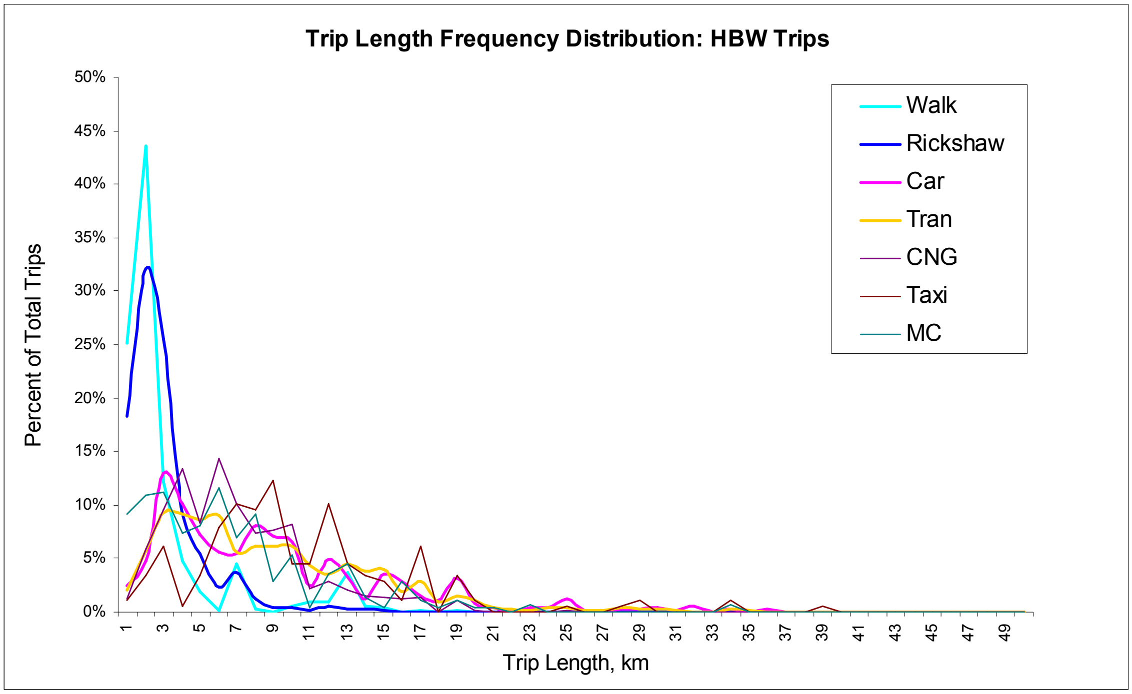


Figure 5-14: Characteristics of Distance Traveled by Different Modes for HBW Trips

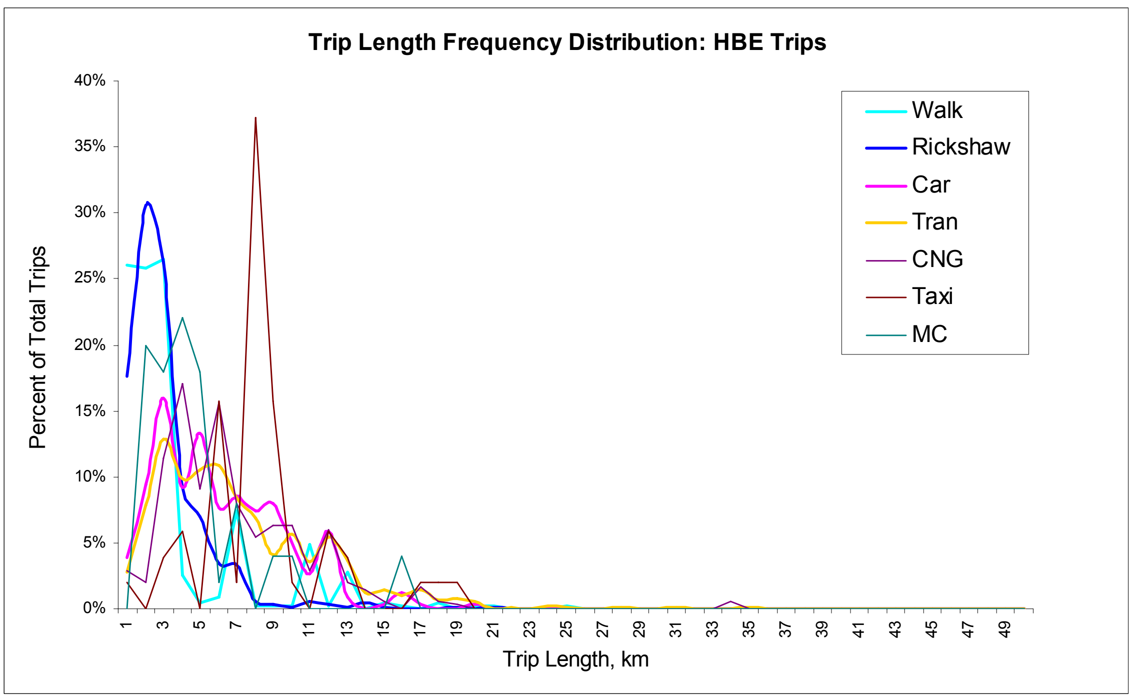


Figure 5-15: Characteristics of Distance Traveled by Different Modes for HBE Trips

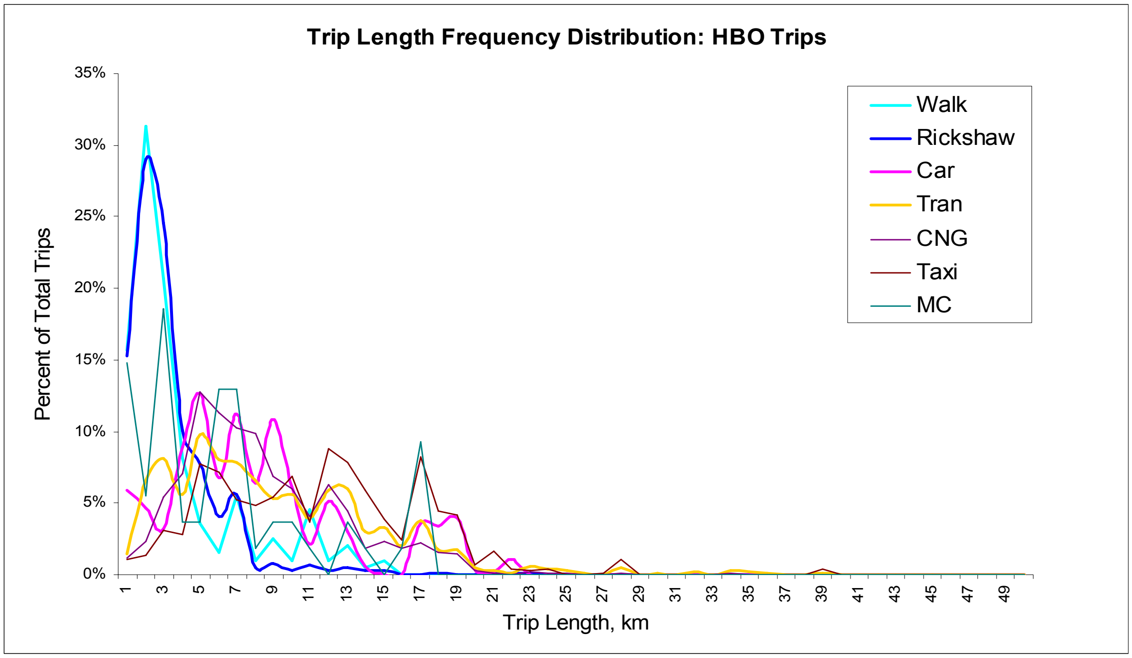


Figure 5-16: Characteristics of Distance Traveled by Different Modes for HBO Trips

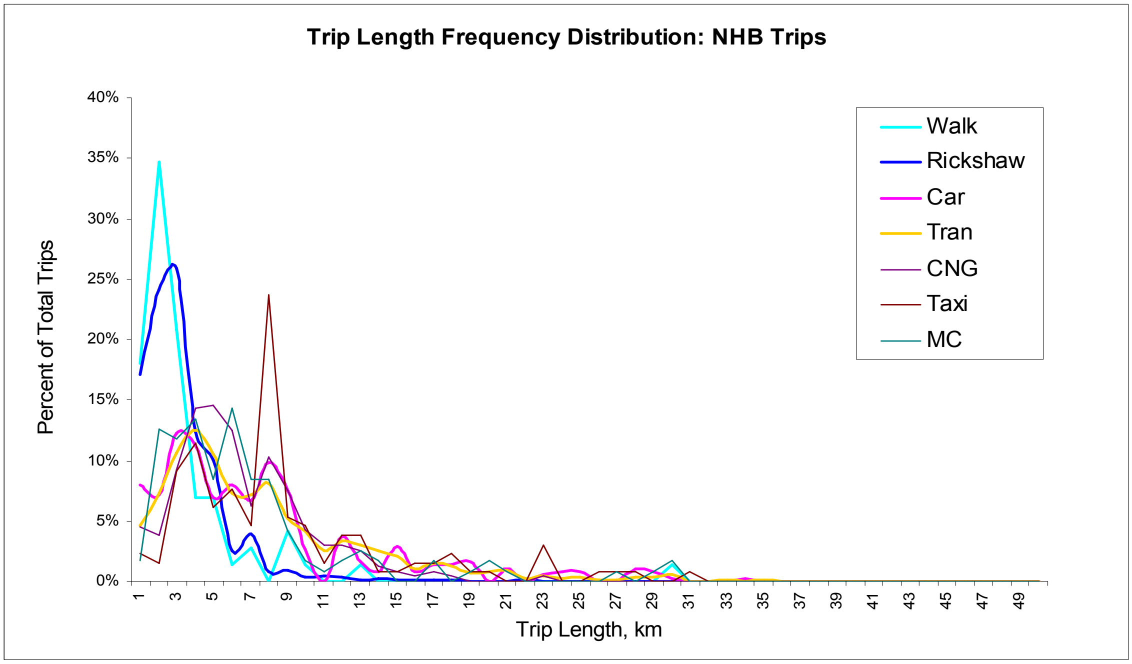


Figure 5-17: Characteristics of Distance Traveled by Different Modes for NHB Trips

5.4.3 Multiple Regression Model

Multiple regression, a time-honored technique going back to Pearson's 1908 use of it, is employed to account for (predict) the variance in an interval dependent, based on linear combinations of interval, dichotomous, or dummy independent variables. Multiple regression can establish that a set of independent variables explains a proportion of the variance in a dependent variable at a significant level (through a significance test of R^2), and can establish the relative predictive importance of the independent variables (by comparing beta weights). Power terms can be added as independent variables to explore curvilinear effects. Cross-product terms can be added as independent variables to explore interaction effects. One can test the significance of difference of two R^2's to determine if adding an independent variable to the model helps significantly. Using hierarchical regression, one can see how most variance in the dependent can be explained by one or a set of new independent variables, over and above that explained by an earlier set. Of course, the estimates (b coefficients and constant) can be used to construct a prediction equation and generate predicted scores on a variable for further analysis.

The multiple regression equation takes the form:

$$y = b_1 x_1 + b_2 x_2 + \dots\dots\dots\dots\dots + b_n x_n + c$$

where, the b's are the regression coefficients, representing the amount the dependent variable y changes when the corresponding independent changes 1 unit.; c is the constant, where the regression line intercepts the y axis, representing the amount the dependent y will be when all the independent variables are 0. The standardized version of the b coefficients are the beta weights, and the ratio of the beta coefficients is the ratio of the relative predictive power of the independent variables. Associated with multiple regression is R^2, multiple correlation, which is the percent of variance in the dependent variable explained collectively by all of the independent variables.

Multiple regression shares all the assumptions of correlation: linearity of relationships, the same level of relationship throughout the range of the independent variable ("homoscedasticity"), interval or near-interval data, absence of outliers, and data whose range is not truncated. In addition, it is important that the model being tested is correctly specified. The exclusion of important causal variables or the inclusion of extraneous variables can change markedly the beta weights and hence the interpretation of the importance of the independent variables.

5.4.4 Model Estimation

In order to investigate the relative importance of the various attributes of persons, households and spatial environments for travel distance, we estimated four regression models for each of the four trip purposes (Tables 5-18 to 5-21). The natural logarithm of the distance traveled was taken as the dependent variable in each case. In case of urban form measures, we took the place of origin of a trip as variable to measure spatial environments for each model as usual for the reasons described earlier.

For all trips purposes, the distance traveled by car depends mostly on car ownership and income level. For work trips (from home to work or from work to home), the distance traveled by car is relatively shorter for people of high income level. Interestingly, household's income is positively related to the distance traveled to work by all modes except car and taxi. People of high income level usually use car and taxi and they are not likely to travel long distances for work trips. This indicates that people of high income level are likely to nearby work places.

The results of the regression models demonstrate the importance of including personal attributes in the analysis of travel behavior. Gender is a strong determinant of distance traveled by each of the seven travel modes in all trip purposes. Women usually do not like all available modes of transport for long distance work trips except personalized motorized vehicles like private car and taxi but they travel longer distances for non-work trips by usual modes of transport. Education level and household size have mixed impact on traveling longer distances by a specific mode for work trips. The higher the level of education, the longer the commuting distances by all modes of transport except the cases of taxi and motor cycle.

The type of urban system and the level of urbanization of the city wherein household resides remain important determinants of all trip purposes, especially for trips by public transport (bus services). The parameter B (a positive value of 0.716) and Beta value (of 0.264) in Table 5-18 for transit (of Planned Type II) indicate people from this area are like to travel distance places for work trips by public transit buses as this sub-urban area is well-linked with available public transit facilities.

For both of the regression models, the independent variables have a clear and (fairly) strong relationship to distance traveled by different modes of transport. In these two models, $R^{2,}$ also called multiple correlation or the coefficient of multiple determination, is the present of the variance in the dependent explained uniquely or jointly by the independents. R^2 can also be interpreted as the proportionate reduction in error in estimating the dependent when knowing the independents. The reported R^2 and adjusted R^2 for each of the models signify the goodness of fit of the model. The corresponding R^2 Change refers to the amount R^2 increases/decreases when a variable is added to or deleted from the equation. Almost all important parameters for each of the four models are significant.

Table 5-18: Regression Model for Distance Traveled (HBW Trips)

Parameter Estimates	Walk			Rickshaw			Car			Transit			CNG			Taxi			Motor Cycle		
	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change
Individual Sociodemographics																					
Female (Ref.=Male)	-0.102	-0.056	0.006	0.007	0.004	0.002	0.108*	0.052	0.006	0.008	0.003	0.000	0.073	0.046	0.002	0.421***	0.209	0.058	-0.114	-0.027	0.000
Age	-0.004*	-0.069	0.002	0	0.007	0.000	0.004*	0.062	0.004	0.003***	0.043	0.006	0.003*	0.060	0.001	0.004	0.071	0.000	-0.006	-0.057	0.025
Education (Ref.=Higher Level)			0.018			0.011			0.007			0.023			0.031			0.047			0.153
Lower Level	-0.383***	-0.265		-0.151***	-0.107		-0.104	-0.042		-0.197***	-0.114		-0.31***	-0.131		0.024	0.010		-0.176	-0.058	
Medium, Lower	-0.206*	-0.126		-0.124***	-0.101		-0.041	-0.019		-0.132***	-0.086		-0.133**	-0.101		0.111	0.065		-0.566***	-0.303	
Medium, Higher	-0.275**	-0.111		-0.079**	-0.055		-0.017	-0.01		-0.040*	-0.025		0.077	0.062		-0.264***	-0.203		-0.114	-0.066	
Household Sociodemographics																					
HH Size (Ref.<=2)			0.008			0.002			0.022			0.004			0.034			0.033			0.025
HH_Size=3	-0.164	-0.095		-0.063	-0.041		-0.152	-0.068		0.103***	0.059		-0.079	-0.056		0.410**	0.284		-0.062	-0.032	
HH_Size=4	-0.184	-0.121		-0.030	-0.024		0.032	0.021		0.052	0.035		0.023	0.018		0.561***	0.403		0.275*	0.162	
HH_Size=5	-0.125	-0.076		-0.055	-0.040		0.066	0.037		0.099**	0.058		0.188*	0.142		0.472**	0.335		-0.094	-0.041	
HH_Size >= 6	-0.425***	-0.234		-0.054	-0.035		-0.084	-0.046		0.198***	0.099		0.379***	0.267		0.432*	0.253		0.350*	0.180	
# workers in HH	0.071**	0.111	0.003	0.018	0.031	0.000	0.064**	0.094	0.014	-0.058***	-0.090	0.003	-0.011	-0.021	0.007	-0.081**	-0.155	0.011	-0.128***	-0.201	0.072
# students in HH	0.088**	0.126	0.005	0.006	0.010	0.000	-0.064**	-0.091	0.007	-0.007	-0.010	0.000	-0.079***	-0.152	0.015	-0.095**	-0.173	0.041	-0.015	-0.018	0.001
HH Income Level (Ref.=HIG)			0.020			0.010			0.014			0.008			0.006			0.083			0.030
Low Income	-0.214	-0.140		-0.046	-0.037		0.255***	0.101		-0.179***	-0.125		0.140*	0.088		-0.301*	-0.135		-0.607**	-0.317	
Medium, Lower Income	-0.313*	-0.178		-0.104*	-0.085		0.204**	0.101		-0.132**	-0.089		0.016	0.012		0.451***	0.243		-0.722***	-0.416	
Medium, Higher	0.055	0.022		0.008	0.005		-0.012	-0.008		-0.015	-0.009		0.075	0.066		0.103	0.083		-0.581**	-0.357	
Types of Urban Forms																					
Spatial Environments at Origin (Ref.=CBD-Core)			0.078			0.087			0.176			0.107			0.085			0.081			0.161
CBD-Mixed	0.161*	0.094		0.168***	0.108		-0.071	-0.039		-0.145***	-0.078		-0.013	-0.009		0.172	0.104		0.063	0.032	
Unplanned Densely Area	-0.403***	-0.138		-0.270***	-0.177		-0.210*	-0.06		-0.132***	-0.043		-0.023	-0.013		0.036	0.010		-0.886***	-0.377	
Planned Type I	0.152	0.029		0.303***	0.066		0.238***	0.105		-0.043	-0.015		0.208**	0.112		0.231*	0.145		0.111	0.029	
Planned Type II	1.418***	0.155		1.080***	0.088		1.001***	0.408		0.716***	0.264		0.902***	0.215		0.605***	0.300		0.932***	0.232	
Planned Type III	0.154*	0.090		0.141***	0.073		0.273***	0.116		0.201***	0.106		0.309***	0.186		0.451***	0.271		0.094	0.039	
Western Fringe	0.170*	0.107		0.203***	0.104		0.080	0.033		0.043	0.015		0.284***	0.145		0.449**	0.188		0.269*	0.094	
Eastern Fringe	0.485***	0.190		0.179***	0.114		0.314***	0.11		-0.165***	-0.092		0.032	0.018		0.213	0.092		0.040	0.019	
Constant	1.301***			0.996***			1.507***			2.071***			1.539***			1.518***			2.818***		
*α = 0.1	R-Sq.:		0.142			0.112			0.249			0.151			0.181			0.354			0.466
**α = 0.05	Adj. R-Sq.:		0.114			0.105			0.225			0.148			0.151			0.267			0.424
***α = 0.01																					

Table 5-19: Regression Model for Distance Traveled (HBE Trips)

Parameter Estimates	Walk			Rickshaw			Car			Transit			CNG			Taxi			Motor Cycle		
	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change
Individual Sociodemographics																					
Female (Ref.=Male)	-0.051	-0.033	0.005	0.016	0.014	0.000	-0.052	-0.04	0.006	0.075***	0.054	0.010	0.061	0.051	0.000	0.282**	0.296	0.001	-0.183	-0.142	0.001
Age	-0.008*	-0.084	0.001	-0.003**	-0.047	0.008	0.002	0.04	0.005	0.007***	0.077	0.075	0.005	0.088	0.034	-0.002	-0.053	0.021	-0.003	-0.084	0.067
Education (Ref.=Higher Level)			0.014			0.023			0.002			0.067			0.037			0.175			0.063
Lower Level	-0.079	-0.047		-0.423***	-0.358		0.017	0.013		-0.481***	-0.33		-0.193*	-0.153		0.05	0.05		-0.595	-0.511	
Medium, Lower	0.13	0.072		-0.258***	-0.211		0.064	0.048		-0.054	-0.04		0.042	0.034		0.381**	0.381		-0.403	-0.339	
Medium, Higher	0.134	0.033		-0.097	-0.05		0.17	0.088		-0.051	-0.029		-0.152	-0.11		0.459**	0.29		-0.141	-0.119	
Household Sociodemographics																					
HH Size (Ref.<=3)			0.068			0.001			0.050			0.004			0.005			0.357			0.375
HH_Size=4.00	-0.105	-0.066		0	0		-0.08	-0.057		-0.146***	-0.106		0.036	0.03		-0.224*	-0.236		-1.754***	-1.633	
HH_Size=5.00	-0.175	-0.105		-0.019	-0.015		-0.243**	-0.185		-0.151***	-0.105		0.197*	0.149		-0.329	-0.266		-1.639**	-1.475	
HH_Size>=6	-0.369**	-0.197		-0.03	-0.02		0.199	0.129		-0.18***	-0.108		0.119	0.082		-0.736**	-0.303		-3.243***	-1.192	
#workers in HH	-0.037	-0.042	0.000	-0.019	-0.025	0.000	-0.032	-0.045	0.002	0.005	0.006	0.000	0.035	0.051	0.012	-0.044	-0.091	0.000	0.331*	0.451	0.022
#students in HH	-0.009	-0.011	0.001	0.002	0.003	0.000	-0.11***	-0.154	0.007	0.007	0.01	0.000	-0.05	-0.092	0.004	-0.074	-0.131	0.025	0.257	0.36	0.004
HH Income (Ref.=HIG)			0.037			0.016			0.179			0.012			0.005			0.049			0.049
LIG	-0.16	-0.103		-0.302***	-0.234		0.009	0.004		-0.034	-0.023		-0.115	-0.06		0.222	0.111		0.061	0.042	
LMIG	-0.414*	-0.253		-0.216***	-0.175		-0.862***	-0.447		0.006	0.004		-0.065	-0.046		0.283	0.116		-0.102	-0.094	
HMIG	-0.313	-0.125		-0.174***	-0.134		-0.44***	-0.346		0.126**	0.087		-0.141*	-0.119		0.341*	0.33		-0.308	-0.277	
Types of Urban Forms																					
Spatial Environments at Origin (Ref.=CBD-Core)			0.295			0.093			0.131			0.096			0.110			0.187			0.060
CBD-Mixed	1.015***	0.48		0.212***	0.143		0.058	0.041		0.104***	0.066		-0.054	-0.042		0.707***	0.654		0.172	0.134	
Unplanned High Densely Older Part	-0.009	-0.003		-0.25***	-0.148		0.125	0.051		-0.065	-0.027		0.151	0.068		0.792***	0.452		0.152	0.085	
Planned: Type 1	1.568***	0.161		0.233***	0.045		0.323***	0.151		0.174***	0.059		-0.013	-0.006		0.738***	0.57		0.172	0.045	
Planned: Type 2	1.762***	0.374		0.944***	0.162		1.084***	0.206		0.85***	0.288		0.867***	0.22		0.743***	0.424		-0.047	-0.017	
Planned: Type 3	0.5***	0.255		0.248***	0.133		0.294***	0.167		0.235***	0.135		0.287***	0.177		0.767***	0.69		-0.292	-0.21	
Western Fringe: Unplanned Mixed 1	0.321***	0.17		0.183***	0.112		-0.252**	-0.159		0.062	0.025		-0.13	-0.072		0.904***	0.451		-0.155	-0.128	
Eastern Fringe: Unplanned Mixed 2	-0.015	-0.007		0.041	0.025		0.324**	0.128		-0.084**	-0.048		0.358***	0.165		-0.091	-0.027		-0.029	-0.011	
Constant	1.276***			1.45***			2.198***			1.655***			1.64***			0.955*			3.02***		
*α = 0.1	R-Sq.:		0.420			0.143			0.383			0.264			0.207			0.816			0.642
**α = 0.05	Adj. R-Sq.:		0.394			0.137			0.344			0.259			0.159			0.694			0.395
***α = 0.01																					

