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A Simplified Travel Demand Modeling Framework: in the Context of a Developing Country City

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Abstract

This paper presents a simplified travel demand modeling framework to determine the modal flows on urban transport network of Dhaka, the capital of a developing country, Bangladesh. The framework consists of a system of models and is developed based on a number of principles such as having strategic perspective, addressing heterogeneous demand characteristics, following disaggregate and simplified modeling approach and capturing the multi-modal nature of Dhaka's transport system. This paper also discusses the modeling issues related to Dhaka's transport context and the principles followed in modeling framework to handle those issues. The structure of the framework is based on four- step modeling process with some modifications in different steps in order to make it suitable for the context.

1. Introduction

The expanding urban traffic growth in developing countries has become a major concern to city planners, transportation professionals and policy makers. Significant investments are being planned in these cities in order to satisfy the growing demand. Although travel demand analysis is an important component of any urban transportation planning exercise it seems to have been neglected in transportation planning activities in the cities of the developing world. Limited attempts have been made to analyze the relationships between various forms of land use and behaviors of travelers to guide planning of major transport developments. Lack of travel demand analysis and in some cases the weaknesses of conducted analyses limit the effectiveness of transportation policies and actions in managing the excessively growing urban traffic in the developing world. One of the principal objectives of such modeling exercise is to predict the demand for transportation facilities and services in the future by extrapolating present travel behavior, growth characteristics and changing socioeconomic conditions (Meyer et al, 1984). 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.

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Dhaka, the largest city of Bangladesh, is the national capital. 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 1991 Dhaka ranked twenty-fifth among the thirty-four mega cities of the world having a population of more than five million, while in 2000 it ranked eleventh and by the year 2015 it is anticipated to be the world's fourth largest city with an estimated population of 21.1 million (SDNP, 2005).

With this rapidly expanding urban growth of Dhaka, a reliable model estimating the urban travel demand of Dhaka is necessary. Nevertheless, to make this model flexible for future enhancement and compatible with the complex future situation a comprehensive modeling framework is also needed. This study develops and implements a comprehensive modeling framework, Dhaka Strategic Transport Model (DSTM) comprising a system of models for simulating the travel demand by applying the four-step modeling process (Hasan, 2007).

Although travel demand analysis is a neglected component of urban transport planning practice in the developing world, several demand modeling studies have been conducted in different developing countries. Ho et al (1999) presented an urban transportation planning model developed for Shanghai, China. This model attempted to effectively simulate people's travel demand characteristics under a fast changing condition. 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 that they can effectively reflect the regional economic growth as well as the urban and transportation development in Shanghai. According to Ho et al (1999), the sequential modeling process is can be considered as 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.

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 developed model had the ability to correlate travel demand with socio-economic variables endogenously. Mode related variables were considered in terms of time, cost, comfort etc. enabling the model to investigate the effects of changes in transportation system.

This paper is organized in several sections. The next section presents the critical travel demand modeling issues for Dhaka city. Then the underlying modeling principles are discussed in section 3. Following it, in section 4, the structure of the modeling framework and the modeling process are presented. Finally, section 5 discusses specific features that are achieved from this framework.

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2. Critical Modeling Issues for Dhaka

Broadly, the critical issues for developing a travel demand model for Dhaka city are the heterogeneous socio-economic structure; the existing mixed transportation system and heterogeneous travel demand behaviors; and the lack of information of people's travel behavior and zonal employment and population forecasting. In this section, the various modeling issues, which need to be addressed in the development of travel demand model for Dhaka, are discussed. The issues are discussed under three following categories.

Socio-economic structure

There has been existence of urban poverty in Dhaka which makes it difficult to analyze the system under a single framework. Moreover, 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.

Transportation supply and demand

Traditionally, Dhaka has been served by a wide variety of transport modes. These modes can be classified into two groups, 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. The travel behaviors 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.

Data availability and forecasting

Data availability is a common major issue for modeling travel demand in developing countries. The scenario is not much different for Dhaka. Sometime the reliability, consistency and extent of the available data are also limited. As Dhaka is the capital city of Bangladesh, every year a huge number of people come to Dhaka for employment and other purposes. There is no reliable information on the numbers of the floating population in the base year though these amounts are very sensitive to demand assessment. It is thus extremely difficult to derive reliable estimates for these variables in the future. 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.

Reviewing the above issues, it is apparent that modeling travel demand for Dhaka city is a complex as well as colossal task. However, not all of these issues 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

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to address the critical issues with reasonable assumptions appropriate for a strategic level of analysis.

