Many practical transportation policy issues are concerned with mode choice. For example, the gain or loss in transit revenues caused by a fare increase depends on how travelers’ mode choices are affected by the increase. Similarly, the effects of changes in transit routes and schedules on ridership, revenues, and traffic congestion all depend on how the changes affect individual travelers’ mode choices. The effectiveness of programs to encourage ridesharing -- for example, preferential parking or preferential access to freeways for carpools -- also depends on how the programs affect mode choice. An understanding of the separate and combined effects of these decisions on travel mode choice is essential to selection of the best plan to meet specific transportation objectives. Dhaka’s transport system is predominately road based. The main characteristic of this transportation system is the low level of motorization and sharing of same road space by MT and NMT. In order to improve operation of motorized (MT) traffic, the operation of non-motorized (NMT) mode of transport especially rickshaw has to be controlled and managed. For developing these management and control policies, first of all it is necessary to understand the people’s choice behavior for rickshaw and relative attitude towards its two main competitors (bus and taxi). Among many available alternative techniques choice modeling can be applied for this purpose. With regard to passengers’ mode choice behavior, we probabilistic mode choice models of multinomial logit type based on the behavioral theory of utility maximization based on objective factors. Then we try to depict the relationship between the mode and the factors other than the objective factors by presenting the strength to which the different latent factors influence the mode choice through developing causal model of linearized structural relation type. Since, an enormous transport-oriented investment in terms of railway development (surface/subway) is unlikely to be implemented due to financial constraints, the strategy which facilitates the operations of bus scheme as an acceptable means of city public transport system is to be worked out and in view of that the sensitivity of different policies on the redistribution of mode choice has been tested.
without sacrificing large parts of the fabric to roads and parking space.

The issue of mode choice, therefore, is probably the single most important element in transport planning and policy making. It affects the general efficiency with which we can travel in urban areas, the amount of urban space devoted towards transport functions, and whether a range of choices is available to travelers. The issue is equally important in inter-urban transport as again rail modes can provide a more efficient mode of transport (in terms of resources consumed, including space), but there is also a trend to increase travel by road. It is important then to develop and use models which are sensitive to those attributes of travel that influence individual choices of mode.

After this introductory section, section two reviews briefly the literature related to discrete choice behavior in different field of research including the transport planning area. Section three deals with data collection and conceptual framework of research. Section four enlighten the fundamentals issues and steps grounding the development, specification, estimation and interpretation of discrete choice model of multinomial logit type. Section five tries to portray the strength to which different latent factors influence the mode choice by depicting causal path. Section six illustrates the possible effects of modal share if certain policies are in consideration of the policy-analyst or the decision-maker. This thesis terminates section seven having concluding remarks about the developed models and scenario analyses.

Probabilistic discrete choice models go back to Thurstone’s (1927a,b) work in psychometrics. He proposed modeling individual choice as an outcome of a process in which a random variable is associated with each alternative, and the alternative with the greatest realization is the one selected. The early transport application of discrete choice models were made for binary choice of travel mode (e.g., Quarmby 1967, Lave 1969, Stopher 1969, Gronau 1970, McGillivray 1972, Winger 1973). Further progress in transport applications following these early studies was the research works during the early 1970s oriented towards mode choice models with more than two alternatives, application to other travel related choices such as trip destination, trip frequency, car ownership, residential location, and residential location and housing (Rassan et al 1971, Brand and Manheim 1973, Richards and Ben-Akiva 1975, Lerman and Ben-Akiva 1975, Oppenheim 1995). The choice of mode for travel to work has been investigated by some researchers (e.g., Artherton and Ben-Akiva 1975, Train 1976). Further research about discrete choice model has been performed by some other researchers (Ben Akiva and Lerman 1985, Morikawa 1989, McFadden 2000). Though several studies concerning Rickshaw (Gupta 1981, Gallagher 1992, Karim 1992, Hoque 1997) were conducted in the past in the study area, however, these studies have shortcomings in analyzing passengers’ choice behavior towards rickshaw and its alternatives.