Table 5-20: Regression Model for Distance Traveled (HBO Trips)

Parameter Estimates	Walk			Rickshaw			Car			Transit			CNG			Taxi			Motor Cycle		
	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change
Individual Sociodemographics																					
Female (Ref.=Male)	0.155	0.106	0.000	0.044**	0.033	0.001	0.002	0.002	0.001	0.051***	0.037	0.002	-0.013	-0.010	0.000	0.081*	0.058	0.008	0.102	0.046	0.004
Age	0.003	0.064	0.000	0.001*	0.025	0.000	0.003	0.054	0.010	0.001*	0.023	0.001	0.001**	0.038	0.001	0.002	0.046	0.002	0.069***	0.786	0.057
Education (Ref.=Higher Level)			0.039			0.001			0.003			0.004			0.000			0.008			0.245
Lower Level	-0.177	-0.121		-0.043	-0.033		-0.070	-0.040		-0.091**	-0.065		0.018	0.015		-0.067	-0.049		-2.619***	-0.568	
Medium, Lower	-0.012	-0.008		0.015	0.012		0.125*	0.082		-0.017	-0.012		0.021	0.018		0.070	0.059		-0.147	-0.068	
Medium, Higher	-0.134	-0.055		-0.017	-0.010		-0.013	-0.007		-0.021	-0.010		0.015	0.010		0.054	0.035		0.679**	0.38	
Household Sociodemographics																					
HH Size (Ref.<=2)			0.025			0.004			0.060			0.003			0.001			0.010			0.111
HH_Size=3.00	0.162	0.094		0.026	0.017		-0.132	-0.052		0.165***	0.095		-0.029	-0.021		0.003	0.002		0.53	0.297	
HH_Size=4.00	-0.017	-0.010		-0.006	-0.004		-0.007	-0.005		0.188***	0.132		-0.016	-0.014		-0.062	-0.049		0.547	0.261	
HH_Size=5.00	0.221	0.118		-0.043	-0.029		-0.249	-0.155		0.182***	0.110		-0.051	-0.038		-0.005	-0.004		0.855	0.381	
HH_Size >= 6	-0.024	-0.014		-0.081	-0.050		-0.113	-0.056		0.319***	0.162		-0.042	-0.027		0.067	0.036		2.243***	0.809	
# workers in HH	-0.074	-0.101	0.032	-0.008	-0.013	0.001	0.028	0.037	0.002	-0.072***	-0.103	0.005	0.031**	0.056	0.000	-0.031	-0.052	0.003	-0.672***	-0.713	0.175
# students in HH	0.059	0.102	0.010	0.018*	0.033	0.000	-0.068*	-0.096	0.012	-0.054***	-0.085	0.006	0.013	0.024	0.000	-0.047*	-0.082	0.003	-0.474*	-0.583	0.044
HH Income (Ref.=HIG)			0.004			0.001			0.034			0.000			0.017			0.020			0.099
LIG	0.202	0.132		-0.012	-0.010		0.465***	0.147		-0.045	-0.032		0.192***	0.165		0.106	0.075		1.21	0.609	
LMIG	0.313	0.183		-0.032	-0.024		0.323***	0.151		-0.025	-0.017		0.21***	0.173		-0.055	-0.042		1.918*	0.577	
HMIG	0.258	0.106		-0.010	-0.007		0.273***	0.188		-0.039	-0.020		0.078*	0.064		0.056	0.047		1.061	0.588	
Types of Urban Forms																					
Spatial Environments at Origin (Ref.=CBD-Core)			0.130			0.089			0.115			0.089			0.117			0.202			0.034
CBD-Mixed	0.212	0.117		0.346***	0.218		0.134*	0.087		-0.073**	-0.043		0.018	0.015		-0.128*	-0.098		0.862	0.384	
Unplanned High Densely Older Part	-0.134	-0.040		-0.064*	-0.034		0.094	0.032		0.096**	0.034		0.141***	0.061		0.009	0.003		0.564	0.203	
Planned: Type 1	0.513*	0.110		0.442***	0.087		0.372***	0.155		-0.066	-0.018		0.049	0.020		-0.082	-0.027		0.247	0.065	
Planned: Type 2	1.146***	0.268		1.256***	0.209		1.006***	0.349		0.756***	0.267		0.838***	0.310		0.65***	0.401		0.611	0.133	
Planned: Type 3	0.075	0.038		0.273***	0.155		0.443***	0.182		0.114***	0.065		0.363***	0.230		0.26***	0.161		0.243	0.125	
Western Fringe: Unplanned Mixed 1	-0.259	-0.161		0.098***	0.050		0.233**	0.107		0.061	0.023		0.189***	0.107		-0.110	-0.050		0.244	0.081	
Eastern Fringe: Unplanned Mixed 2	0.108	0.046		0.101***	0.068		-0.031	-0.012		-0.113***	-0.070		0.179***	0.112		0.137*	0.079		0.216	0.083	
Constant	0.710			0.833***			1.464***			1.982***			1.583***			2.119***			-1.681*		
*α = 0.1	R-Sq.:		0.239			0.097			0.237			0.110			0.137			0.255			0.767
**α = 0.05	Adj. R-Sq.:		0.148			0.092			0.207			0.106			0.130			0.234			0.614
***α = 0.01																					

Table 5-21: Regression Model for Distance Traveled (NHB Trips)

Parameter Estimates	Walk			Rickshaw			Car			Transit			CNG			Taxi			Motor Cycle		
	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change	B	Beta	R-sq Change
Individual Sociodemographics																					
Female (Ref.=Male)	-0.28	-0.14	0.070	0.054	0.038	0.001	0.392***	0.168	0.044	-0.056	-0.021	0.001	0.23***	0.158	0.015	0.006	0.003	0.001	-0.246	-0.071	0.008
Age	0.005	0.074	0.013	0.002	0.045	0.001	0.002	0.029	0.000	0.005***	0.077	0.005	0.001	0.016	0.002	0.003	0.042	0.000	-0.005	-0.064	0.007
Education (Ref.=Higher Level)			0.029			0.001			0.008			0.005			0.007			0.012			0.076
Lower Level	0.571*	0.395		-0.053	-0.036		0.293**	0.136		-0.095*	-0.057		0.108	0.067		0.03	0.015		-0.515*	-0.195	
Medium, Lower	0.319	0.206		0.019	0.015		0.086	0.044		-0.042	-0.026		0.078	0.059		0.21	0.124		-0.178	-0.117	
Medium, Higher	0.234	0.125		0.021	0.015		0.043	0.023		0.053	0.03		0.04	0.03		0.04	0.03		-0.348**	-0.237	
Household Sociodemographics																					
HH Size (Ref.<=2)			0.099			0.003			0.004			0.002			0.012			0.044			0.035
HH_Size=3.00	-1.056***	-0.647		-0.02	-0.012		-0.172	-0.075		-0.086	-0.048		0.296**	0.194		0.252	0.155		-0.301	-0.168	
HH_Size=4.00	-0.774*	-0.52		0.016	0.013		-0.22	-0.128		-0.063	-0.04		0.213*	0.167		0.242	0.173		0.161	0.107	
HH_Size=5.00	-0.337	-0.214		-0.052	-0.033		-0.32*	-0.166		-0.017	-0.009		0.24*	0.164		0.504*	0.333		0.041	0.025	
HH_Size >= 6	-0.352	-0.168		-0.024	-0.014		-0.314	-0.144		-0.079	-0.037		0.179	0.104		0.196	0.103		-0.08	-0.038	
# workers in HH	-0.305**	-0.398	0.011	0.005	0.008	0.000	0.087*	0.129	0.015	-0.02	-0.028	0.000	0.002	0.004	0.003	0.008	0.012	0.000	-0.099	-0.137	0.036
# students in HH	-0.026	-0.039	0.020	-0.001	-0.002	0.000	0.018	0.025	0.003	-0.007	-0.01	0.000	-0.026	-0.046	0.001	-0.074	-0.112	0.010	-0.141*	-0.196	0.001
HH Income (Ref.=HIG)			0.075			0.013			0.014			0.003			0.006			0.035			0.042
LIG	-0.591	-0.425		-0.157	-0.117		-0.143	-0.068		-0.143	-0.094		-0.049	-0.031		0.092	0.037		0.348	0.229	
LMIG	-0.317	-0.198		-0.141	-0.109		0.091	0.042		-0.088	-0.055		0.069	0.049		0.264	0.12		0.469*	0.281	
HMIG	0.197	0.109		-0.263***	-0.193		-0.122	-0.072		-0.055	-0.032		0	0		0.008	0.006		0.369*	0.259	
Types of Urban Forms																					
Spatial Environments at Origin (Ref.=CBD-Core)			0.109			0.052			0.144			0.129			0.135			0.195			0.247
CBD-Mixed	0.07	0.045		0.176***	0.118		-0.074	-0.038		0.12**	0.065		0.064	0.047		-0.018	-0.012		0.293*	0.171	
Unplanned High Densely Older Part	-0.303	-0.129		0.134**	0.082		0.245	0.058		0.262***	0.094		0.265***	0.129		-0.418	-0.078		0.249	0.084	
Planned: Type 1	0.327	0.108		0.455***	0.108		0.283**	0.132		0.239***	0.098		0.171*	0.088		0.155	0.09		0.328*	0.156	
Planned: Type 2	-0.881	-0.149		1.355***	0.175		1.199***	0.369		1.171***	0.339		1.408***	0.162		1.159***	0.447		1.29***	0.404	
Planned: Type 3	0.545*	0.283		0.294***	0.126		0.442***	0.143		0.571***	0.225		0.717***	0.336		0.317	0.109		1.249***	0.448	
Western Fringe: Unplanned Mixed 1	0.377	0.195		0.113	0.052		0.231*	0.077		0.295***	0.1		0.244**	0.105		-0.055	-0.019		0.527**	0.227	
Eastern Fringe: Unplanned Mixed 2	0.212	0.036		0.231***	0.103		0.209	0.063		0.314***	0.135		0.456***	0.191		0.199	0.068		0.194	0.086	
Constant	2.475**			0.875***			0.734**			1.688***			0.837***			1.436***			1.231*		
R-Sq.:			0.428			0.071			0.233			0.145			0.180			0.297			0.452
Adj. R-Sq.:			0.187			0.045			0.187			0.133			0.135			0.162			0.333

*α = 0.1

**α = 0.05

***α = 0.01

5.5 Summary

This chapter has described the fundamental part of this research work which includes the development and calibration of various types of models used for this study with details theoretical explanations of each model types. Besides, some descriptive analyses have also been presented as required to clarify the model estimation in context of real world.

Mode choice models developed in this study is a discrete choice model of two types: multinomial logit and nested logit models which have been described in details. Data requirement and data assembly procedures for modal split model have also been discussed. To examine the effects of exogenous variables on modal choices, separate multivariate techniques have been developed for each trip purposes.

To determine the trip rates by person and by household four trip frequency models have been developed as binary choice models between less than or average number of trips versus more than average number of trips by person and by household as well.

Lastly, we presented four regression models for distance traveled. We also presented the trip length frequency distribution (TLFD) for all four trip purposes to understand the characteristics of distance traveled by different modes of transport.

CHAPTER 6

BASELINE ANALYSES AND NEED ASSESSMENT FOR PLANNING

6.1 General

The transportation system is a critical component of urban infrastructure and the lifeline of a city. A well-developed and planned transportation system is an integral part to the development of economic and social activity and accelerates economic growth. The ever-growing population of Dhaka has resulted in mounting pressure on the transportation system and this is bound to increase further in coming years. The urban transportation system now has to be developed to cater to the burgeoning population growth and economic advancement.

An adequate and efficient transport system is a pre-requisite for both initiating and sustaining economic development. Investment in improving transport efficiency is the key to expansion and integration of markets - sub-national, national and international. It also helps the generation of economies of scale, increased competition, reduced cost, systematic urbanization, export-led faster growth and a larger share of international trade.

In Bangladesh, development and maintenance of transport infrastructure is essentially the responsibilities of the public sector. The development of surface transport system in Bangladesh is constrained by three distinct sets of factors. These are physical (e.g., difficult terrain, periodic flooding, poor soil condition, siltation and erosion of rivers, inherited management weaknesses etc.), low investments and maintenance, and importantly inadequate institutional framework (many transport sector parastatals & agencies and lack of co-ordination and autonomy of transport parastatals etc.).

Being the administrative, commercial & cultural capital of Bangladesh, the Mega City Dhaka has a major role to play in the socioeconomic development of the country and in the era of regional and sub-regional cooperation. But the existing transportation system is a major bottleneck for the development of the city. Unplanned urbanization, especially poor transportation planning and lower land utilization efficiency, has turned the city into a dangerous urban jungle. There is now an ever-increasing urgency for mitigating the complex transportation problems. It is high time that we could take some lesions from advanced countries and move in a planned and phased manner for solving the ever increasing urban transportation problems. The purpose of this chapter is to briefly discuss the output of the current study in light of the key urban transport characteristics and also to present some improvement options for future development as a possible solution strategies for enhancing mobility, safety and the environment by means of better transportation measures.

6.2 Results Analyses and Discussion

6.2.1 Overview

The results and outputs obtained from different models used in this study are presented in this section. A series of models were developed and calibrated in this study to understand the complex nature of people's travel behavior in Dhaka City. The influence of socioeconomic characteristics (personal and household distinctiveness) and spatial urban forms on travel behavior are simultaneously analyzed within the scopes of this study. The results of this study imply that both sets of factors have a clear, strong influence on people's mode choice, distance traveled and number of trip making for each type of trip purposes.

6.2.2 Mode Choice and Effect of Exogenous Variables on Mode Choice

One of the main objectives of this study was to develop a comprehensive mode choice model for Dhaka City in order to predict the diversified mode shares of different modes of transport including the dominant non-motorized mode rickshaw and all possible minor modes available in the city with an attempt to provide background information for the strategic urban transportation planning process. The modeling approach presented here was a discrete choice model based on the random utility maximizing principles, as the research direction currently being pursued in discrete choice modeling - the merging of behavioral models and predictive choice models.

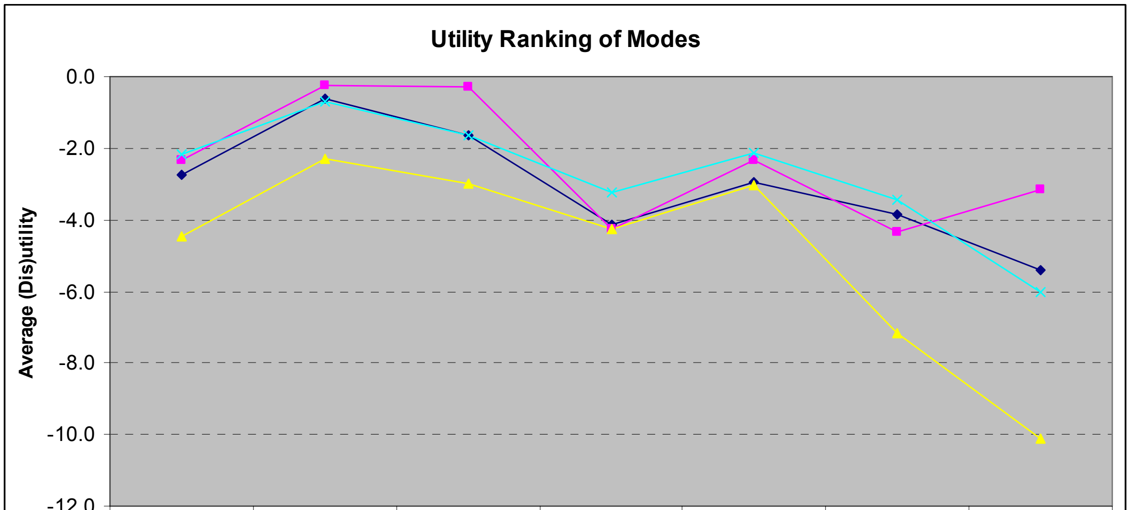
In this study, seven modes of transport namely walking, rickshaws, car, transit (buses), taxi, CNG and motor cycle were considered to develop two types of discrete choice models for each of the four trip purposes. The modal shares of rail transport and other minor modes have not been considered here, as they are very insignificant for modeling. Initially, the MNL model was developed. This model assumes that individual utility is calculated for all possible alternatives; then the alternative with the highest utility is chosen (Meyer and Miller, 2001). Later, Nested logit (NL) model, which has been utilized in this study, is a model that has been developed in order to overcome the so called independence of irrelevant alternatives (IIA) limitation in the multinomial model by modifying the choice structure into multiple tiers. Besides, several multi-stage disaggregate models were developed for different market segments based on Dhaka's socioeconomic characteristics to identify the group specific differences in mode choices and to estimate travel behavior stratified by residential locations and by household income levels.

6.2.2.1 Utility Ranking of Modes

One interesting output of this study is concerning the utility ranking of modes using the derived utility equations of each mode. The average utility of each mode is a measure of how travelers put importance to the chosen mode from among the choices available to him.

Only those travelers that use a given mode are included in computing for the average utility of that mode. The utility ranking of the modes gave almost consistent results wherein the transit (bus services) is always at the top of the utility ranking having the lowest disutility (Figures 6-1) for all four-trip purposes except the case of education trips where both the bus and rickshaw have the same scores. This is then followed by the rickshaw, CNG (auto-rickshaw), or car and then the taxi, motor cycle and at the bottom is the walking, having the highest disutility. The utility ranking between bus and rickshaw are very competitive and interestingly, private car and CNG are highly competitive with each other although the car ownership in Dhaka is very limited and cars are mostly owned and used by the richer part of the society. Large portion of the society are general users of other available transports. The possible reason for the competitive ranking score between private car and CNG is that people who can afford but do not own private car are likely to travel by CNG as it is convenient, relatively cheaper than taxi and seems to be a personalized vehicle like car. Figures 6-1 shows the results of utility ranking for the four trips purposes.

Nevertheless, in practical, the transit (buses), rickshaws, auto-rickshaw (CNG) and Taxi are open players on Dhaka's road and the majority of people are compelled to use these alternatives as the household/personal level vehicle ownership (either private car or motor cycle) is till very low in Dhaka City. In real world, rickshaw, auto-rickshaw and transit directly compete with one other and most of the people are captive users of these vehicles under financial and other constraints. As majority people have no options to choose a better transport mode for their everyday trip making, they have to choose one from available alternatives before them. Thus, the highest utility ranking of transit essentially does not mean the satisfaction level of choosing the specific mode by a traveler for a trip purpose.



	Car	Bus	Rickshaw	Taxi	CNG	Motor Cycle	Walking
HBW	-2.74	-0.61	-1.65	-4.14	-2.96	-3.83	-5.39
HBE	-2.33	-0.27	-0.27	-4.24	-2.33	-4.35	-3.13
HBO	-4.47	-2.31	-2.97	-4.25	-3.03	-7.16	-10.13
NHB	-2.16	-0.71	-1.66	-3.25	-2.15	-3.46	-6.01

Figure 6-1: The Estimated Average (Dis)utility of Modes for all Trip Purposes

From the attitudinal Survey conducted by STP (2005) we can see that 73% respondents use bus as usual travel mode for HBW trips only for cheaper mode of transport and 69% travelers use buses as there is no other alternative mode of transport before them. Many of bus riders expressed the view that bus journey in Dhaka are hazardous. In reply to the question 'what are the existing problems you face in bus travel mode' people mentioned several problems: 56% mentioned that bus stop is away from their residence; 32% said there is no bus service to their localities; 20% said the bus takes longer travel time; 18% said they need several transfers; 52% said the bus is not comfortable; and another 16% said they are unreliable. About 4% of the respondents feel bus journey is dangerous (attack during political program, fire incident, death and injury, etc.) and 15% feel they are unsafe (pick pocketing, hijacking, robbery, mal-treatment, abuse and physical assault by crew staff). People who do not use bus for commuting trips could use bus transit if the following improvements are made: improvements should include time saved (64%), seat assured (61%), reliable and comfortable journey (30%), air conditioned (22%) and express service or limited stop service (27%). The respondent also expressed that they would prefer to pay some extra amount (up to 50% higher than the existing fare) for improved services (STP, 2005).