3. Modeling Principles

In order to deal with the specific modeling issues in Dhaka as discussed above, a 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:

i. **Simplified modeling approach:** The structure and methodology of each sub-model as well as the interactions between model components are based on simplified approach so that the data availability issues can be overcome and model elements can be updated, implemented and applied easily.

ii. **Multi-modal model:** The modeling framework considers the presence of heterogeneous travel modes such as non motorized vehicles (rickshaws) and motorized vehicles (auto-rickshaws, private cars and buses) and provides separate information for each mode.

iii. **Strategic model:** The model will be able to address broader transport issues in wider perspective, assess present status, analyze different future scenarios and evaluate different strategic options.

iv. **Heterogeneous socio-economic structure:** The heterogeneity in socio-economic structure has been addressed by segregating the households into different income groups and analyzing their travel demand separately.

v. **Heterogeneous demand market oriented:** 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.

vi. **Addressing the urban poverty issue:** Most of the earning of the urban poor is used for food and shelters while spending very small portion of their earning on their other incidentals (Hossain, 2005). Therefore, the extreme urban poor, being unable to afford to use the transport system being modeled, have been excluded from the analysis.

vii. **Disaggregate model:** The model has sub-models that follow ‘disaggregate’ (e.g., household based) approach of calibrating and validating different parameters so that it can determine parameters with greater accuracy with limited available data.

viii. **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 with limited changes in other components.

ix. **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.

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4. Modeling Process

Considering the principles mentioned above, a comprehensive modeling framework is developed. The model consists of a sequence of sub-models or model components with relatively simple structures so that the models can be calibrated, updated, implemented and applied easily. Figure1 summarizes the entire modeling process consisting the following sequential steps:

i. Development of a trip generation model, which estimates the zonal trip productions and attractions.
   a) Trip Production Model- Cross classification models are developed to calculate trip rates for different trip purposes for different categories of households.
   b) Trip Attraction Model- Based on land use characteristics of the city available in GIS map and trip attraction rates.

ii. The Pre-Distribution Walk or Intra-zonal Trip Split Model separates the total zonal trips into zonal walk or intra-zonal trips and zonal non-walk inter-zonal trips.

iii. Then the Pre-Distribution Personal Motorized Trip Split Model separates the zonal total non-walk inter-zonal trips into zonal personal motorized trips and zonal auto-rickshaw, rickshaw and transit trips. The personal motorized trips include trips using private cars, microbus and taxis.

iv. The personal motorized trips and rickshaw/auto-rickshaw/transit trips are then distributed independently with separate trip distribution models.

v. Subsequently the Post-distribution Mode Split Model considers the travel time and the travel costs of these three competing modes such as the rickshaw, auto-rickshaw and transit.

vi. The personal motorized trip table is then assigned to the road network

vii. The rickshaw trip table is then assigned to the NMV network

viii. Subsequently, the transit trip table is assigned to the transit network

ix. The background information of volume of rickshaw trip assignment and transit assignment is then used in auto assignment.

x. Link volumes are obtained from the assignment results

5. Specific Model Features

Travel demand market segmentation

Before the trip distribution procedure, DSTM estimates two kinds of trips: personal motorized trips and auto-rickshaw, rickshaw and transit trips. Since these two types of trips represent two different travel markets with minimum interaction, they can be considered separately. First, the personal motorized trips are usually made by the people with motorized vehicles available. Second, the rickshaw/auto-rickshaw/transit market represents the majority of the travel made by the people. Rickshaw, auto-rickshaw and transit directly compete with one other. 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 the trip distribution and subsequent mode choice processes.