Main features of collected data:
- Secondary data were collected from Dhaka Integrated Transport Study (DITS) and Dhaka Urban Area Study (DUAS).
- Primary data were collected through household interview survey of about two hundred respondents. After thorough scrutiny, one hundred and eighty (180) samples were selected for further analysis.
- Since the model was intended for work-trip of middle class people, data were collected giving emphasis on the widely used modes (rickshaw, bus, baby-taxi) of the target group. These three modes contribute to about seventy percent of all the vehicular trips of Dhaka city.

A significant number of variables were initially selected for assessing their feasibility of being incorporated in the proposed model. After several trials, with the variables with reasonable statistical significance, two models were specified and estimated using different combination of variables in table 4.1 and 4.2.

The first model (trinomial logit model) has been estimated by using two alternative-specific constants and three travel attributes. The specification of the model is given in tabular form in table 4.2b. The entries in the table define the variables that enter into the model, the coefficient estimates and their statistical information.

### Table 4.1 (Model one) Trinomial logit model using two alternative-specific constants and three travel attributes

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Coefficient estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const_r</td>
<td>1.23</td>
<td>0.42</td>
<td>2.89</td>
</tr>
<tr>
<td>Const_b</td>
<td>0.94</td>
<td>0.67</td>
<td>1.39</td>
</tr>
<tr>
<td>IVT</td>
<td>-0.06</td>
<td>0.02</td>
<td>-2.75</td>
</tr>
<tr>
<td>OVT</td>
<td>-0.11</td>
<td>0.045</td>
<td>-2.55</td>
</tr>
<tr>
<td>TC</td>
<td>-0.043</td>
<td>0.018</td>
<td>-2.36</td>
</tr>
</tbody>
</table>
Summary statistics
Number of observations = 180
Initial log likelihood, $L(0) = -197.75$
Log likelihood with constants only, $L(c) = -175.423$
Final log likelihood, $L(\hat{\beta}) = -169.156$
First likelihood ratio, $-2[L(0) - L(\hat{\beta})] = 57.2$
Second likelihood ratio, $-2[L(c) - L(\hat{\beta})] = 12.5$

According to the model the deterministic components of the utility functions are

$$V_{\text{rickshaw}} = 1.23213 - 0.060054 \times IVT - 0.115455 \times OVT - 0.043684 \times TC$$

$$V_{\text{bus}} = 0.945505 - 0.060054 \times IVT - 0.115455 \times OVT - 0.043684 \times TC$$

$$V_{\text{taxi}} = -0.060054 \times IVT - 0.115455 \times OVT - 0.043684 \times TC$$

Where, $IVT = \text{In-vehicle travel time}$,
$OVT = \text{Out-of-vehicle travel time}$,
$TC = \text{Travel cost}$,

Interpretation of estimation results

The most basic test of the model estimation output is the examination of the values of the co-efficient of estimates. Usually we have a priori expectation with respect to the signs and relative values of the coefficients. In the estimation results given in Table 4.1, all the coefficient estimates have expected signs.

The second model (trinomial logit model) has been estimated by using two alternative-specific constants, two travel attributes and one mixed travel-socioeconomic attribute. The specification of the model is given in tabular form in Table 4.2. The entries in the first column define the variables that enter into the model, the second column corresponds to the five coefficients labeled $\beta_1$ through $\beta_5$ and the subsequent columns represent the coefficient estimates and their statistical information.

Table 4.2 (Model two)

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Label of the coefficients</th>
<th>Coefficient estimate</th>
<th>Standard error</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const_r</td>
<td>$\beta_1$</td>
<td>0.086</td>
<td>0.44</td>
<td>0.19</td>
</tr>
<tr>
<td>Const_b</td>
<td>$\beta_2$</td>
<td>-1.64</td>
<td>0.99</td>
<td>-1.65</td>
</tr>
<tr>
<td>IVT</td>
<td>$\beta_3$</td>
<td>-0.068</td>
<td>0.024</td>
<td>-2.80</td>
</tr>
<tr>
<td>OVT/OWD</td>
<td>$\beta_4$</td>
<td>-1.42</td>
<td>0.35</td>
<td>-4.00</td>
</tr>
<tr>
<td>TC/HI</td>
<td>$\beta_5$</td>
<td>-2211.55</td>
<td>373.22</td>
<td>-5.92</td>
</tr>
</tbody>
</table>