Now it is clear that the maximum utility for buses necessarily does not indicate users willingly preferences for that services, rather it represent that people are forced to use that mode of transport due to unavailability of suitable alternatives before them. It is expected that the improvement of the transit system will primarily attract people who otherwise ride rickshaws or auto-rickshaws. Moreover it is also anticipated that the restrictions on rickshaw movement will primarily divert people to ride buses or auto-rickshaws. It is thus necessary to consider these three modes together in future mass transportation planning for the mega city Dhaka.

6.2.2.1 Mode Choices

People travel for different purposes by different modes of transport under a number of constraints. Modal split varies substantially across the type's household/personal socioeconomic characteristics and types of urban forms (including level of urbanization, availability of transport infrastructures etc.) where people live, work and travel for their everyday interactions. From this study, it is evident that household/personal attributes and the characteristics of the residential/work place environments have a strong relationship with modal choice. The purpose of trip undertaken also influences modal choice. The model outputs of this study clarify how people's travel behavior in Dhaka City is influenced by socioeconomic characteristics and spatial urban environments.

To analyze the mode shares and the effects of household/personal socioeconomic attributes in association with the influence of spatial environments on mode choices for designated four trip purposes we developed two separate schemes: first one with discrete choice modeling (both MNL and NL approaches) framework for modal split prediction, and second one for assessing the effects of the exogenous variables on modal choice by multivariate (multinomial logistic regression) analysis. In case of discrete choice analysis, firstly, MNL models were fitted to all four-trip purposes. Then two-level NL models were developed and calibrated with same data set for all trip purposes based on specified market segmentations. The multinomial logistic regression (MLR) models were developed with a set of distinguished (personal/household attributes and characteristics of urban forms) independent variables to judge their effects on modal choices for all trip purposes as well. In all cases, seven alternative modes of transport were considered accordingly. The results of estimated modal shares based MNL models are presented in Figures 6-2 and 6-3 in association with observed modal shares for each cases as MNL models are very popular for policy planning purpose.

The results indicate that public transit buses have maximum mode share for all trip purposes and non-motorized mode rickshaws have also substantial mode share especially in case of education and other recreational or shopping trips. Rickshaws play the key role as a primary mode of transport for HBE trips and have significant shares for HBO trips although they have comparatively smaller shares for HBW and NHB trips. In spite of low level of car ownership in Dhaka city, its predicted modal share is significant.

In Dhaka, rickshaw is the favorite mode of transport, although the popularity of private car is increasing with economic advancement. Even people of low and medium income level are main users of rickshaws, this mode of transport is eventually expensive and some extent unsafe especially for women and aged people. Most of the people are captive users of public transport buses, as they have no suitable alternatives to choose.

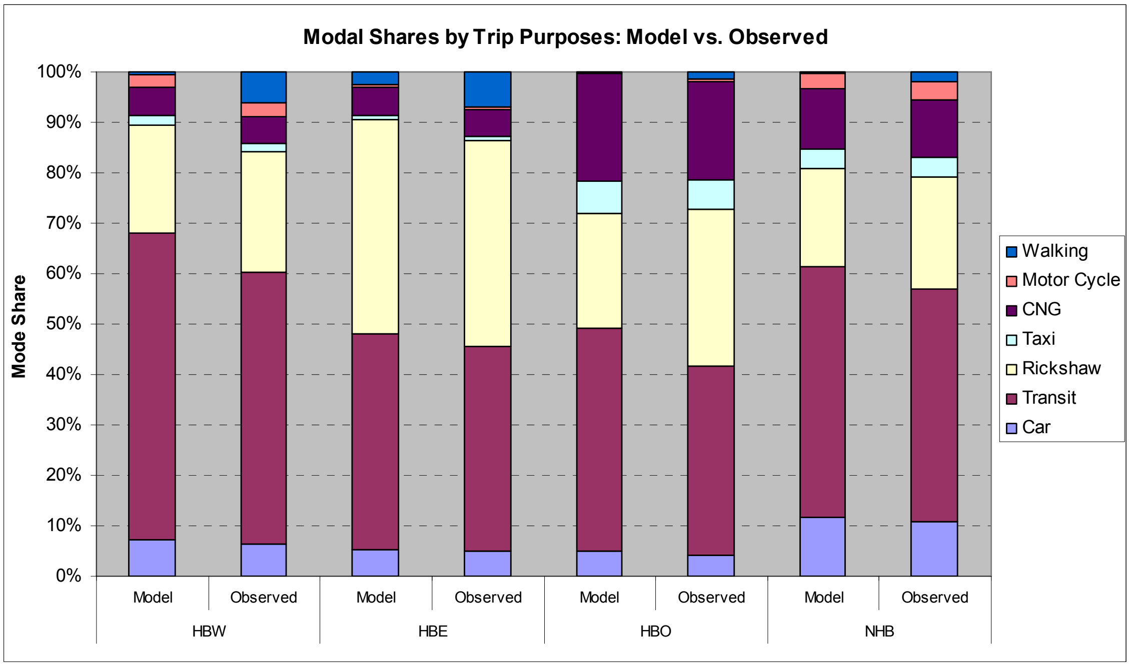
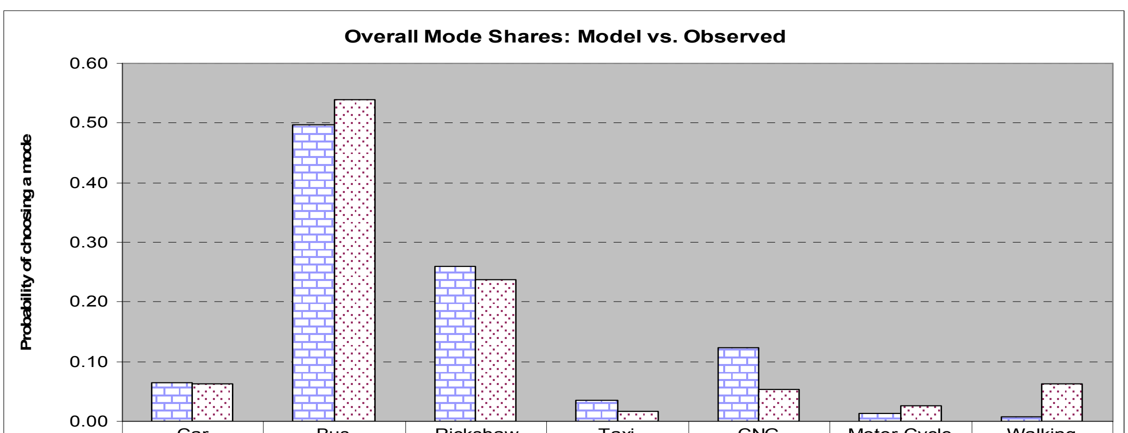


Figure 6-2: Mode Shares by Trip Purposes: Model vs. Observed



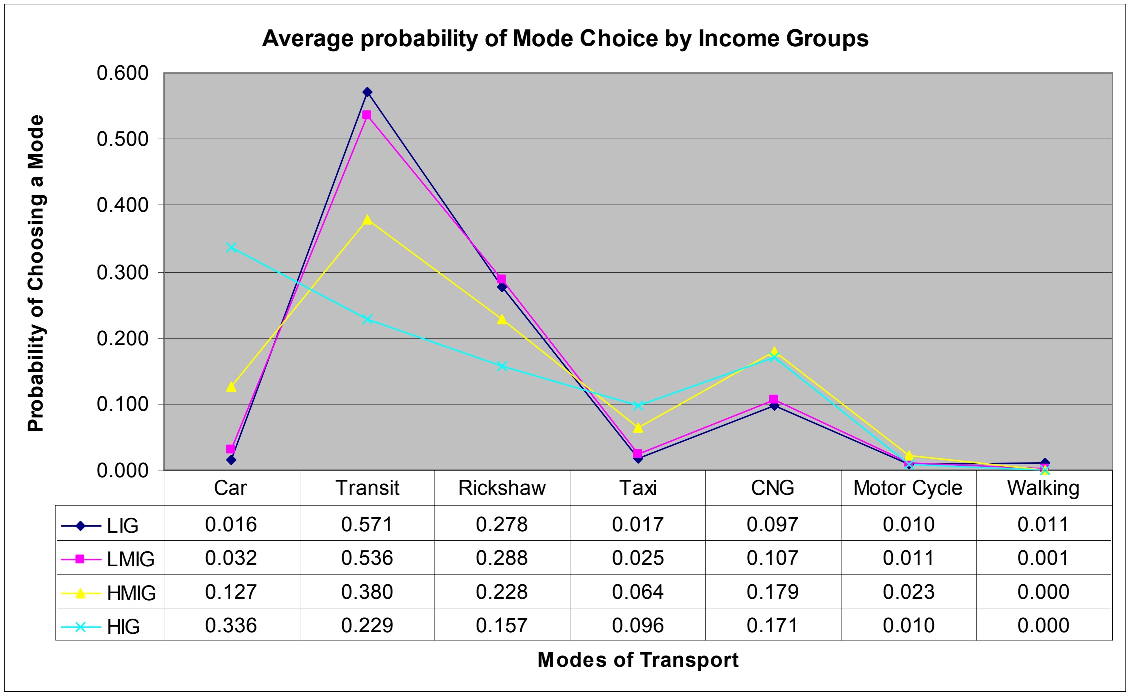
	Car	Bus	Rickshaw	Taxi	CNG	Motor Cycle	Walking
Model	0.06	0.50	0.26	0.04	0.12	0.01	0.01
Observed	0.06	0.54	0.24	0.02	0.05	0.03	0.06

Figure 6-3: Overall Mode Shares: Model vs. Observed

The parameters estimated in MLR models for all four-trip purposes clearly shows that there is a strong influence of people's socioeconomic characteristics as well as urbanization level on travelers mode choice decisions in Dhaka city. The present bus services provide inefficient, unproductive, and unsafe level of services. Long waiting, delay on plying, overloading, discomfort, and long walking distance from the residence/work place to bus stoppages are some of the obvious problems that confront the users in their daily life. In peak hours they very often load and unload in unspecified stops. It is a common practice in rush hours to deny access to the old, women, and children passengers, because this group has a tendency to avoid fighting during boarding and alighting. This is why women are very much reluctant in using buses for their work as well as all other trip purposes.

People of low-income level having lower education (especially garment workers, majority of them are women and other day-workers) are used to travel by walk although the availability of suitable pedestrian walkways/facilities is rare in any parts of Dhaka City. Household patterns, in terms of number of HH members, numbers of workers and students per HH have mixed influence on mode choice behavior. After all, HH level income is the most important determinant in owning a private vehicle or choosing a specific mode of transport in Dhaka city. To examine the effects of household income levels on mode choices we developed separate discrete choice models stratified by household income levels. Average probability of choosing a mode irrespective of trip purposes by people of different income levels are shown in Figure 6-4.

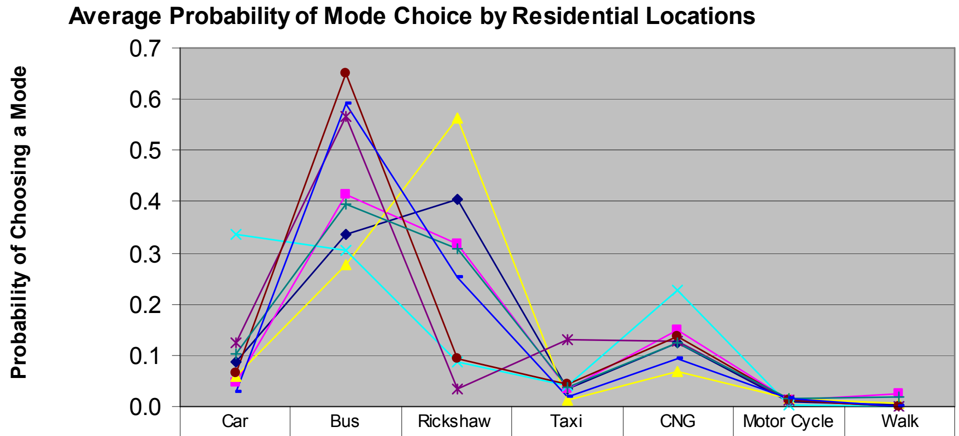
Residential environment as well as characteristics of work/destination places seems to influence the use of the different travel modes. Relatively few trips by transit, rickshaw or walk are undertaken by those living in affluent areas especially in Gulshan, Banani areas (Planned Type 1). People of older Dhaka relatively like rickshaws for all trip purposes. People living in planned areas along with good public transport facilities are more likely to use public transit buses for their trips. Those who live in Uttara (Planned Type 2) or in Mirpur (Planned Type 3) areas are big users of buses. A better supply of public transport in these areas gets people off in using rickshaws. People of western fringe area are not likely to use buses and even rickshaws due to unavailability of suitable bus routes and direct rickshaw routes in this area.



	Car	Transit	Rickshaw	Taxi	CNG	Motor Cycle	Walking
LIG	0.016	0.571	0.278	0.017	0.097	0.010	0.011
LMIG	0.032	0.536	0.288	0.025	0.107	0.011	0.001
HMIG	0.127	0.380	0.228	0.064	0.179	0.023	0.000
HIG	0.336	0.229	0.157	0.096	0.171	0.010	0.000

Figure 6-4: Average Probability of Mode Choices by Income Groups

In Dhaka, most of the roads are aligned in north-south direction and the CBD are situated in the southeast part of the city. The direct communication from western fringe to CBD areas sometimes hazardous and several numbers of transfers are involved. To examine the effects of residential locations on mode choices we also developed separate discrete choice models stratified by residential location. The average probability of mode choices by travelers of different regions are shown in Figure 6-5.



	Car	Bus	Rickshaw	Taxi	CNG	Motor Cycle	Walk
CBD-Core	0.088	0.336	0.404	0.036	0.124	0.008	0.004
CBD-Mixed	0.047	0.414	0.318	0.033	0.149	0.013	0.024
Unplanned High Densely Older Part	0.058	0.278	0.563	0.014	0.068	0.015	0.005
Planned: Type 1	0.336	0.306	0.086	0.039	0.228	0.004	0.000
Planned: Type 2	0.125	0.566	0.035	0.132	0.128	0.013	0.000
Planned: Type 3	0.066	0.649	0.095	0.043	0.136	0.011	0.000
Western Fringe: Mixed 1	0.102	0.396	0.308	0.036	0.125	0.016	0.017
Eastern Fringe: Mixed 2	0.029	0.591	0.251	0.019	0.094	0.015	0.001

Modes of Transport

Figure 6-5: Average Probability of Mode Choices by Residential Locations

The distribution of modal choices in Dhaka is unique among cities of comparable size in the world. The primary mode of transport is particularly interesting, with about a third (34%) using rickshaws, almost half (44%) using transit/buses; and a quarter (22%) comprised of walk (14%) and non-transit motorized (8%) modes (STP, 2005) considering all intra and inter-zonal trips. Buses & minibuses are the cheapest mode available as mass transit and average cost of transport ranges from about 8% of household income for high income groups to 17% for low income groups (DITS, 1993). Large groups within the society have very poor access to transport services. Since 1995 to 2005, the roads of Dhaka have increased only by 5%, but population and traffic have increased by over 50% and 134% respectively. Rapid population growth, the absence of planning control and poor economic conditions have contributed to the lack of organization on the public rights-of-way. There is also a high level of operation disorder, which significantly diminishes the efficiency and effectiveness of the existing transport systems.

6.2.3 Trip Frequency

Trip Frequency (the number of trips made by an individual or a household per day) is a measure of travel behavior. In this study, we developed trip frequency model as a binary choice model between less than or average number of trips versus more than average number of trips (per person and per household).

Estimated results indicate that households with relatively high income are more likely to make higher than average number of trips for the trip purposes except HBO trips. Households with high income have a higher value of time and this is reflected in fewer HBO trips. Women on the other hand are more likely to make fewer than average number of trips for HBW and NHB trips, but more likely to make higher than average number of HBO and HBE trips in Dhaka City. Women tend to conduct most of the non-work activities in household including drop-off and pick up of children at school and shopping. A higher trip frequency is to be expected in case of HBE and HBO trip purposes by women for this reason. The number of women in household however, does not strongly appear to affect trip making in a household. People of lower education level are likely to make fewer than average number of trips. Age level has mixed effects on number of trip making. HH Size, numbers of workers and students per household have steady weight on number of trip making per HH.

Location is significantly important for making trips. On an average people of all locations except those who live in older Dhaka are likely to make fewer than average number of work trips. Most people in older part of Dhaka are traditionally concentrated within the area they live for almost all of their daily activities. Many of them have own business close to their residents and they frequently travel between their homes and offices. A higher trip frequency is to be expected in older Dhaka for this reason. People of all regions are likely to make more than average number of HBO and NHB trips in reference to core CBD area.

6.2.4 Distance Traveled

Many countries now have policies to reduce distances traveled by private car and to favor the use of public transport, cycling and walking. The development of compact urban forms and the design of urban communities which favor walking are seen as particularly effective strategies for reducing car dependency. The factors which determine travel behavior are not fully understood, so that effective policies influencing travel patterns are difficult to formulate.

Apart from urban form and design, personal attributes and circumstances have an impact on modal choice and distances traveled. General observation is that people with higher incomes are more likely to own and use private cars and want to live in well-planned suburban areas apart from central congested business districts in most of the large cities of the world. Nevertheless, exceptionally in Dhaka, the richer people who only have access to private cars are likely to live within the central city areas as all available limited facilities are concentrated in these areas. Figures 6-6 to 6-9 present the probability of choosing a mode of transport with distance traveled for four distinguished trip purposes.