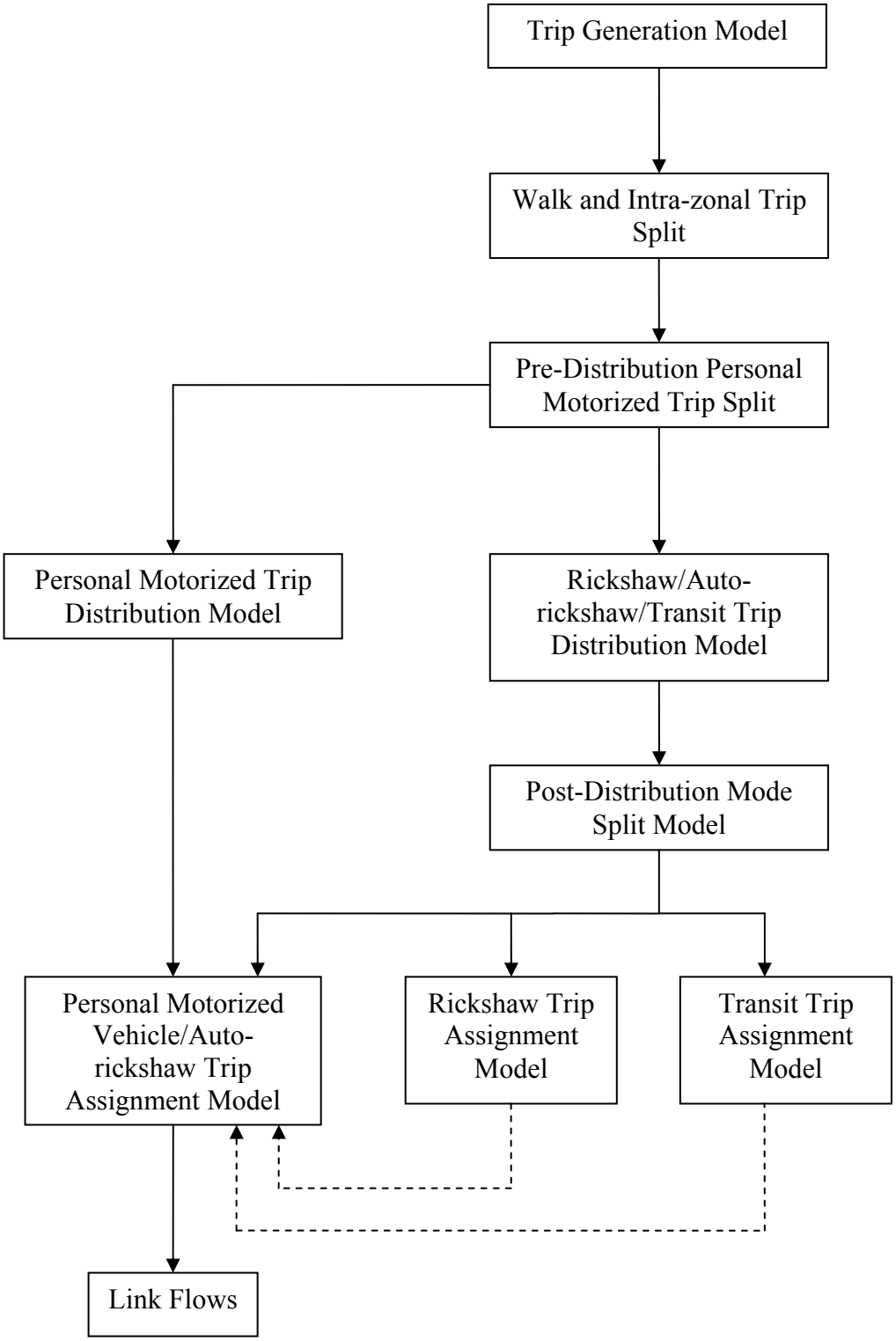

Figure 1 Structure of the Modeling Framework Dhaka Strategic Transport Model (DSTM)

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Multistage modal split

Another specific feature of this modeling framework is that the modal split procedure is broken down into three sub-models to be carried out separately before or after the trip distribution model. This "multi-stage" modal split procedure, as suggested by Ho et al (1999), can be effectively used for dealing with the specific situation in Dhaka, as compared with the single pre-distribution or post-distribution modal split model. First, the multi-stage modal split procedure can effectively reflect the impacts of the development of the transportation system on modal split. Second, it handles two distinct travel markets (i.e., personal motorized and rickshaw/auto-rickshaw/transit) in two sub-models separately. Third, 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. Fourth, it has greater flexibility for modal split procedure modification, if necessary, to handle any new travel modes. Finally, the multi-stage procedure allows us to conduct detailed demand analysis of individual travel modes. For example, the Post-Distribution Model allows us to estimate a rickshaw trip table, which can subsequently be used for detailed rickshaw network analysis.

Multi modal

One of the significant features of DSTM is that, it successfully implements the multi modal nature of Dhaka's transport in EMME/2 (a transportation planning software). Three different traffic assignments are prepared and run for this purpose as auto and auto-rickshaw assignment, rickshaw assignment and transit assignment.

Integrated with land use

Another significant feature of DSTM is that, it is integrated with the land use characteristics of Dhaka city. The mixed land use pattern of Dhaka is therefore expected to be truly reflected in the trip distribution or O-D pattern.

Congestion effects of mixed traffic

DSTM assignments are designed in such a way that it can give the traffic volumes of all modes simultaneously. Moreover, the background volumes of rickshaws and transit vehicles are considered in the auto assignment. Therefore, the congestion effects due to the presence of mixed traffic in Dhaka's network are well reflected in DSTM results.

6. Conclusions

In this paper, a comprehensive travel demand modeling framework is presented in order to handle the critical modeling issues for Dhaka city. The framework attempts to develop a system of models which can determine the complex travel demand applying the four-step modeling process. It follows a simple modular structure so that individual model elements can be updated, implemented and applied easily. Different modeling issues and modeling processes have been discussed. This framework has achieved some important features: segmentation of demand market with a multi-stage modal split procedure; implementation of multi-modal nature of Dhaka's transport system; integration with land use features; and capturing congestion effects of the mixed traffic

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system. The simplified approach, followed in this study, can be used in similar developing country cities where information are not available for sophisticated analysis without ignoring the heterogeneous socioeconomic nature of these cities. Modeling details along with its calibration and validation results can be obtained from the research work conducted by the authors (Hasan, 2007).

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