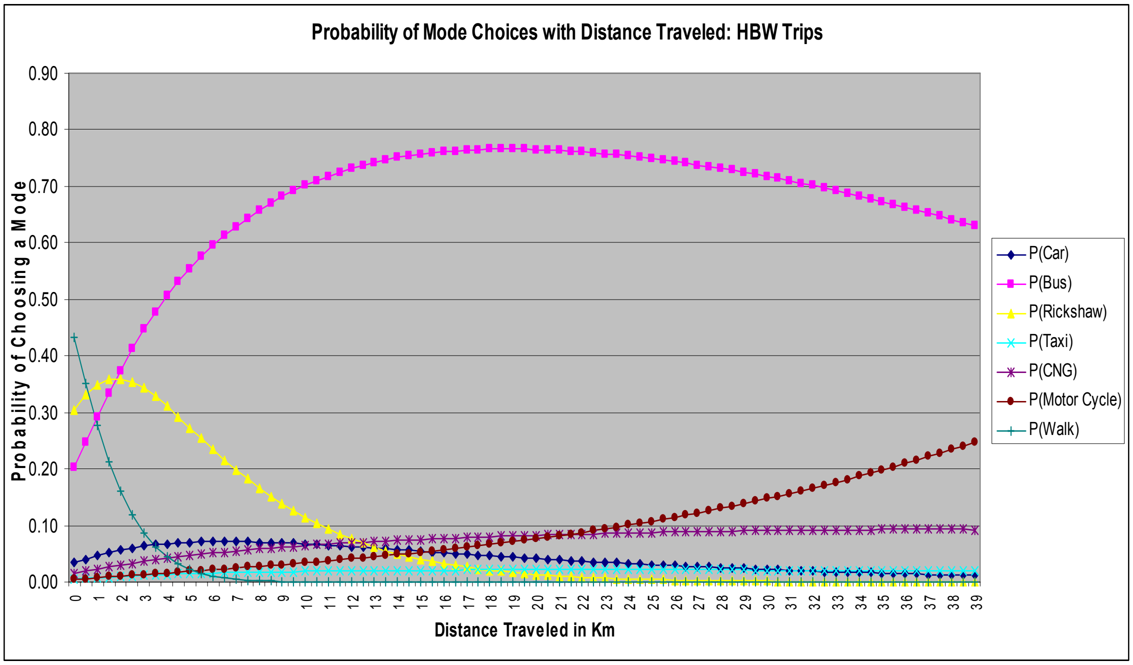


Figure 6-6: Probability of Mode Choices with Distance Traveled for HBW Trips

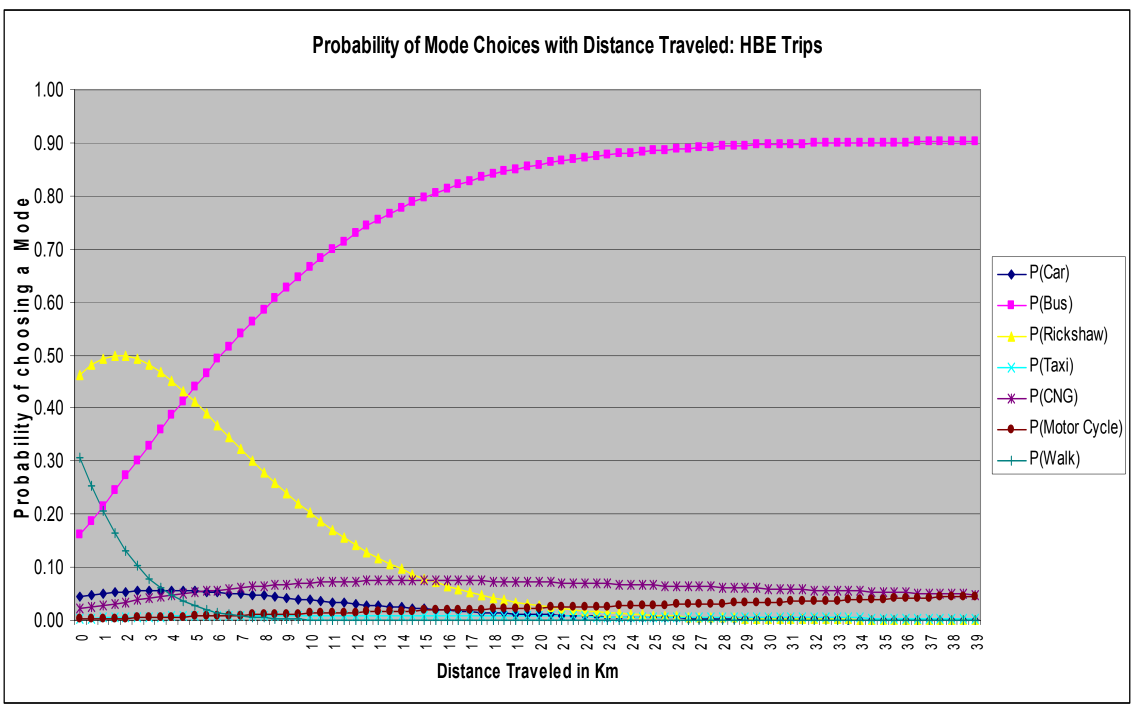


Figure 6-7: Probability of Mode Choices with Distance Traveled for HBE Trips

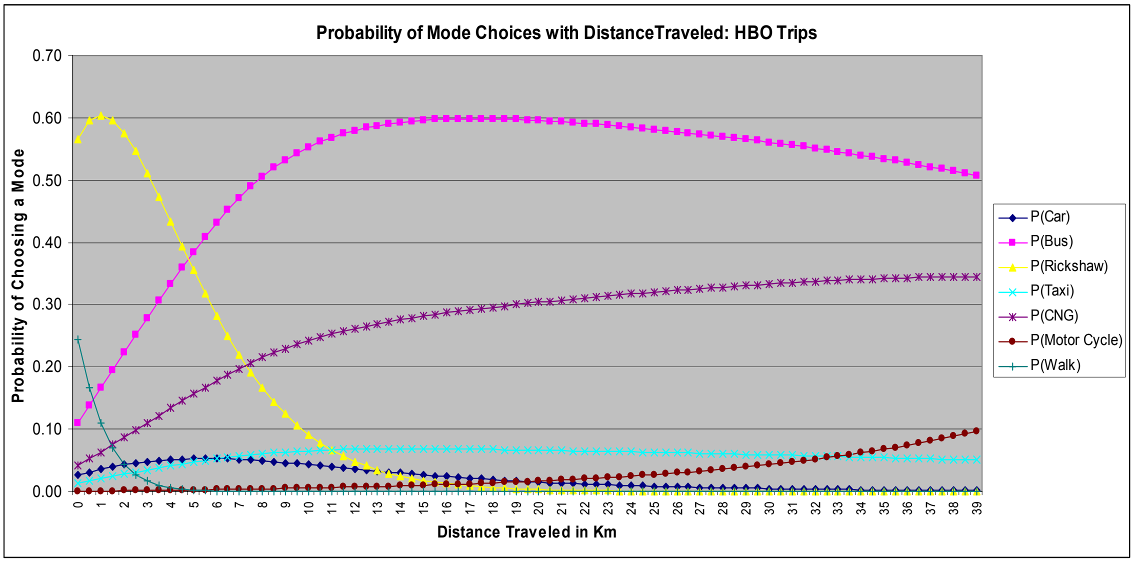


Figure 6-8: Probability of Mode Choices with Distance Traveled for HBO Trips

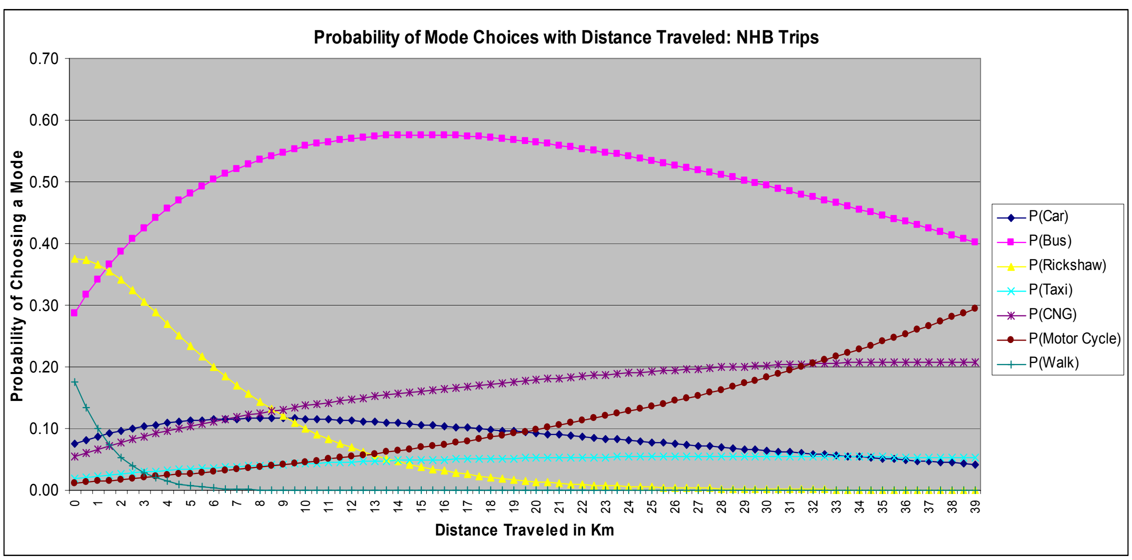


Figure 6-9: Probability of Mode Choices with Distance Traveled for NHB Trips

In all trip purposes, rickshaws play vital role as dominant mode of transport up to a distance of around five kilometers. In HBO and HBE trips, the role of rickshaws is more significant. In case of working trips, walking is an important mode of travel up to a distance less than two kilometers. The reason is that there are large numbers of working women in Dhaka city mostly working in Garments Sectors usually live nearer their work places and make trips by walking. Bus services are dominant for travel distances beyond five kilometers for all trip purposes. Auto-rickshaw (CNG) plays significant role for distance traveled in HBO trips, whereas private car is comparatively important for NHB trips.

In context of Dhaka, the private car ownership is very low comparing to other large developing cities of the world due to existing socioeconomic conditions. As explained earlier, people with higher incomes who own private car usually like to live within the central city areas as limited available facilities are concentrated within the central areas. In Bangladesh, everything is centralized to Dhaka, more importantly, there are no well-planned sub-urban cities equipped with urban facilities to attract people due to lack of proper planning initiatives.

To measure the effects of household/personal attributes and the type of urban system on travel distances by different modes of transport, we estimated four regression models for each of the four trip purposes. The results of the regression models demonstrate the importance of including personal attributes in the analysis of travel behavior. Gender is a strong determinant of distance traveled by each of the vehicular modes except motor cycle. Exceptionally, in case of HBO trips made by motor cycle, women usually shares motor cycle with their husbands or partners. In Dhaka, women travel distances as much distances as men in many cases, regardless of which mode of transport they use.

Education is also strongly related to distance traveled by different modes of transport. In case of HBW trips, the higher the education level, the longer the commuting distances are observed. HH income is a strong determinant for distance traveled by different modes of transport. People, with high incomes who own cars, travel comparatively smaller distances by cars for all trip purposes except HBO trips. The reason behind this is that people with high-income level live nearer their wok places as well as those areas where all urban facilities are concentrated and they usually travel distance places by car for non-work activities like recreational, shopping or other purposes. HH size and number of workers and students per HH have mixed effects on distance traveled by different modes of transport as well. In most of the cases, age is positively related to the distance traveled by different transport modes.

The type of daily urban system and the level of urbanization of the residential as well as work place environments within these areas remain important determinants of distance traveled for all trip purposes, especially for trips by public transport. People those who live in high densely older part of the city are less likely to travel distance places for their work trips by irrespective of transport modes used. People resided in planned sub-urban areas like Uttara (Planned Type 2) and Mirpur (Planned Type 3) are more likely to travel distance places by public transit buses as well as other modes of transport.

6.3. Issues Related to Transport of Dhaka and Need Assessment for Planning

Bangladesh, one of the most densely populated countries of the world, with a population of about 150 million, has already surrendered nearly 25% of its land to human settlements and related uses. With the current 30 million urban populations, the share of urban land is about 2 percent of all lands and nearly 10 percent of land under settlements. Due to various factors, including absence of an urbanization policy or a human settlement policy, urban growth and urban development in Bangladesh is Dhaka oriented. The trend is continuing and it is becoming more entrenched. Dhaka City is presently one of the 10th largest Mega-cities of the world with a population of about 15.0 million having the highest annual growth rate. Already over 30% of the urban population and about 10% of the total population of the country are concentrated in Dhaka Megacity region, although Dhaka's land area is less than 1% of the country's total area. The population of Dhaka is expected to be 36.0 million by 2024 with estimated total 70 million person trips a day (STP, 2005). The rapid rise in population along with increased and versatile urban land use patterns has generated considerable travel demand as well as numerous transport problems in Dhaka City. It has resulted in deterioration in accessibility, level of service, safety, comfort, operational efficiency and urban environment. The additional population in coming decades will add new dimensions to the urban fabric of Dhaka.

Any large city experiencing such phenomenal population growth would understandably face multifarious problems. If such a city happens to be the capital of a poor country and governed by inexperienced people also lacking in vision, commitment and integrity, the problems soon assume crisis proportions. This is what has been happening in the case of Dhaka. Dhaka city is growing with accelerating rate but unfortunately, transport infrastructure development of the city could not keep pace with the travel and transport demand of growing population and area. Its present traffic congestion not only causes increased costs, loss of time & psychological strain, but also poses serious threats to our socioeconomic environment.

The transport system of Dhaka is primarily road based and is comprised of many modes of travel – both motorized and non-motorized – often using the same road space – resulting in a high level of operational disorder, that significantly diminishes the efficiency and effectiveness of the resulting transport uses. Dhaka is perhaps the only city of its size in the world without a well-organized properly scheduled bus system or any type of mass rapid transit system. The deteriorating traffic conditions are causing increasing delays and worsening air pollution, and seriously compromise the ability of the transport sector to serve and sustain economic growth and quality of life. In the following sections, we analyze the burning issues related to Dhaka's transport environment by highlighting transport sector energy demand trends and the consequent impacts on environment and on the economy of the country.

Transport sector is a major consumer of energy in Bangladesh and the transportation system of Dhaka has significant liability in this context. The role of transportation has become even more important in the context of energy scarcity. Traditionally, transportation in Dhaka is based on an extensive roadway network, resulting in a burden on the economy through the import of gasoline as transport fuel. Due to rapid increase of fuel price in recent years, dependency on gasoline is causing ever increasing pressure on national economy. The road based, energy intensive transport scenario has evolved due to lack of vision in long term transport policy. High dependency on imported fuel and the increasing trends of oil price seem to be upsetting to the prospective socioeconomic growth, target of sustainable environment and millennium development goal of the country. Besides, transportation is probably one of the sectors of society where policies aiming to reduce greenhouse gas emissions will be most important as it is one of the major contributors to the global warming though burning fossil fuels.

Transport service in Dhaka has several deficiencies resulting from a combination of factors - physical, developmental and institutional-cum-policy framework-related which lead to lower efficiency, higher transport costs, longer waiting & travel time, discomfort and more significantly, “transport unreliability” with major adverse consequence for the economy & environment. An example of the absence of good traffic management and coordination among agencies is the chaotic disorder that exists in many areas of Dhaka today. Rapid population growth, the absence of planning control and poor economic conditions have contributed to the lack of organization on the public rights-of-way. There is also a high level of operation disorder, which significantly diminishes the efficiency and effectiveness of the existing transport systems.

Though Dhaka is one of the least motorized cities in the world, its traffic congestion is the most common phenomenon in our everyday life. Unplanned urbanization, especially poor transportation planning and lower land utilization efficiency, has turned the city into a dangerous urban jungle. Today the mega city Dhaka is one of the world's crowded & congested cities. Many have expressed their apprehension that Dhaka is destined to be the world's largest slum, if we make further delays to take corrective measures. With its present situation of traffic systems, the city stands in dire need for a radical transformation in the structural sense. Until and unless there is immediate and effective solution, the system will collapse. We need to take comprehensive view of the present shortcomings and future potentialities of the metropolis to identify and work out plans for formulating strategies to standardize the efficiency of traffic flow and effectiveness of transportation system because choices about transportation system concern the kind of city we want to live in. To maintain the economic viability of this city and to keep its environment sustainable, an efficient mass transportation system is imperative.

6.4 Implications of Transport Policy on Energy Demand

6.4.1 Assessment for Alternative Scenarios

Dhaka, the capital city of Bangladesh and overburdened with huge population, has also the predominantly road-based transportation system, which has already been proved as inefficient and ineffective in all respects. The rapid urbanization process, high roads-based vehicular population growth and that of the mobility, inadequate transportation facilities and policies, varied traffic mix with over concentration of non-motorized vehicles, absence of dependable public transport system, and inadequate traffic management practices have created a significant worsening of traffic and environmental problems in Dhaka city. On the other hand, the high dependency on imported fuel has exerted extreme pressure on the overall economy of the country.

The distribution of modal choices in Dhaka, which is primarily road-based, is unique among cities of comparable size in the world. Although 37-km long rail-road passes through the heart of the city but it has little contribution to city's transport system due to policy constraints. The transport system of Dhaka as well as that of the country is fully dependent on imported fuel as the local energy supply is very limited. Figures 6-10 represents the estimated energy demand by transport sector in Dhaka mega city areas over time as business as usual (BAU) or reference scenario.

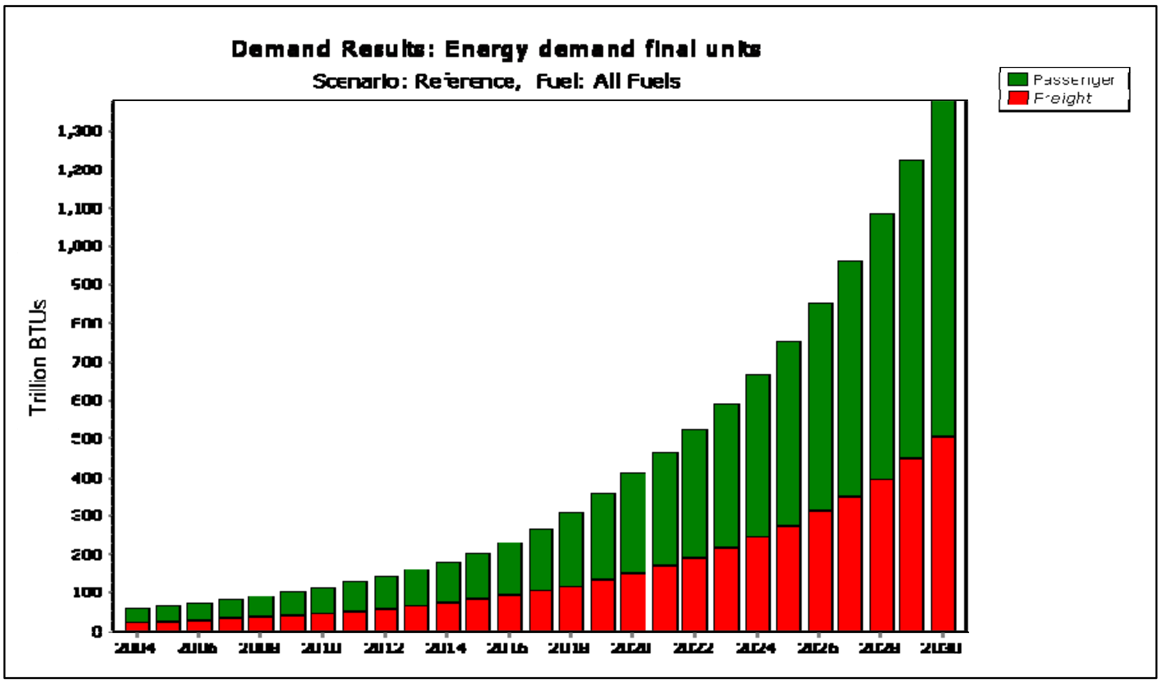


Figure 6-10: Estimated Total Transport Sector Energy Demand in Dhaka City (Scenario: Reference)

If there is a shift of modal share by 50% (both passenger and freight transportation) from existing road-based transportation system to rail system in addition to increased use of CNG in road vehicles within next 30 years considering other things remain constant, a significant improvement in energy demand is observed. Figures 6-11 shows the estimated energy demand by transport sector in Dhaka mega city areas over time based on this mitigation scenario.

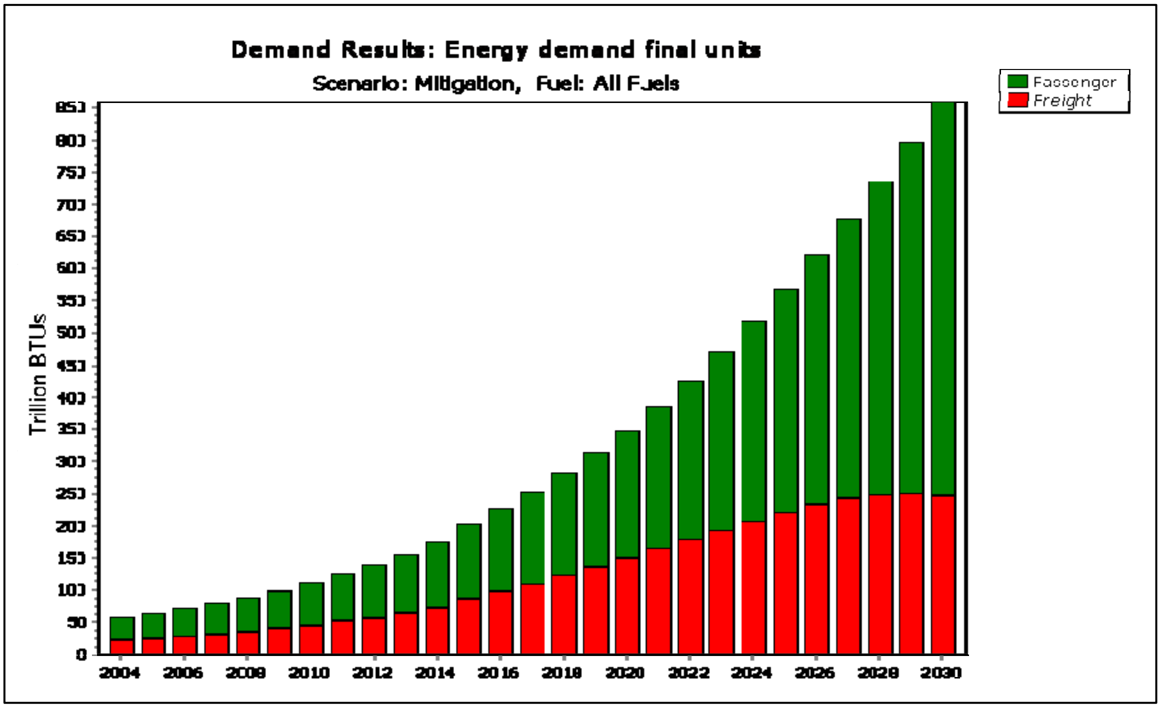


Figure 6-11: Estimated Total Transport Sector Energy Demand in Dhaka City (Scenario: Mitigation)

6.4.2 Transport Policy on Reducing Transport Emissions and Climate Change

Vehicle emissions have a direct and deleterious impact on the health and environmental targets in the Millennium Development Goals. The air pollutants most immediately damaging to human health are lead, fine suspended particulate matter (for example, dust), and ozone in some cases. Respiratory and other diseases related to local air pollution in developing countries contribute to the premature death of more than half a million people each year, imposing an economic cost of up to 2 percent of GDP in many countries (Gwilliam *et al.* 2004). Transport typically causes about a quarter of this impact, mainly from private and commercial vehicles.

Globally, motorized transport emissions also contribute to the greenhouse gases responsible for climate change (Stern 2006, IPCC 2007). Countries that are signatories of the Kyoto Protocol have made commitments to reduce these greenhouse gas emissions. To date, attention has been mainly given to the reductions attainable in power generation and large industrial processes. The progress in these other sectors, combined with the high growth in transport demand, means that the proportion of global emissions attributable to transport will increase. Climate change is undeniably the most urgent problem facing the world today. The global warming and consequent threat of sea level rise may bring disaster to the inhabitants of Bangladesh (Rahman, M.S., 2007). Other low-lying countries are also at risk, such as the Netherlands and tiny islands in the South Pacific that could eventually be swallowed by the expanding oceans. But the population of these countries is only a fraction of that of Bangladesh. A little increase in temperature, a little climate change, has a magnified impact here. That's what makes the population here so vulnerable. Global warming is, of course, much more than just a transport issue and not one that implies action only, or even mainly, by developing countries.

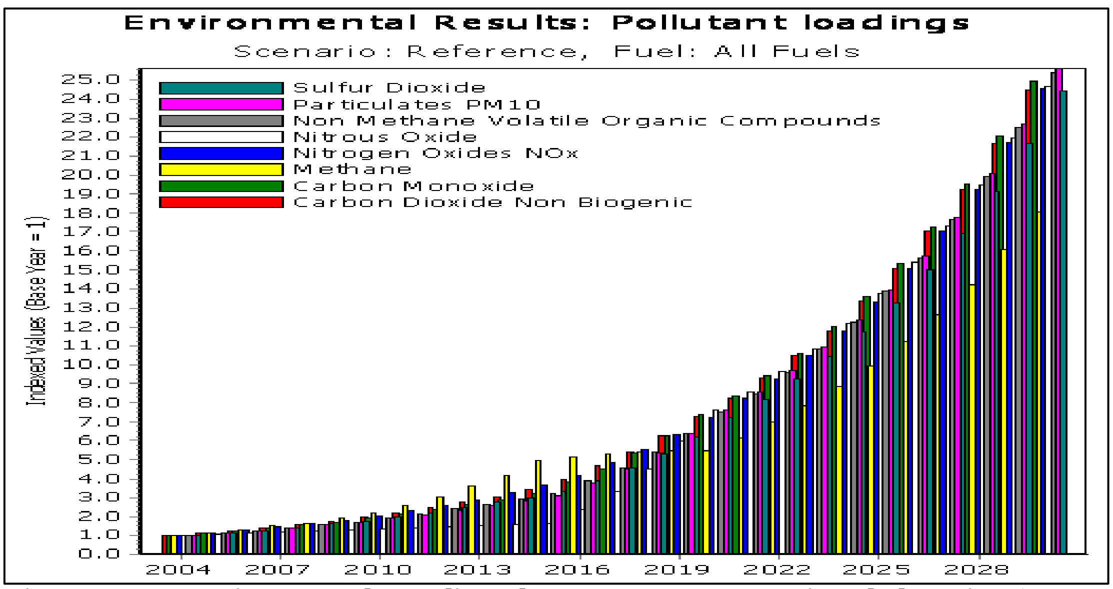


Figure 6-12: Environmental Loadings by Transport Sector in Dhaka City (Scenario: Reference)

The transport sector generates about 15 percent of global greenhouse gas emissions. In the developing world, greenhouse gas emissions from transport are growing at 3–5 percent each year, compared with 1–2 percent a year in the developed countries. As a result, it is expected that transport energy use in the developing countries will increase from 32 percent of the global transport total in 2000 to 46% in 2030. This should become one of the factors to be considered in national transport strategies and policies for both passenger transport, which contributes about 53 percent of transport emissions of greenhouse gases, and for freight transport, which contributes the remaining 47% (IEA/SMP 2004). Figure 6-12 represent the emitted environmental loadings by transport sector of Dhaka city as business as usual scenario.

There is a nearly direct short- and medium-term relationship between the volume of transport activity, the amount of energy used for that activity, and the generation of greenhouse gases. More than 95 percent of global transport energy use consists of oil-based fuels used in internal combustion engines. Policies will need to be multimodal, taking account of country circumstances, but will generally need to give particular attention to private road transport that at a global level accounts for around 70 percent of emissions, and aviation, which accounts for 12 percent (though less in developing countries). These modes are in many circumstances (though not always) the most energy intensive per traffic unit; moreover, they are fastest growing in terms of traffic volumes. Sea and inland waterway transport are together 11 percent, and railways (freight and passenger) 2 percent of total emissions (World Bank, 2007).

While economic growth contributes directly to economic welfare and poverty reduction, without international action to reduce the carbon intensity of transport in general, and road transport in particular, the consequences of growth will be to increase both the quantum of emissions from transport and its proportional contribution to total emissions. The energy efficiency of specific transport modes is crucial because virtually all measures that increase the efficiency of energy use will reduce greenhouse gas emissions per unit of transport: in other words, they can permit the benefits of transport to be sustained while making it more climate-friendly. But policies will also need to consider how to alter the demand for transport and modal distribution of transport in economically efficient ways to reduce aggregate carbon intensity. In case of 50% modal share from existing road transport to rail-based mass transit by the year

2030, the improvement on emitted environmental loading by Dhaka's transport sector are presented in Figure 6-13.

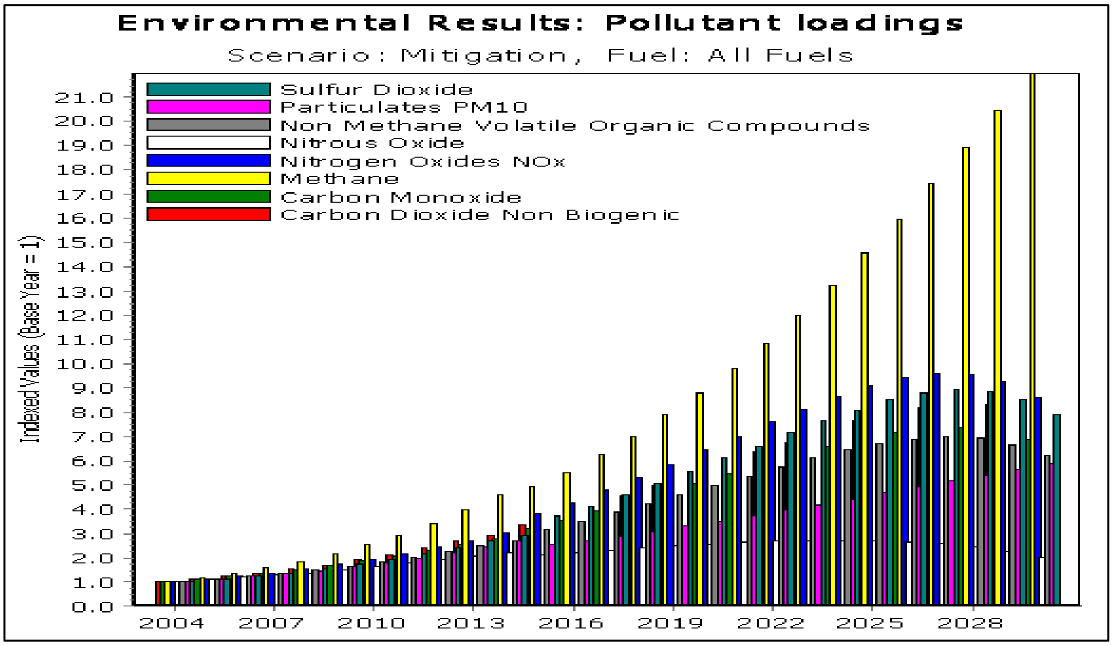


Figure 6-13: Environmental Loadings by Transport Sector in Dhaka City (Scenario: Mitigation)

This nexus between economic growth and transport-generated greenhouse gases can be moderated over time by changes in travel behavior (of people), by logistics decisions (affecting freight), by technology choices (in fuel, engine, and vehicle design), and by distribution of transport modes (cars versus mass transit, for example). These, is turn, can be influenced by planning, fiscal and regulatory measures, and public infrastructure investments. Within the policy mix, it seems likely that taxes on fuel will need to play a central role because carbon emissions are directly correlated with fuel consumption. Thus, pricing signals will affect both the immediate consumption and, if high fuel costs are expected to be permanent, the longer-term technological and behavioral responses to achieve greater energy efficiency. Moreover, revenues from such taxes can provide part of the source of public investment in less carbon-intensive transport. However, price mechanisms alone are unlikely to be politically or socially acceptable, nor sufficient for the challenge. It will take concerted and sustained long-term effort using a mix of policies, applied over decades and on an international scale, just to stabilize the level of transport–related greenhouse gas emissions.

6.5 Alternative Transportation Planning Options for Dhaka

Transport is the life of a city and choices on public transit options are fundamental decisions about a city's future growth and development. An efficient transportation system increases accessibility and improves quality of life. In terms of maintaining a transit-friendly city form and ensuring the urban poor have access to work, the selection of an appropriate public transportation system is a crucial factor to secure long-term advances – or at least to stabilize the share of people traveling by public rather than private transport. Road-based public transport, given adequate operational support can handle peak corridor flows up to a certain level, but higher flows necessitate a 'heavy' rail-based system with a higher capacity. Rail (particularly light rail and tram systems) is also justified (over a road-based system) for lower passenger flows on such grounds as being less polluting and presenting a better urban image.

A rapidly growing large city with limited supply of urban land and high density may also require rail-based mass rapid transit (MRT) to keep the city sustainable in the long run. A large city, like Dhaka, especially when it reaches a stage where the concentration of travel demand cannot be efficiently handled by the road-based system, the development of an urban rail system becomes essential. From the experience of other mega cities, road system alone cannot satisfy the need for transportation of such a large city. The existing infrastructure and social condition have not enough provision to introduce bus only lanes and bus prioritization. Due to lack of sufficient road capacity and limited scope for future expansion, bus services alone will not be able to meet the future transportation demand.

On the other hand, energy crisis as well as environmental impacts exerted by transport emission is a global concern and a very active field of research for transport planners as existing road-based transportation system is highly dependent on fossil fuel. Investigations being conducted here in this regard range from alternative fuel and vehicular technology to demand management options. Considering technical and economic constraints many alternatives that are being pursued in the developed countries might not be feasible in the context of Bangladesh. In the limited scope of this study, impacts of few feasible alternatives are discussed below:

a) ***CNG Conversion***: in recent years, government has been actively promoting the use of Compressed Natural Gas (CNG) as alternative fuel for transport vehicles. In the last three years, all the urban three wheeler para-transits have become CNG based and about 10 percent of other motorized vehicles have been converted to CNG. Due to CNG conversion policy total imported consumption will reduce. It is worthy to mention that although consumption of CNG as transport fuel may reduce economic burden in the short term, policy makers should be concerned with its limited availability, international market price and opportunity cost.

b) ***Modal Shift to Rail Transport System***: Flat terrain, almost square shaped geographical layout and inherited railway system make the capital city Dhaka highly suitable for rail transport system. Unfortunately, it has been severely neglected in the last couple of decades resulting in reduction in its role in urban as well as national transportation.

Although 37-km long rail-road passes through the heart of the city but it has little contribution to city's transport system due to policy constraints. Recently government has taken initiative to revitalize rail system, which is more efficient with respect to energy and environmental considerations. A 50 percent diversion of modal share from road to rail, in addition to increased use of CNG in road vehicles, may reduce transport energy import demand to about 522.40 trillion BTU in 2030 and result in significant amount of cost reduction (Figure 6-14). Electrification of rail system will also have a beneficial effect on petroleum imports as natural gas is the principal fuel to generate electricity in the country. Meanwhile, it should be recognized that for materialization of the modal shift improvement in service quality is required which needs commensurate investment.

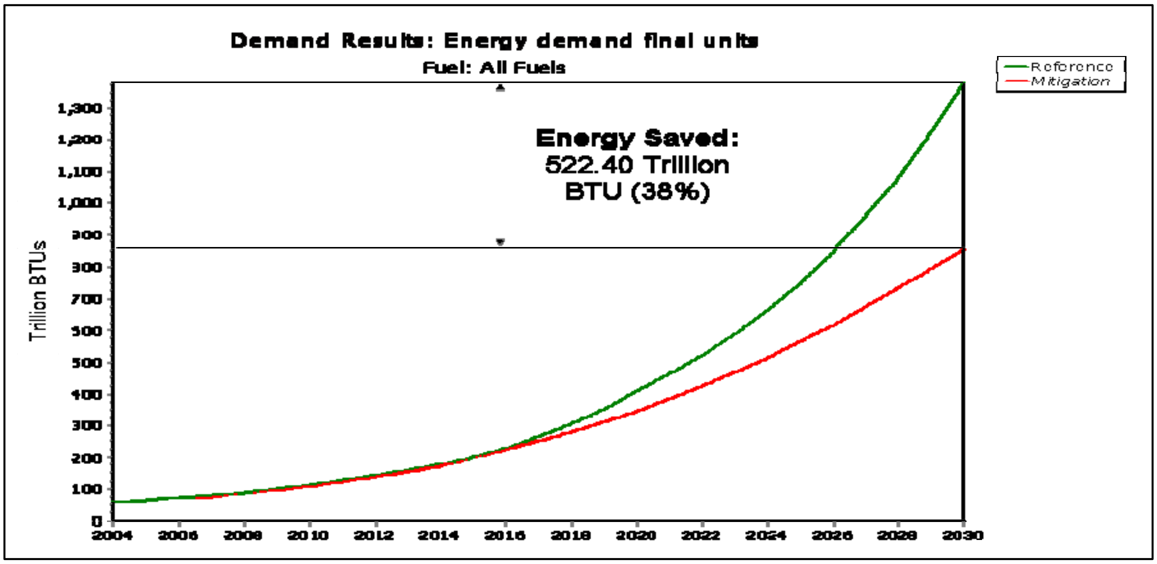


Figure 6-14: Effects of Policy Options on Transport Sector Energy Demand

c) *Modal Shift to Water Transport System*: Dhaka has unique potential for waterways development due to surrounding rivers and waterways in the metropolitan area. The Buriganga River, the Turag River, the Balu River, and the Sitalakhya River together, encircle all of Dhaka City. They also serve nearby areas that are in the process of being developed and are most likely to experience significant development in the future. At one time, there were also a number of open water canals and inland lakes throughout Dhaka. However, many of these canals and lakes have been filled-in or blocked. Due to lack of proper attention, role of the waterways is very insignificant. Through appropriate planning and investment, its role can be enhanced thereby reducing pressure on road network. In terms of shift in modal share especially for freight transportation, waterways can play vital role as this can be achieved through minimal investment, which may result in reduction of energy demand significantly.

Moreover, the useful insights regarding strategic options obtained from this study highly suggest the following policy measures for the sustainable transportation system of Dhaka city:

- Reorient traffic priority, putting pedestrians first, followed by cyclists, rickshaws, and energy-efficient environment-friendly mass rapid transit (MRT). Cars should be given the least priority.
- Provide street-level crossings throughout the city for pedestrians and create cycle lanes, making a continuous cycle network throughout the city.
- Invest in the development of improved rickshaws and provide licenses and adequate training for all mechanically fit rickshaws and rickshaw pullers respectively. Provide adequate road space for rickshaws, preferably under an integrated public transit and fuel-free transport (FFT) system.
- Completely ban car parking on footpaths. Charge for car parking in all public areas including street at market rates, by the time for which the car is parked. Enact a range of measures to restrict the growth in cars, including limiting licenses, restrictions on imports, and higher taxes on car and remove all type of fuel subsidy thereby rendering alternative options to be economically equitable. Abandon car-friendly and capital-intensive transport policy and explore eco-friendly & sustainable alternatives.
- Adopt integrated demand and supply management for the development of a sustainable transport system for Dhaka City.
- Adopt a sustainable 'smart' land use policy to promote concentrated and mixed-use land development and reduced travel need. Relocate garments and other large industries form DCC areas and decentralize the public administrations.
- Adopt a people-oriented transport policy aiming at maximizing door-to-door mobility & accessibility of people and goods, not just movement of vehicles within road links.

- Reduce fuel use by providing government officials with bus services, reduce parking spaces, and provide economic incentives to walk or cycle work. Introduce car-free zones in CBD and roadside shopping areas.
- Assess transport policy by considering key wider policy issues such as economy, environment, accessibility, safety and social equity.
- Properly integrate an-well designed MRT system [the MRT system proposed by the STP (2005) study needs more careful and details feasibility study considering the local needs in context of socioeconomic as well as geopolitical situation of the country as a whole] with improved local transports, ensuring adequate and continuous FFT and pedestrian facilities.
- Strengthen the existing railway service as primary mode of transport for commuter trips of mass people from surrounding suburban areas. Retain the central railway station at Kamlapur, and reorient and connect it with circular and commuter rail services.
- Finally, develop an integrated waterways network for Dhaka City as Dhaka has very strong potentialities for circular waterways development.

Transport not only plays a key role in the daily functioning of cities but can also be a tool for managing growth. A unique opportunity exists to meet the challenge of the exponential growth of development of Dhaka in more sustainable directions through rationalized and accessible transport. Therefore, transport policies should be integrated with efficient land use plan as a fundamental part of city development program to secure long-term benefits and to ensure sustainable development. It is important to embed these issues within a wider policy context that reflects economic efficiency, social equity and political feasibility. Policies also need to reflect local circumstances. However, transport in all its facets is a remarkably diverse sector. Roads, railways, buses, metros, taxis, bicycles, tri-cycles/rickshaws, waterways, and the many combinations of these—all these diverse modes of transport may serve particular parts of a wide spectrum of needs that arise in moving freight and passengers in a city. As trade has globalized and incomes have risen, the demand has mounted for all types of transport services and the infrastructure on which they rely. This more holistic view of transport, which is reflected in the business strategy, supports both integrated urban transport systems to serve regional integration and international trade. Balanced investment in many modes of public transport can contribute to making cities work better: urban roads, railways, and even non-motorized transport all contribute most effectively when the service offered to the public is integrated to create physical connectivity, spatial coverage, and ease of transfer.

6.6 Summary

This chapter analyzed the output results of the study and discussed related issues in details. It is found that the complexity of people's travel behavior in Dhaka City is highly influenced by socio-economic as well as spatial characteristics of the city itself. The diverse modal choice behavior of travelers is greatly influenced by household/personal attributes and types of urban forms and urbanization level. This chapter analyzed and discussed the issues related to transport of Dhaka and highlighted the need assessment for planning. Implications of transport policy on transport sector's energy demand and consequent environmental impacts are analyzed through alternative policy scenarios. Finally, a short discussion on alternative transport planning options for future Dhaka was presented analyzing different issues related the present and prospective socioeconomic and geo-political conditions as well as growth and development pattern of Mega City Dhaka.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The critical issues for developing a travel behavior model for Dhaka City are how to handle the extensive growth of a mixed land use pattern, the heterogeneous socio-economic structure, complex travel pattern and the mixed-mode transportation system. An attempt has been made to address these crucial issues in this study. In order to deal with the matter, a comprehensive modeling framework, consists of several sub-models namely mode choice models, trip frequency models and distance travel models, is developed and implemented to simulate the travel behavior of Dhaka city considering the influences of socioeconomic characteristics and spatial environments of the places where people live, work and travel. It comprises a system of models for simulating the travel behavior by applying a series of relevant models. The framework is developed based on a number of principles such as having strategic perspective; being market oriented; addressing heterogeneous demand characteristics; following disaggregate approach and capturing the multi-modal nature of the transport system of Dhaka.. The complexity of the travel behavior of Dhaka is addressed by following a simple, modular and flexible structure so that individual model elements can be refined, enhanced and applied easily.

The mode choice models presented in this study are discrete choice models based on the random utility maximizing principles as the research direction currently being pursued in discrete choice modeling. The multinomial (MNL) and nested logit (NL) models are considered the traditional approaches of discrete choice modeling and this study is focused on these traditional approaches of discrete choice modeling; because, these models can already provide answers to the objectives being put forward. Moreover, there are still quite a few studies of this nature in developing countries like Bangladesh and these closed form models are still very popular when used in transport policy applications.

Before development of the modes, all intra-zonal trips have been separated from the total zonal trips by using purpose specific percentages of intra-zonal trips observed in obtained data set in the pre-distribution trip split stage. Then the inter-zonal trips have been divided into four groups considering the four trip purposes. The post-distribution mode choice models derive the mode choice coefficients using multinomial logit and nested logit models considering seven modes of transport namely motorized modes - private car, taxi, auto-rickshaw (CNG), transit/buses and motor cycle; and non-motorized modes – rickshaw and walking. One of the significant importance of the developed mode choice models for four distinguished trip purposes is that the models exploit the widely used traditional approaches of discrete choice modeling (both MNL and NL) framework considering the dominant non-motorized mode rickshaw and all possible minor modes available in Dhaka City which is an awesome attempt for Dhaka City. The coefficients of time and cost for different trip purposes have been estimated. The model calibration results give satisfactory goodness-of-fit measures.

To examine the effects of exogenous variables on mode choice behavior, separate multinomial logistic regression models (multivariate techniques) are developed for each of the four trip purposes as these multivariate techniques are very useful for travel studies because so many factors are at play.

Trip frequency is a measure of travel behavior. In this study, trip frequency models are developed as a binary choice (logit based binary models) model between less than or average number of trips versus more than average number of trips (per person and per household) to identify how socioeconomic attributes and land use type influence on making number of trips by person and by household level.

The measure of distance traveled by a traveler for different trip purposes is another important device of assessing the travel behavior pattern of a city. To measure the effects of household/personal attributes and the type of urban system on travel distances by different modes of transport, four regression models are developed for each of the four trip purposes. The results of the regression models demonstrate the importance of including personal attributes in the analysis of travel behavior. Moreover, to measure the variation in distance travel by different modes, four separate trip length frequency distribution (TLFD) models are developed for distinguished trip purposes.

In addition, several analyses based on Multiple Classification Analysis (MCA) to clarify the travel behavior pattern of the city dwellers are also presented in this study. The variables considered in the MCA are region/location of household, household income, household size, the number of employed persons and the number of students in the household and personal attributes like sex, age, education etc. Three-way cross classification trip rates have been established for four trip purposes. Multiple classification analysis is applied in calculating the trip rates in household level.

Finally, an attempt has been made to evaluate alternative planning options for the transportation system of future Dhaka based on the performance evaluation of existing transport infrastructure in context of aggregate level assessment of transport sector energy demand/consumption and consequent environmental impacts under various scenarios, using a modeling framework based on Long-range Energy Alternatives Planning (LEAP).

In conclusion, using the models developed in this study, transport policies should be tested and reflected through the transport policy variables in the utility equations. The transport policies should be tested according to their most likely effects on mode choice probabilities considering future energy demands and socioeconomic contexts. Moreover, given prevailing issues and problems related to the urban transport system of Dhaka, the application of discrete choice modeling presented in this study considering minor and non-motorized modes to adequately capture tangible and intangible factors affecting the urban traveler's mode choice behavior is a daunting task.

7.2 Major Findings of the Study

The results of the study presented in this research using different models can be translated into specific land use and transportation policies for any developing cities like Dhaka. The analyses have confirmed that spatial configuration of land use and transport infrastructure as well as socioeconomic characteristics has a significant impact on travel behavior of the city dwellers. Urban structures as well as people's socioeconomic characteristics affect mode choice, trip frequency and travel distance for different travel purposes. Personal characteristics remain important in travel behavior when spatial environment is taken into account. The characteristics of spatial environments retain their impact on travel behavior when personal characteristics are held constant. Some major findings of this study are summarized below:

- ❖ Travel behavior is a complex phenomenon which is highly influenced by daily personal activities, household socioeconomic characteristics and spatial urban forms of the places where people live, work and travel through in a fast growing developing city like Dhaka.
- ❖ There is a high propensity of the city dwellers to choose specific modes for certain trip purposes on some specific grounds which are also influenced by the personal/household attributes and land use pattern of the city.
- ❖ Public transit bus and non-motorized mode rickshaws are very competitive although buses have maximum shares for all trip purposes. Rickshaws are highly dominant for education trips and have significant shares in home-based other non-work trips.

- Private car and auto-rickshaws (CNG) are highly competitive with each other although the car ownership level in Dhaka is till very low and cars are mostly owned and used by the richer part of the society. As affordability increases, people move to personalized vehicles and in Dhaka CNG is comparatively suitable alternative of private car for majority of people as it is convenient, relatively cheaper and available than taxi and seems to be a personalized vehicle.
- Gender has significant effect on mode choices – women are more likely to use rickshaws for works trips, but they do not like rickshaws for longer distances; they usually dislike bus for its low standard service quality and strongly disagree in using Motor Cycle.
- Women are relatively more likely to make fewer trips than men, but they have high tendency to make more non-work trips especially shopping trips and education trips.
- Education level and HH Size present mixed effects on mode selection and distance traveled. Low educated people usually make fewer trips.
- Income level has strong influence on modes selection and distance traveled. People of lower and lower medium income levels prefer walking, rickshaws or transit other than personalized motorized vehicles as captive users.
- People of high income level usually use car and taxi and they are not like to travel long distances for work trips, like to have residential locations nearer to workplaces, a contrary finding to that observed in developed countries. Households with high income make higher than average number of trips.
- Spatial environments i.e. places where people live and work have very strong influence on travel behavior- people living at well planned and affluent areas and suburban areas show sharp decline in the likelihood of using slow moving rickshaws for their work trips comparing autos. People living at unplanned densely areas are likely to travel fewer distances and like rickshaws. People living in planned and suburban areas are likely to

use transit for long distance traveling. People from all regions show tendency for making more than average no. of trips comparing to CBD-core but this magnitude in planned and suburban areas is smaller.

Moreover, the useful insights regarding the strategic options found from the assessment of transport sector energy demand and consequent impacts on environment exerted by the existing road-based transport systems highly suggest for energy-efficient alternative transit options to handle increasing travel demand of Dhaka City as well as to secure long-term benefits of the economy and environment of the city and the country as a whole.

7.3 Limitations of the Study

The scope and limitations of this study are mentioned in details in section 1.4 of the first chapter. In addition, we faced some specific difficulties. Although the demographic and socio-economic variables used in the study are based on several authentic secondary sources; however some contradictions remain among sources for their accuracy level as to maintain the level of precision for thus types of information especially in context of developing country like Bangladesh is highly questionable. Although the data used in this study obtained from a large number of samples based on household interview survey (HIS) conducted by the STP (2005) Study, there are some lacking of equal presentation of all social groups in all regions of the study area especially for some minor modes like motor cycles, taxi, and walking. Besides, detail information on travel cost by different modes of transport are not available in the data bank obtained from the original STP (2005) HIS. A large-scale more detailed survey would be more appropriate for better estimation of travel behavior of all social groups. However such a survey requires huge funds as well as much time.

7.4 Recommendations for Future Research

This study has the potentials for opening a new avenue for researchers involved in transportation planning for Dhaka City. Several areas for future researches have been identified in connection with this study. Modeling framework and structure proposed in this study can be tested and its performance can be evaluated. For example, in the current study separate multivariate techniques were developed to examine the effects of exogenous variables on mode choice, but a comprehensive mode choice model can be developed and calibrated considering all possible exogenous variables in a single modeling framework. Besides, someone can test the models by deleting, adding or changing some variables and thus the individual model elements can be further refined or enhanced. Nevertheless the GIS land use database can be strengthened with new land use category appropriate for transportation model. Importantly, a comprehensive travel demand modeling framework should be developed and calibrated for Dhaka city considering the prevailing issues of Dhaka's transport systems, mixed land use pattern, level of urbanization and trends of overall growth and development of the city.

The most significant research can be made using the framework suggested in this study for transport sector energy demand assessment and consequent impacts on environment is evaluating alternative planning options for Dhaka city. Future transport sector energy demand can be predicted and performance of the proposed transport facilities can be evaluated under the future demand in terms of energy consumption and environmental loadings. In this regard, it is necessary to develop a comprehensive travel demand forecasting modeling framework suitable for heterogeneous traffic system of Dhaka to predict the future travel demand more accurately and simultaneously it is obligatory to generate alternative policy scenarios based on reliable forecasting of socioeconomic indicators and thus the alternative strategic options can be evaluated for their effectiveness in solving the future transport related city developmental problems of Dhaka City in local contexts.

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APPENDIX – A: FIGURES AND MAPS

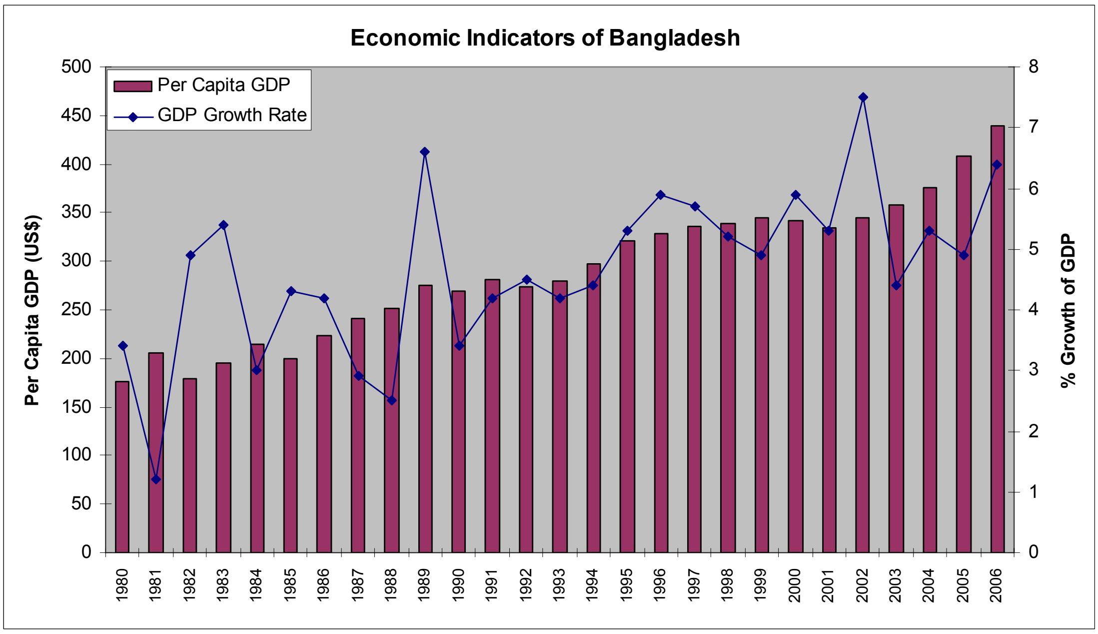

Figure A-1: Per Capita GDP and Overall Growth of GDP in Bangladesh: 1971-2004
Sources: GOB (2000); BBS (2005)

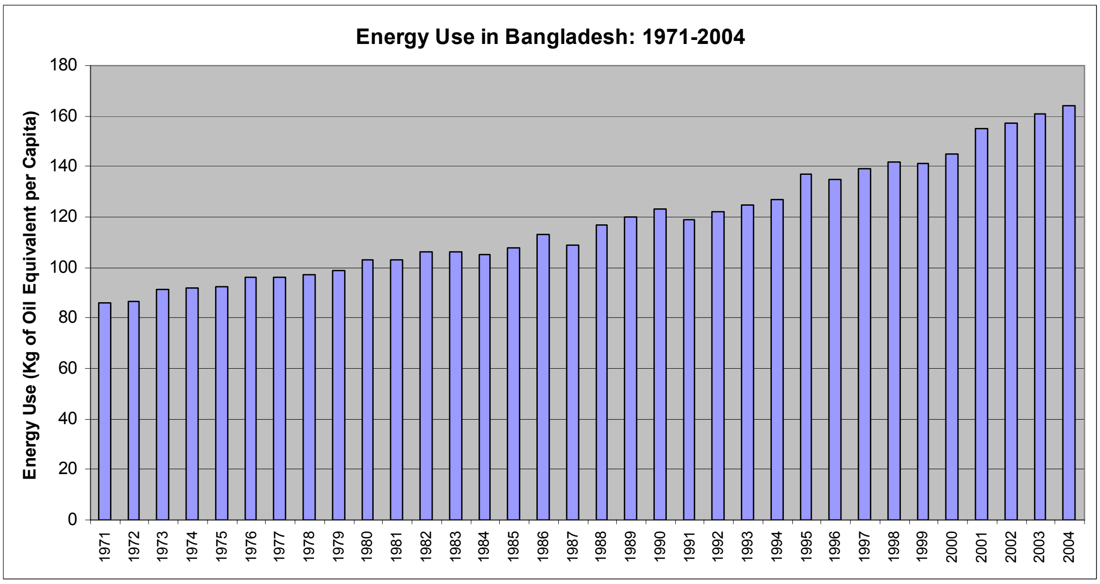

Figure A-2: Per Capita Energy Use in Bangladesh:1971-2004
Source: Source: World Bank, "World Development Report 2000/2001

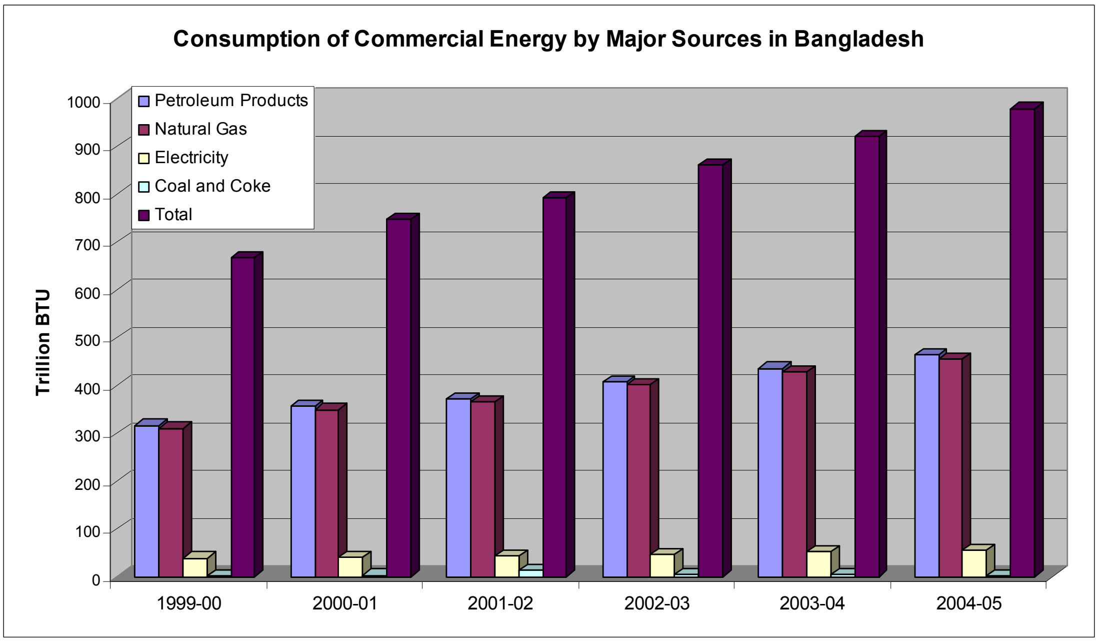

Figure A-3: Consumption of Commercial Energy by Major Sources in Bangladesh
Source: BBS (2005)

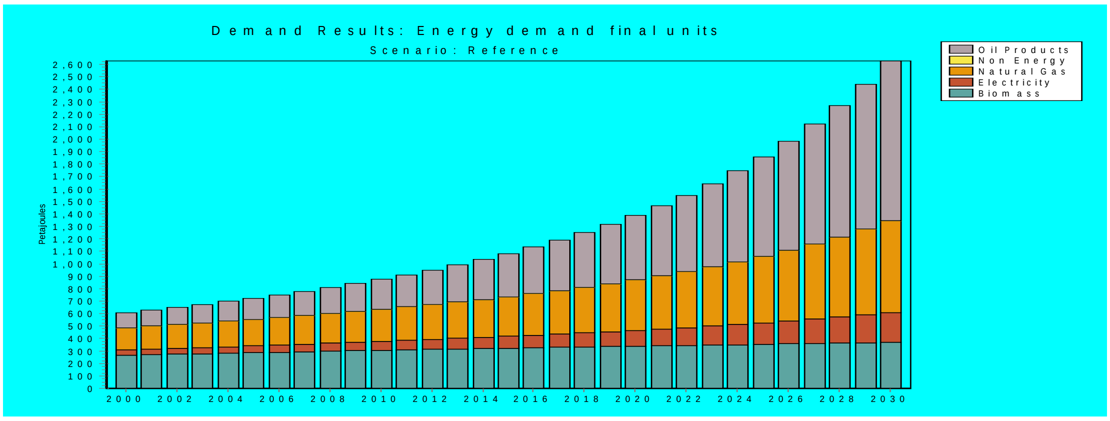

Figure A-4: Projected Energy Demand in Bangladesh
Source: J.B. Alam (2008)

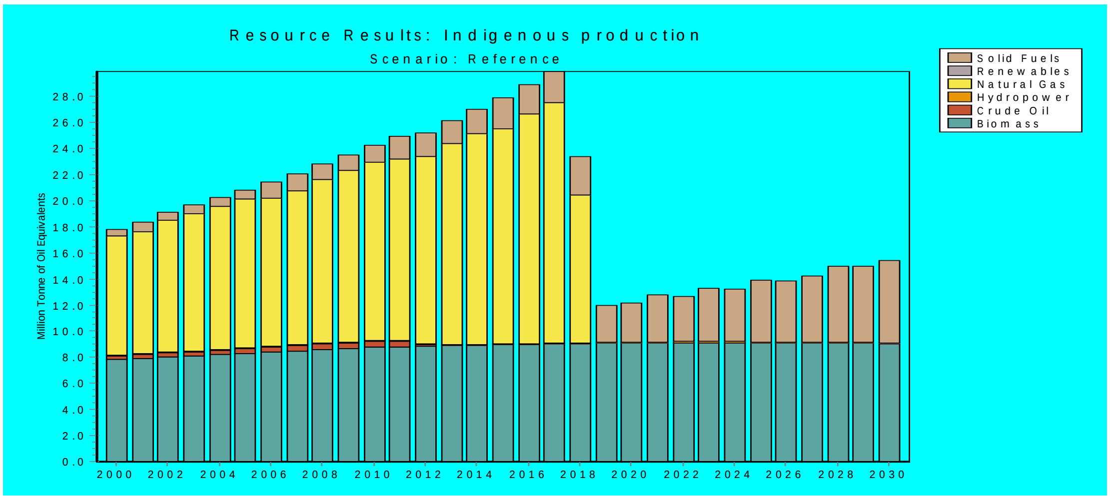

Figure A-5: Projected Energy Supply from Different Sources in Bangladesh
Source: J.B. Alam (2008)

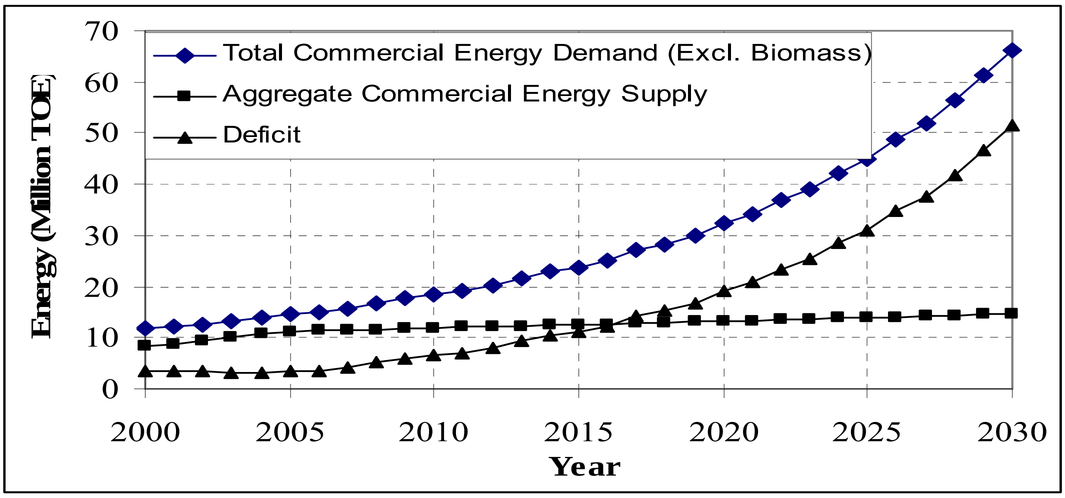

Figure A-6: Projected Energy Situation in Bangladesh
Source: J.B. Alam (2008)

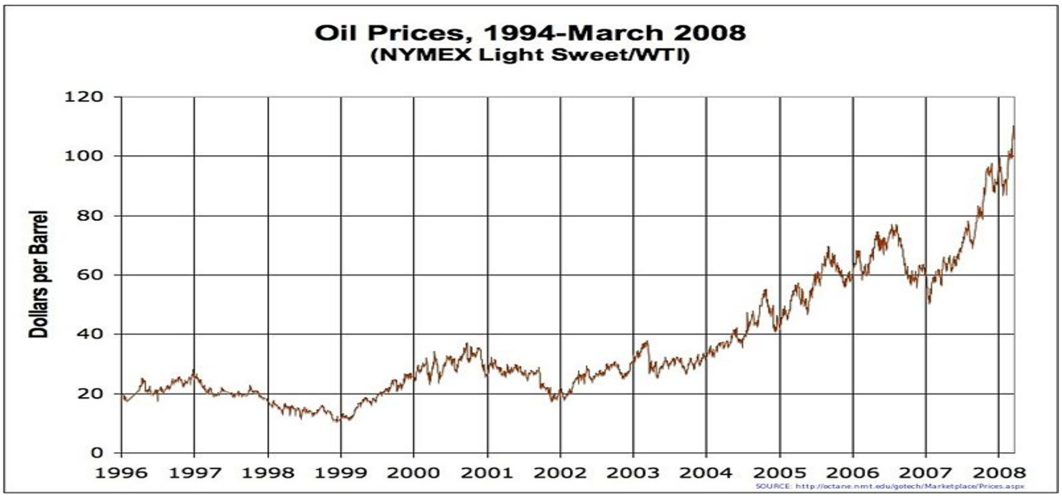

Figure A-7: Trends of Oil Price Increase over Time
Source: http://en.wikipedia.org/wiki/Oil_price_increases_of_2004-2006

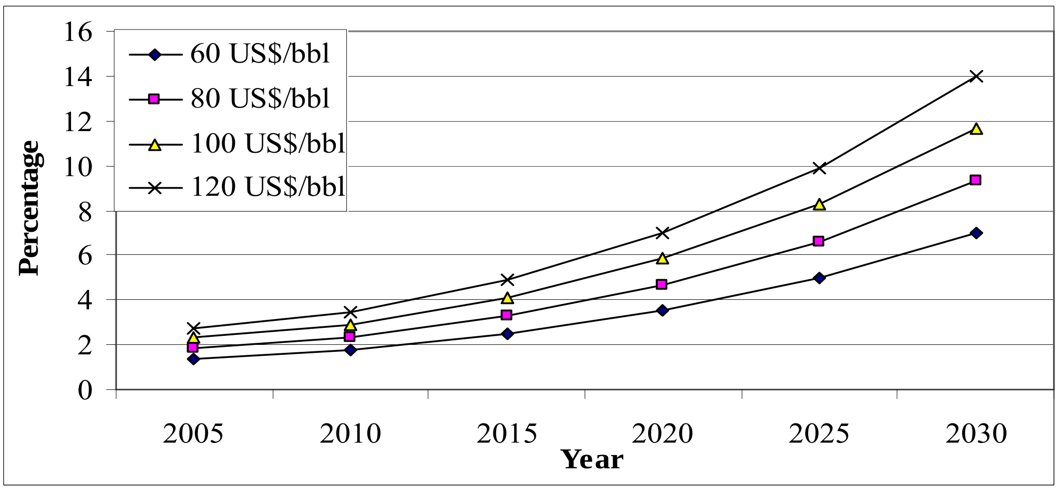

Figure A-8: Effect of Fuel Price Increase as Percentage of GDP
Source: J.B. Alam (2007)

Figure A-9: TAZ locations and their boundaries of the Study

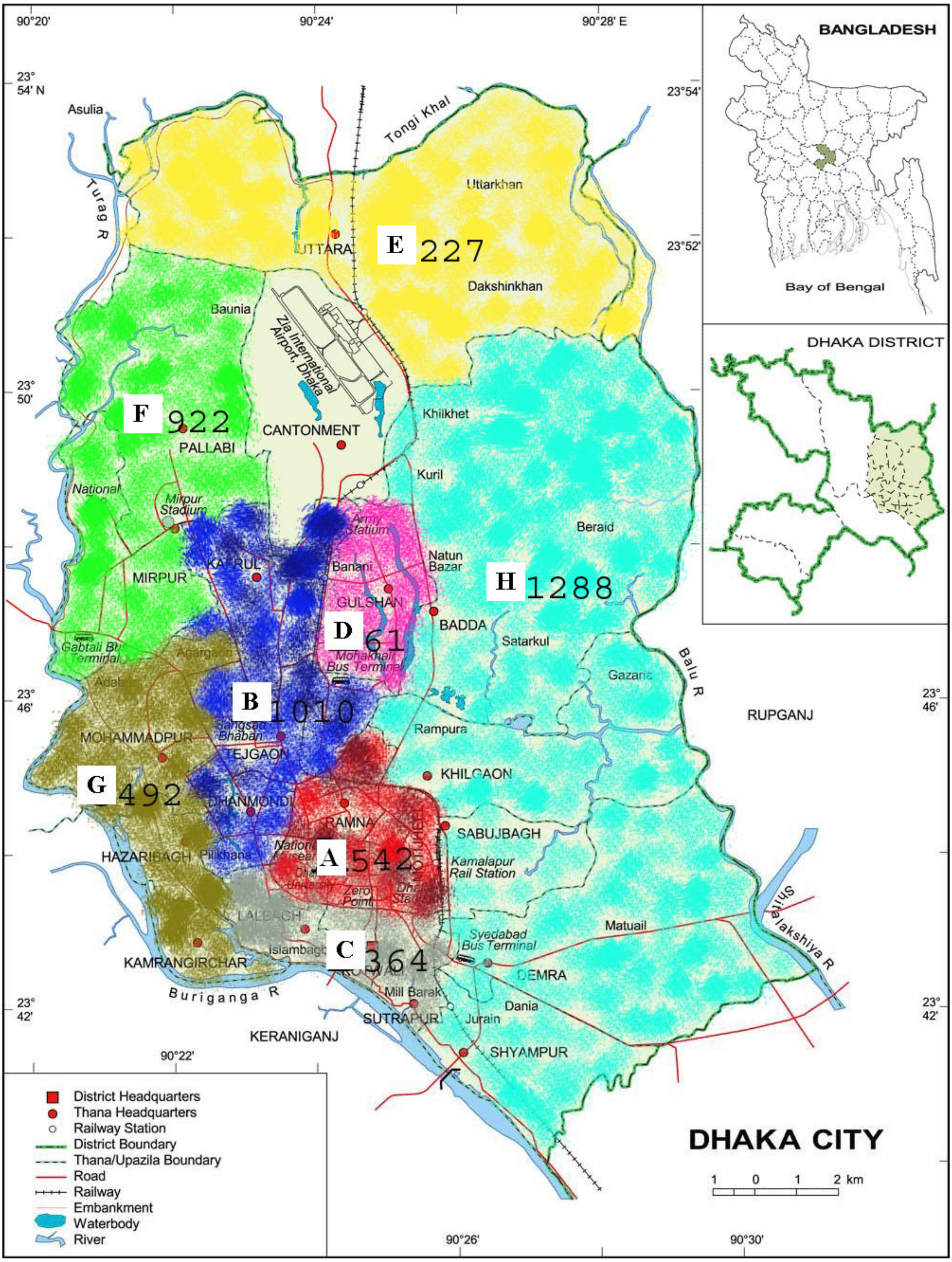

Figure A-10: SPZ Locations and their Boundaries of the Study Area with HH Data Samples
Source: Banglapedia and STP (2005)

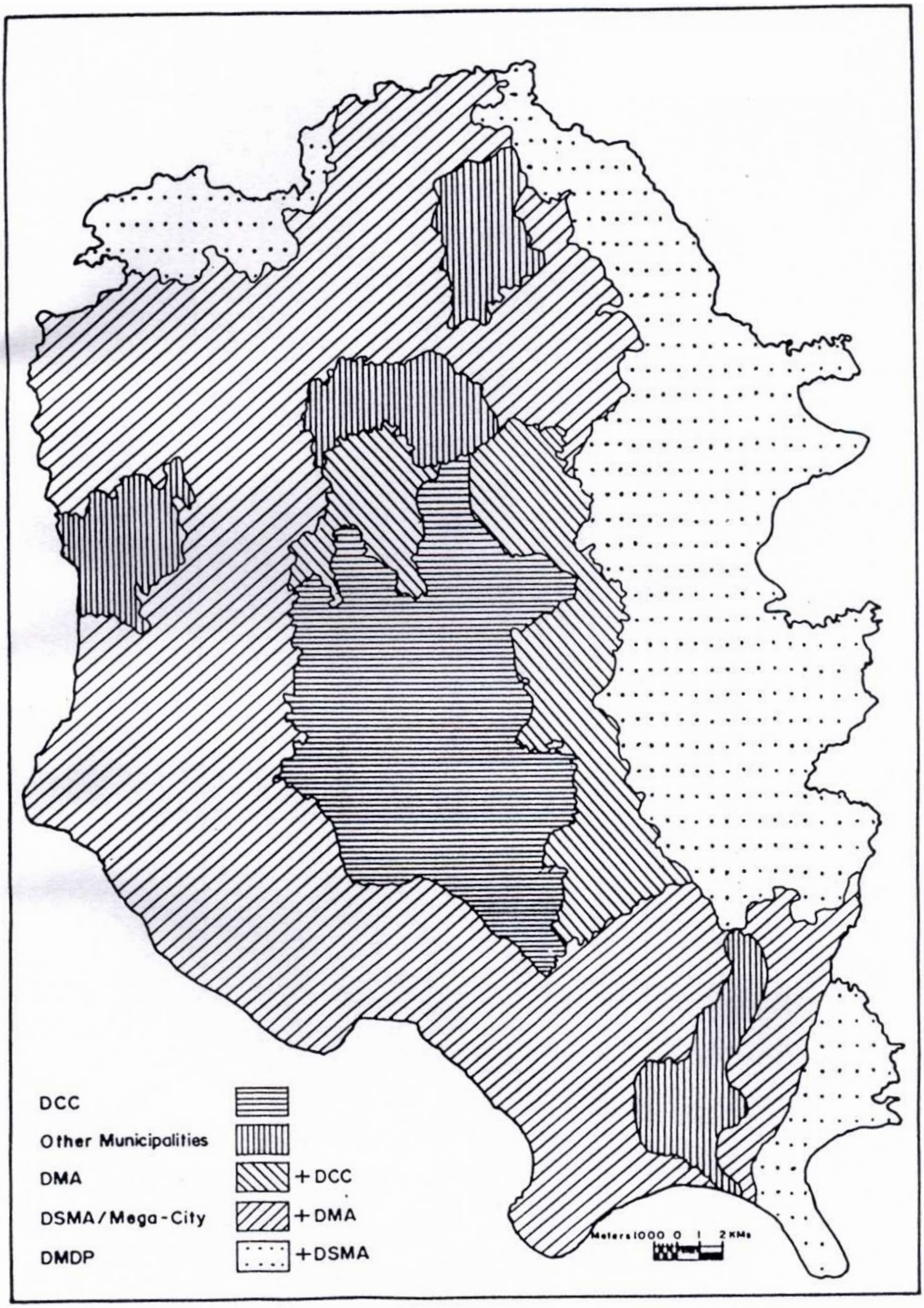

Figure A-11: Configuration of Dhaka

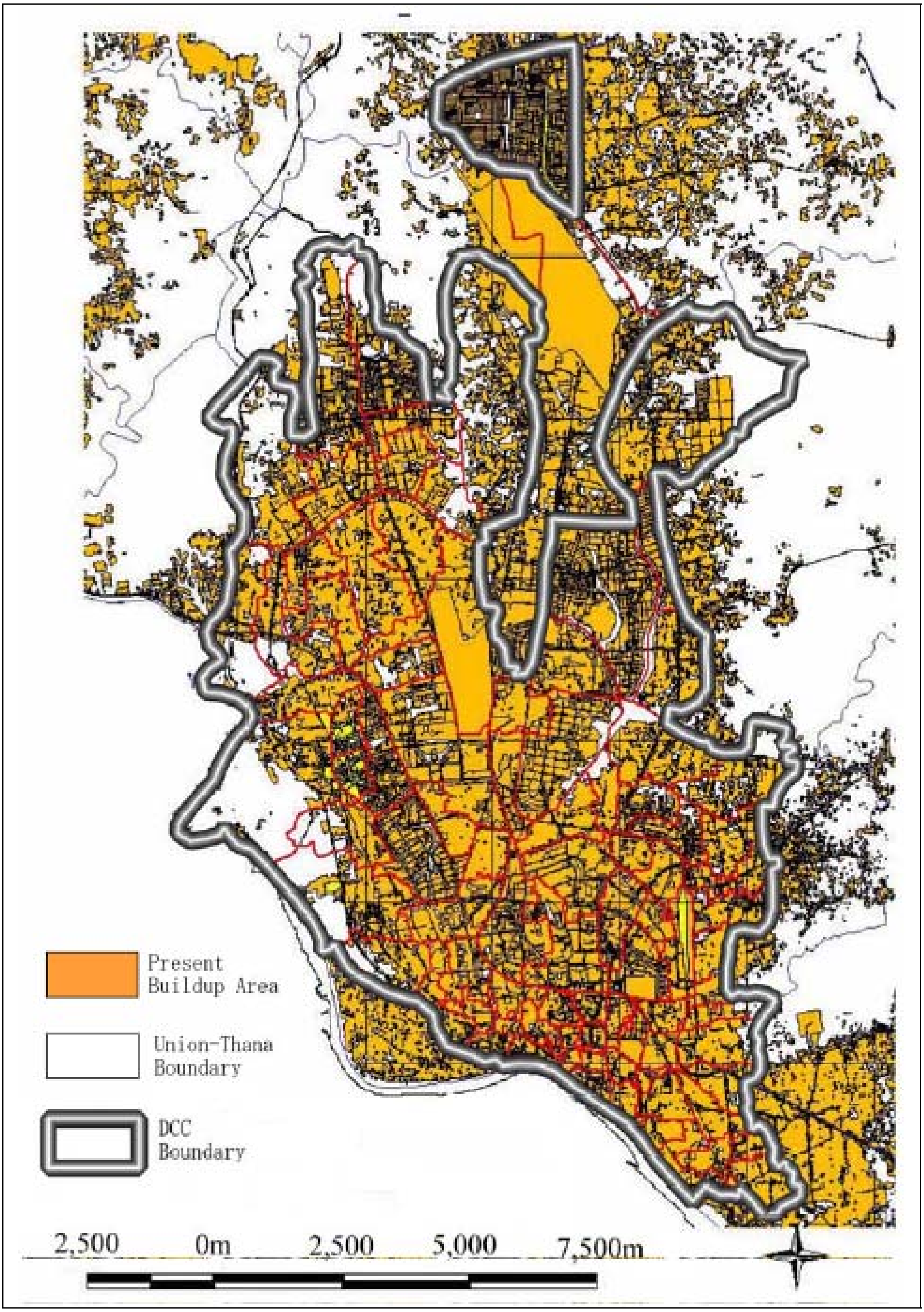

Figure A-12: Built-up Area of DCC and Adjacent Area (2002)
Source: Pacific and Yachiyo, 2005

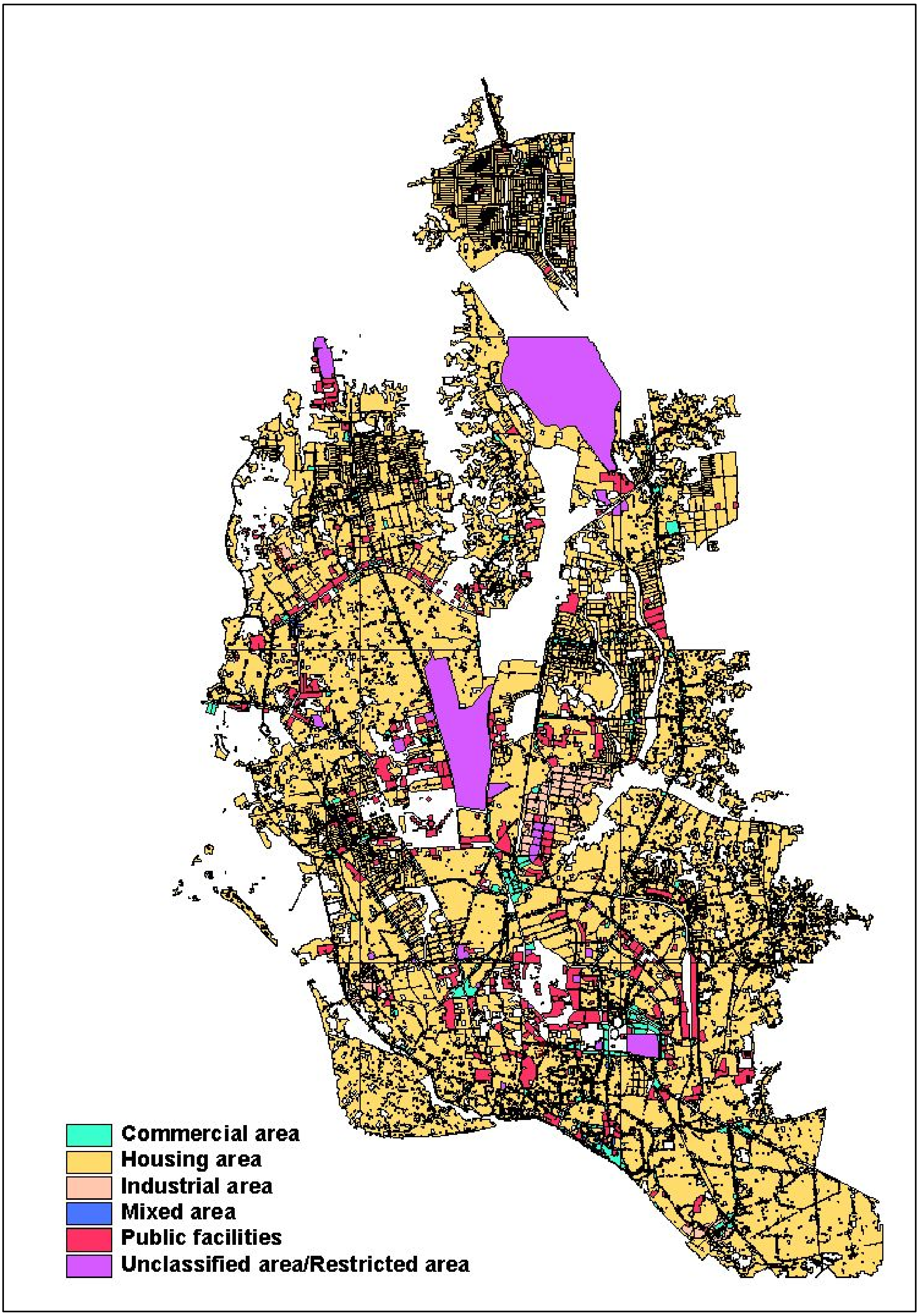

Figure A-13: Land use Category within Built-up Area of Dhaka City
Source: Pacific and Yachiyo, 2005

Figure A-14: Generalized Land use Map (2004) of Greater Dhaka City

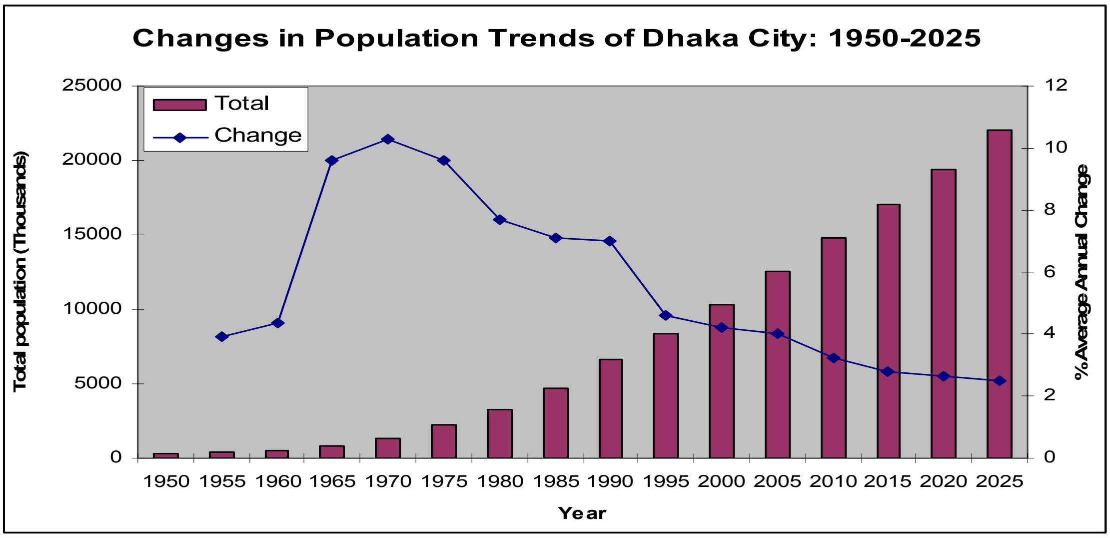

Figure A-15: Population Explosion of Dhaka City over Time
Source: UN Population Division (2007)

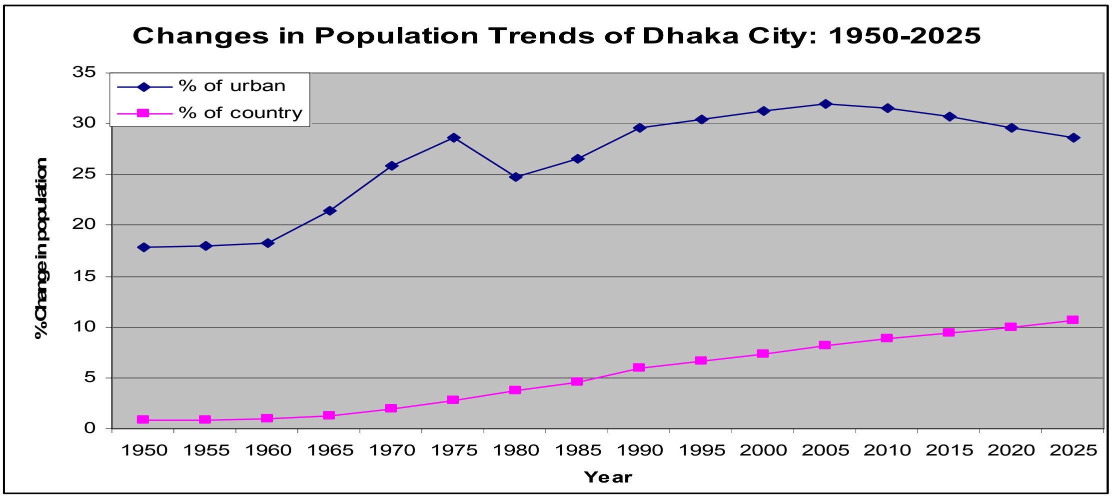

Figure A-16: Percentage Share of Population by Dhaka City over Time
Source: UN Population Division (2007)

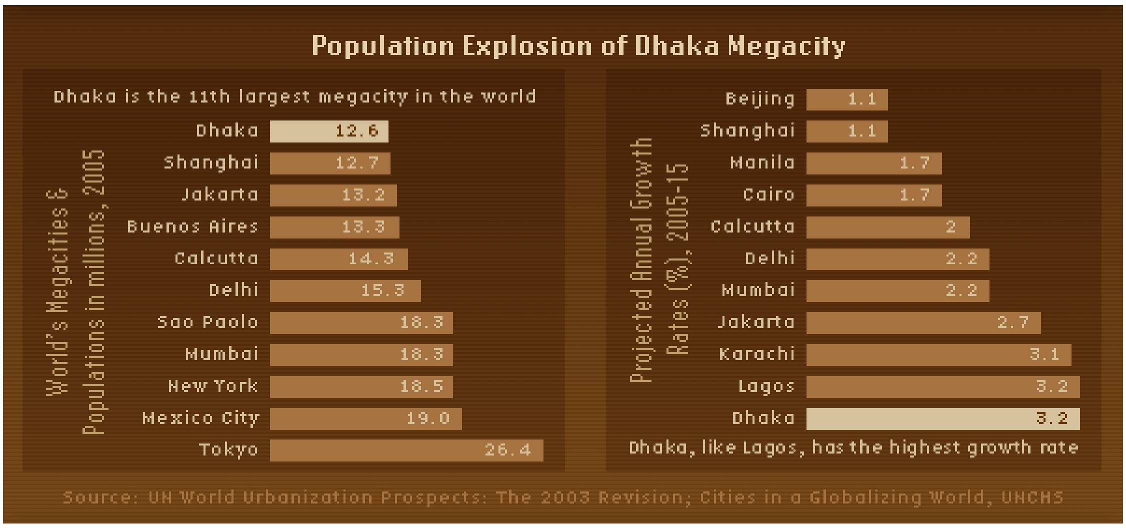

Figure A-17: Estimated Population Growth Rate of Dhaka City: 2005-15
Source:http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/

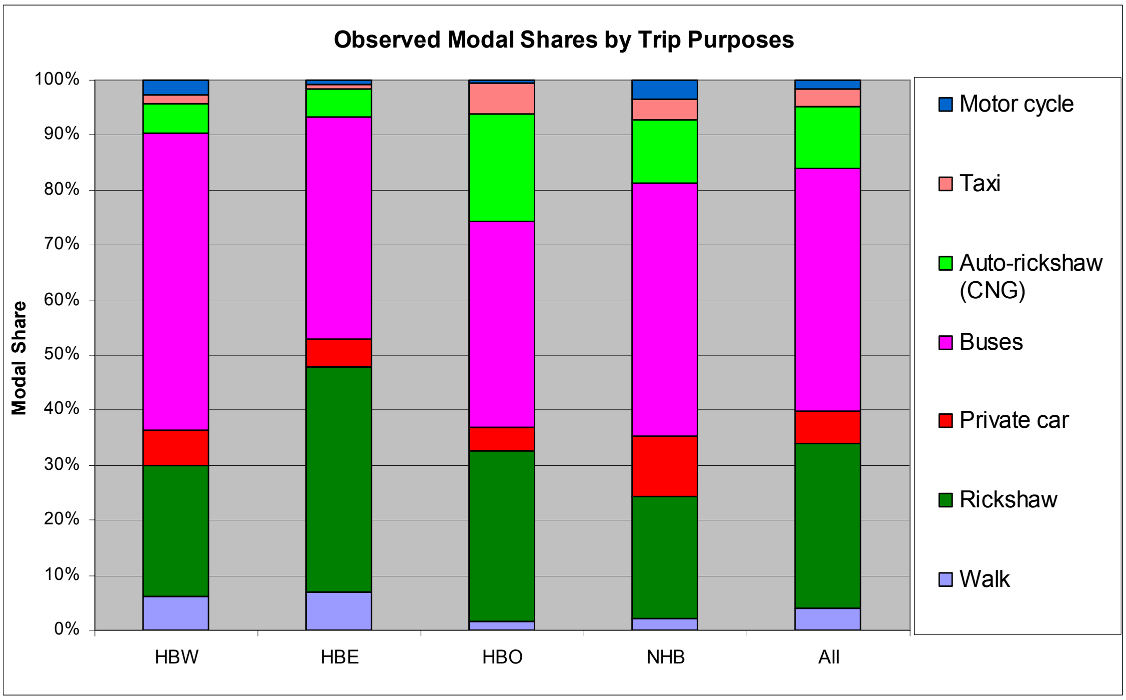

Figure A-18: Observed Modal Choices by Trip Purposes (Inter zonal trips)

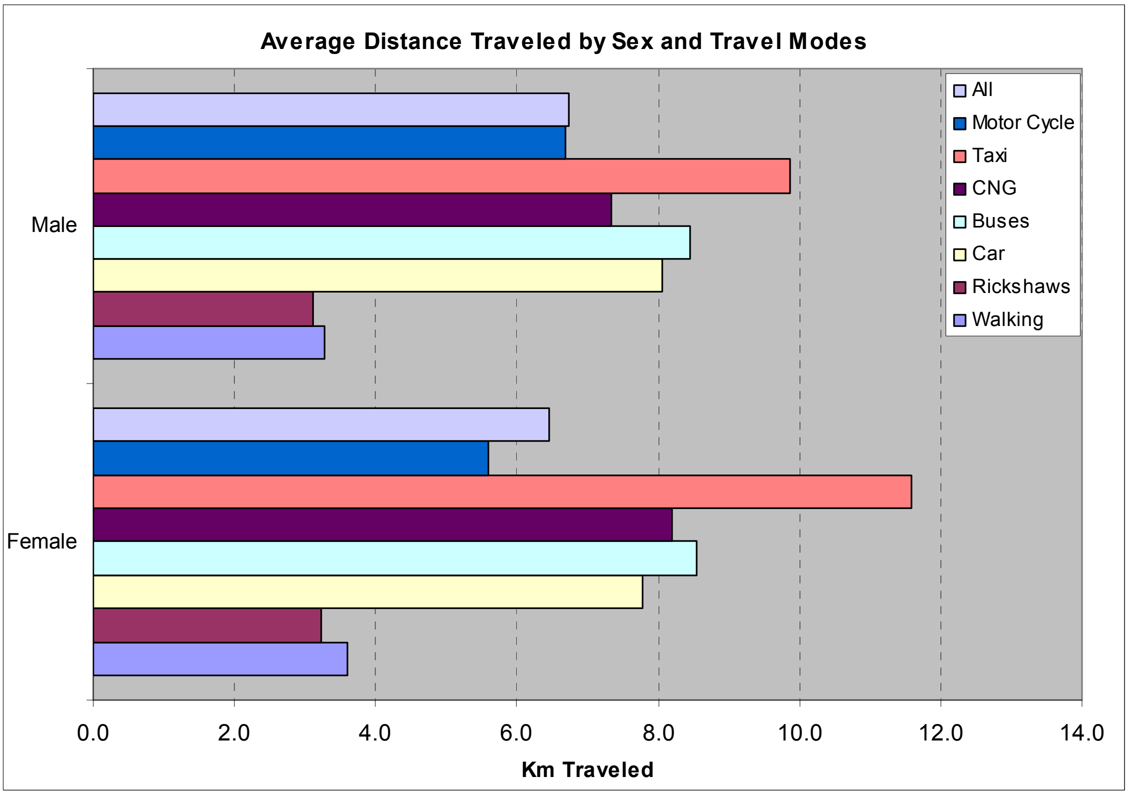

Figure A-19: Average Distance Traveled by Sex and Travel Modes

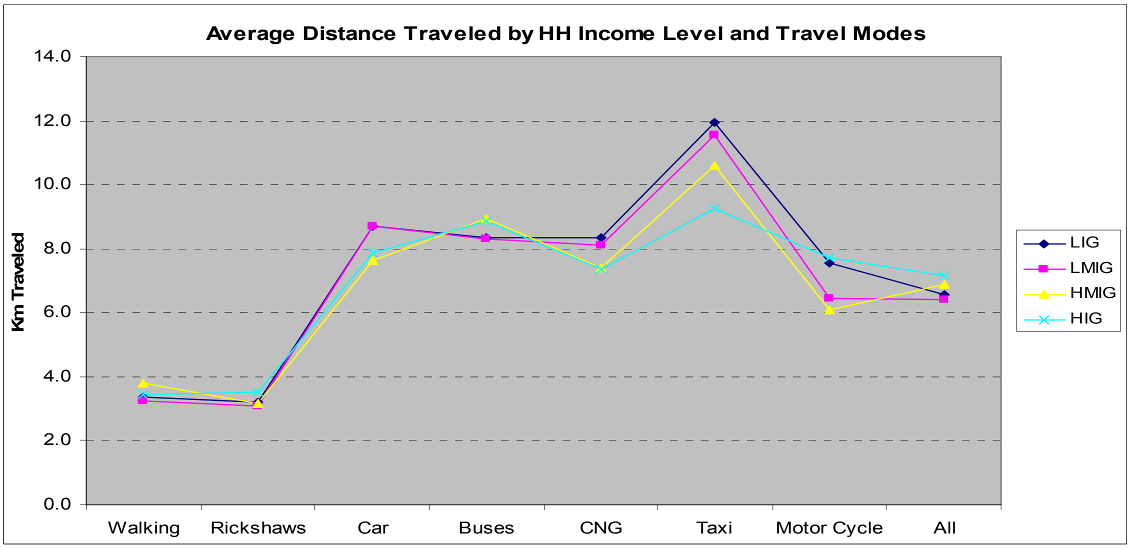

Figure A-20: Average Distance Traveled by Household Income Level and Travel Modes

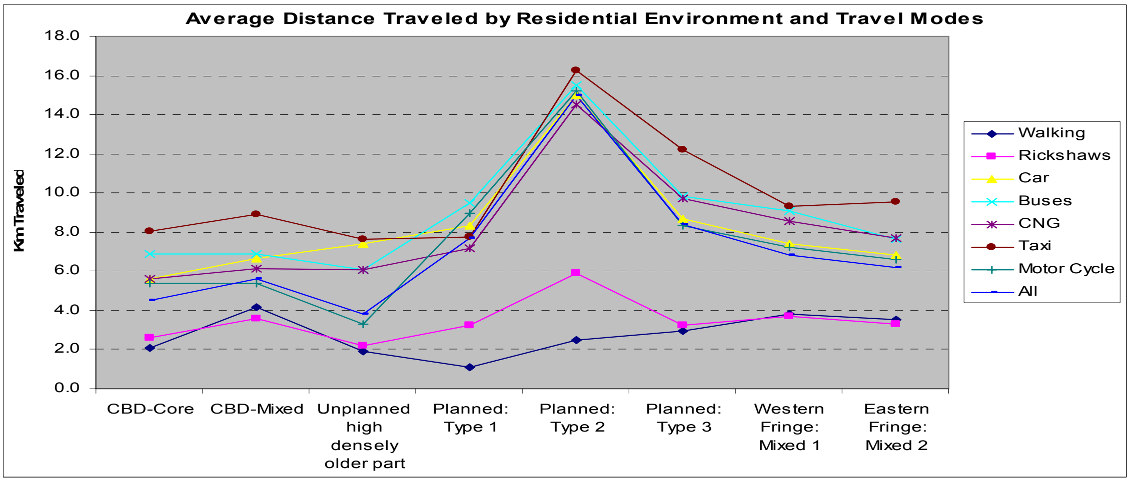

Figure A-21: Average Distance Traveled by Residential Location and Travel Modes

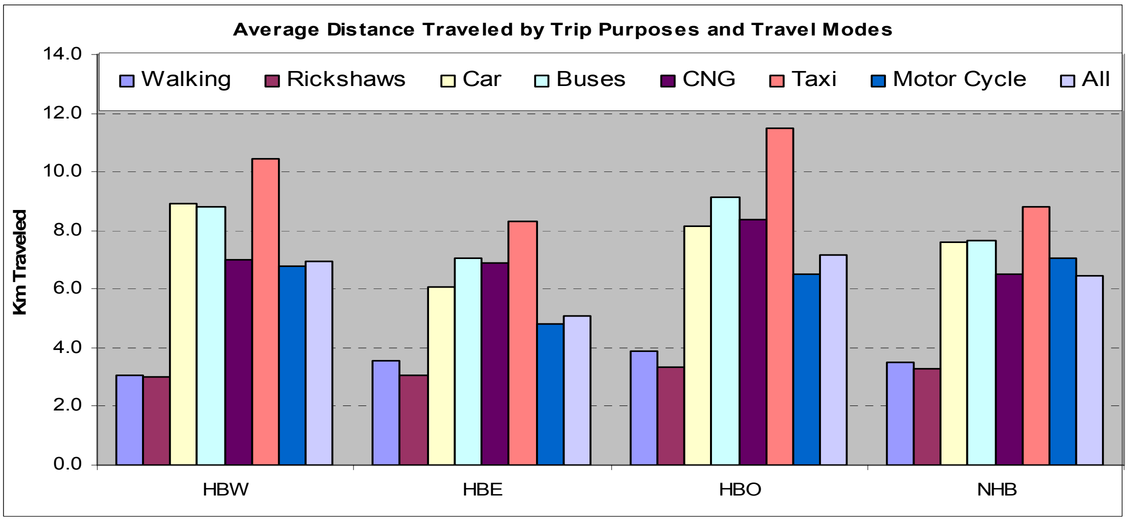

Figure A-22: Average Distance Traveled by Trip Purposes and Travel Modes

APPENDIX – B: TABLES

Table B-1: Sector-wise Final Consumption of Commercial Energy in Bangladesh

Sectors	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	Average
Consumption by All Sectors							
Trillion BTU	667	748	793	861	921	979	-
% change	-	12.14%	6.02%	8.58%	6.97%	6.30%	8.00%
Consumption by Transport Sector							
Trillion BTU	152.11	181.49	198.66	212.93	218.29	239.84	-
% change	-	19.31%	9.46%	7.18%	2.52%	9.87%	9.67%
As % of Total Consumption	22.81%	24.26%	25.05%	24.73%	23.70%	24.50%	24.18%
As % of Total Petroleum Consumption	48.14%	50.98%	53.40%	52.19%	50.07%	51.58%	51.06%

Source: BBS (2005)

Table B-2: Vehicular Emission Inventory of Dhaka City in 2004

Vehicle Type	Pollutants (Tons/year)				
	CO	NO_x	SO_2	HC	PM-10
Cars	47,752	2,865	153	7,640	191
Taxis-CNG	2,040	612	0	816	12
3W Taxis-CNG	2,728	819	0	1,091	16
LD Diesel	2,806	4,770	224	1,122	449
Buses	5,870	9,978	470	2,348	939
Trucks	4,228	7,188	338	1,691	677
Motorcycles	6,369	382	25	5,095	127
Total	71,793	26,614	1,211	19,804	2,412

Source: BCAS, 2005

Table B-3: Parameters for Energy Demand Analysis

Vehicle Type	Annual Usage (km)	Annual Hour Driven	Occupancy (Pass./veh.) or Loading Rate (ton/veh.)	Fuel Efficiency (km/l)
Bus	120000	2864	41.42	2.8
Minibus	56000	2121	35.59	3.23
Microbus	31000	1652	4.17	7.64
Car	24000	1276	1.85	9.82
Taxi	24000	2145	1.2	9.82
Auto-rickshaw	52000	2079	1.85	42
Motor cycle	14000	809	1.6	52.5
Auto-tempo	44000	2126	11	5
Rickshaws	14000	1000	1.63	-
Truck	36000	2036	11	2.62

Sources:Road User Cost, RHD (2004-05 and 1999-2000); STP (2005); Alam et al. (2007)

Table B-4: TAZ Location of the Study Area

TAZ Location	Number
DCC	90
Cantonment Board	1
Peripheral to DCC	6
Surrounding to DCC	5
Total	102

Table B-5: Characteristics of Specific Zones

Region Category	SPZs	Density			HH Income (Taka 2004)*
		HHs/km^2	Pop./km^2	Pop/HH	
A	CBD-Core	11,185	57,343	5.13	18,334
B	CBD-Mixed	10,650	51,684	4.85	22,728
C	Unplanned high densely older part	19,717	101,974	5.17	21,244
D	Planned: Type1	7,663	33,792	4.41	50,544
E	Planned: Type2	1,731	8,321	4.81	22,673
F	Planned: Type 3	11,067	50,895	4.60	19,156
G	Western Fringe: Mixed 1	11,649	54,442	4.67	22,763
H	Eastern Fringe: Mixed 2	12,366	57,508	4.65	17,417

Sources: Bangladesh Census Data (2001); STP (2005)

Table B-6: Past Population of Dhaka City Corporation (DCC)

Census Year	Population	Annual Population Growth Rate (%)
1961	0.36	-
1974	1.31	9.90
1981	2.82	10.93
1991	3.61	2.49
2001	5.38	3.80

Data Source: BBS 1997 & 2001

Table B-7: Population Density of Dhaka City

Year	Dhaka Mega City (persons/sq. km)	Dhaka City Corporation (persons/sq. km)
1991	5,059	16,255
2001	7,918	19,485
2004	8,352	21,521

Source: BCAS, 2005

Table B-8: Number of Selected HHs in Different SPZs

Region Category	SPZ	No. of HH
A	CBD-Core	542
B	CBD-Mixed	1010
C	Unplanned high densely older part	364
D	Planned: Type1	61
E	Planned: Type2	227
F	Planned: Type 3	922
G	Western Fringe: Mixed 1	492
H	Eastern Fringe: Mixed 2	1288
Total		**4906**

Table B-9: Basic Information of Selected Data

HH Income Group	HH No.	Total Persons	Total Trips	Sex Ratio	Average HH Income (Taka 2004)	Persons /HH	Trips/ HH	Trips/ Person
LIG (<Taka 12,500)	2,157 (43.97%)	8216	16794	1.1	8,134	3.8	7.8	2.0
LMIG (Taka 12,500 ~<25,000)	1,458 (29.72%)	6142	13168	1.2	17,193	4.2	9.0	2.1
HMIG (Taka 25,000~ <55,000)	1,085 (22.12%)	4809	10589	1.2	34,256	4.4	9.8	2.2
HIG (>=Taka55,000)	206 (4.20%)	985	2137	1.2	98,904	4.8	10.4	2.2
All	**4,906**	**20,152**	**42,688**	**1.2**	**20,415**	**4.1**	**8.7**	**2.1**

Table B-10: Travel Speed and Travel Cost of Different Modes of Transport in Dhaka City

Modes	Travel Speed* (km/hour)	Travel Cost (Taka 2004)	Remarks
Private Car	21	Tk. 15.00/km	Travel cost is based on STP
Transit (Bus)	17	Tk. 1.00/km	Travel cost is based on STP
Taxi	21	Tk. 15 for 1st 2 km and then Tk. 6 for each km	Travel cost is based on Government Fare Rate
CNG	21	Tk. 12 for 1st 2 km and then Tk. 5 for each km	Travel cost is based on Government Fare Rate
Rickshaws	11	Tk. 5.00/km	Travel cost is based on Survey and Literature Reviews
Motor cycle	25	Tk. 5.00/km	Travel cost is based on Survey considering all costs over its whole life span
Walking	5	0	Travel cost is based on Survey and Literature Reviews

*Travel speed is based on STP Survey Results: Volume I-III, 2005

Table B-11: Intra-zonal Trips Separation by Trip Purposes and Travel Modes

Trip purpose	Mode	Total	Intra-TAZ		Inter-TAZ	
Home-work	Walk	1796	1125	62.64%	671	37.36%
Home-work	Rickshaw	3492	921	26.37%	2571	73.63%
Home-work	Private car	728	50	6.87%	678	93.13%
Home-work	Transit (bus)	5910	88	1.49%	5822	98.51%
Home-work	CNG	593	8	1.35%	585	98.65%
Home-work	Taxi	179	1	0.56%	178	99.44%
Home-work	Motor cycle	318	33	10.38%	285	89.62%
All HBW		**13016**	**2226**	**17.10%**	**10790**	**82.90%**
Home-education	Walk	2070	1602	77.39%	468	22.61%
Home-education	Rickshaw	4853	2053	42.30%	2800	57.70%
Home-education	Private car	402	64	15.92%	338	84.08%
Home-education	Transit (bus)	3048	280	9.19%	2768	90.81%
Home-education	CNG	357	6	1.68%	351	98.32%
Home-education	Taxi	51	0	0.00%	51	100.00%
Home-education	Motor cycle	58	8	13.79%	50	86.21%
All HBE		**10839**	**4013**	**37.02%**	**6826**	**62.98%**
Home-other	Walk	543	345	63.54%	198	36.46%
Home-other	Rickshaw	5152	1040	20.19%	4112	79.81%
Home-other	Private car	596	35	5.87%	561	94.13%
Home-other	Transit (bus)	5027	108	2.15%	4919	97.85%
Home-other	CNG	2606	25	0.96%	2581	99.04%
Home-other	Taxi	753	12	1.59%	741	98.41%
Home-other	Motor cycle	56	2	3.57%	54	96.43%
All HBO		**14733**	**1567**	**10.64%**	**13166**	**89.36%**
Non-home based	Walk	112	40	35.71%	72	64.29%
Non-home based	Rickshaw	921	142	15.42%	779	84.58%
Non-home based	Private car	405	30	7.41%	375	92.59%
Non-home based	Transit (bus)	1657	52	3.14%	1605	96.86%
Non-home based	CNG	401	2	0.50%	399	99.50%
Non-home based	Taxi	132	1	0.76%	131	99.24%
Non-home based	Motor cycle	126	7	5.56%	119	94.44%
All NHB		**3754**	274	7.30%	**3480**	92.70%
Grand Total: All Trips		**42342**	**8080**	**19.08%**	**34262**	**80.92**

Table B-12: Modal Choices Stratified by Residential Environments and Income Groups

IG	HH Environment	Modes of Transport						
		Walking	Rickshaws	Car	Buses	CNG	Taxi	Motor Cycle
LIG	CBD-Core	7.5%	47.0%	0.8%	32.5%	9.6%	2.2%	0.5%
	CBD-Mixed	8.6%	31.6%	0.6%	46.2%	11.8%	0.7%	0.5%
	Unplanned high densely older part	8.5%	50.3%	1.9%	35.8%	2.8%	0.0%	0.8%
	Planned: Type 1	0.0%	18.5%	8.5%	43.8%	29.2%	0.0%	0.0%
	Planned: Type 2	0.4%	4.4%	2.2%	67.1%	12.9%	9.5%	3.4%
	Planned: Type 3	8.4%	17.6%	1.5%	61.6%	8.8%	1.4%	0.8%
	Western Fringe: Mixed 1	14.9%	31.2%	4.3%	39.2%	7.6%	1.6%	1.2%
	Eastern Fringe: Mixed 2	2.4%	26.8%	0.8%	60.7%	6.9%	1.1%	1.3%
LMIG	CBD-Core	7.1%	44.5%	7.4%	29.3%	9.2%	1.3%	1.2%
	CBD-Mixed	4.5%	34.3%	1.8%	41.9%	12.8%	3.2%	1.5%
	Unplanned high densely older part	3.0%	66.5%	0.5%	22.3%	5.5%	1.1%	1.0%
	Planned: Type 1	0.0%	25.0%	4.8%	44.0%	23.8%	2.4%	0.0%
	Planned: Type 2	0.4%	7.6%	10.9%	65.5%	8.4%	7.1%	0.0%
	Planned: Type 3	2.3%	18.1%	3.4%	59.0%	12.5%	3.4%	1.4%
	Western Fringe: Mixed 1	6.4%	30.7%	3.5%	44.1%	10.5%	2.6%	2.2%
	Eastern Fringe: Mixed 2	1.6%	34.8%	1.1%	52.7%	7.6%	1.1%	1.0%
HMIG	CBD-Core	1.4%	37.1%	16.5%	20.8%	17.9%	4.8%	1.6%
	CBD-Mixed	2.4%	29.3%	8.7%	33.2%	18.9%	5.3%	2.2%
	Unplanned high densely older part	0.4%	51.5%	12.0%	15.9%	12.9%	1.6%	5.6%
	Planned: Type 1	0.0%	5.0%	40.0%	17.5%	27.5%	10.0%	0.0%
	Planned: Type 2	0.4%	2.9%	21.9%	43.8%	14.5%	16.4%	0.0%
	Planned: Type 3	1.7%	15.4%	8.5%	48.1%	16.6%	7.2%	2.4%
	Western Fringe: Mixed 1	3.0%	30.9%	11.3%	34.1%	14.7%	4.2%	1.8%
	Eastern Fringe: Mixed 2	0.4%	31.8%	6.7%	40.4%	13.4%	4.1%	3.1%
HIG	CBD-Core	2.8%	24.8%	22.1%	11.7%	16.6%	17.2%	4.8%
	CBD-Mixed	2.9%	30.6%	22.6%	18.9%	16.2%	8.0%	0.8%
	Unplanned high densely older part	3.0%	28.4%	23.1%	23.1%	11.2%	11.2%	0.0%
	Planned: Type 1	1.0%	4.0%	76.0%	4.0%	8.0%	5.0%	2.0%
	Planned: Type 2	0.0%	4.8%	22.6%	26.2%	14.3%	32.1%	0.0%
	Planned: Type 3	0.8%	12.5%	34.5%	26.2%	18.1%	7.2%	0.6%
	Western Fringe: Mixed 1	0.6%	18.4%	35.4%	15.0%	21.0%	8.8%	0.8%
	Eastern Fringe: Mixed 2	0.4%	27.8%	21.6%	32.4%	14.5%	2.1%	1.2%