According to the model the deterministic components of the utility functions are

$$V_{\text{rickshaw}} = 0.86528 - 0.060054 \times IVT - 1.4295 \times OVT/OWD - 2211.55 \times TC/HI$$

$$V_{\text{bus}} = -1.64464 - 0.060054 \times IVT - 1.4295 \times OVT/OWD - 2211.55 \times TC/HI$$

$$V_{\text{taxi}} = -0.060054 \times IVT - 1.4295 \times OVT/OWD - 2211.55 \times TC/HI$$

Where, $IVT = \text{In-vehicle travel time}$, $OVT = \text{Out-of-vehicle travel time}$, $TC = \text{Travel cost}$, $OWD = \text{One Way Distance}$, $HI = \text{Household Income}$,

Interpretation of estimation results

The most basic test of the model estimation output is the examination of the values of the co-efficient of estimates. Usually we have a priori expectation with respect to the signs and relative values of the coefficients. In the estimation results given in Table 4.2, all the coefficient estimates have expected signs.

A ratio of two coefficients appearing in the same utility function provides information about a trade-off or a marginal rate of substitution between two corresponding variables. The estimated value of the trade-off between two components of travel time, out-of-vehicle and in-vehicle, is

$$\frac{1 + \beta}{\beta_{(\text{one-way-distance})}} = \frac{208}{\text{one-way-distance}}$$

which for the sample average distance of 7.06 km equals approximately 2.95 out-of-vehicle minutes per minute of in-vehicle-minute.

Another important trade-off is between components of travel time and cost. Since the specification given in Table 4.2 distinguishes between in-vehicle and out-of-vehicle travel time, there are two relevant rates of substitution between time and cost.

For in-vehicle time the implied rate of
substitution is

\[
\frac{\beta_3}{\beta_5} \times (\text{household income})
\]

For an average income of taka 16,105 (sixteen thousand one hundred and five), the estimate is 0.5 taka per minute of in-vehicle time, or 30 taka per hour of in-vehicle time.

In case of out-of-vehicle time the rate of substitution is given by

\[
\left[ \frac{\beta_3 + \frac{\beta_4}{\beta_5 (\text{one-way - distance})}}{\beta_5} \right] \times (\text{household income})
\]

Using average distance 7.06 km and average income taka 16,105, we obtain an estimated rate of substitution of approximately 1.97 taka per minute of out-of-vehicle time, or 118.5 taka per hour of out-of-vehicle time.

Three causal models were depicted to describe the strength to which different latent factors affect the mode choice. Table 5.1 shows the direct correlation between the latent indicators and the chosen mode. Comparison between the causal paths and correlation table reveals similar type of strength of the latent factors influencing the chosen mode. It seems that people’s concern about relax and privacy leads them to choose rickshaw, people’s concern about reliability leads them to choose bus and people’s concern about security lead them to choose taxi.

Table 5.1 Correlation of different latent indicators with chosen mode

<table>
<thead>
<tr>
<th></th>
<th>Rickshaw</th>
<th>Bus</th>
<th>Taxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relax</td>
<td>.74</td>
<td>.59</td>
<td>.39</td>
</tr>
<tr>
<td>Safety</td>
<td>.59</td>
<td>.59</td>
<td>.48</td>
</tr>
<tr>
<td>Reliability</td>
<td>.70</td>
<td>.77</td>
<td>.50</td>
</tr>
<tr>
<td>Security</td>
<td>.65</td>
<td>.52</td>
<td>.63</td>
</tr>
<tr>
<td>Privacy</td>
<td>.66</td>
<td>.51</td>
<td>.48</td>
</tr>
<tr>
<td>User-friendly</td>
<td>.63</td>
<td>.60</td>
<td>.21</td>
</tr>
</tbody>
</table>

In general, rickshaw got high values for most of its indicators. This reveals people’s preference towards rickshaw at least from psychological point of view. Rickshaw got the highest value for its relax and privacy indicators because of the inherent nature of the vehicle. Bus got the highest score is reliability. This may be confusing because the reliability of bus is, in general, perceived to be low comparing to other modes. Taxi got the highest score is security because people may fear the danger of pick-pocketing in bus.

Policies considered for analysis:
In case of estimating the effect of change of a certain policy variable, it has been assumed that the change occurs only on the policy variable in concern with all other things remaining the same. Policies considered for analysis are:

- If certain improvement plans are implemented for decreasing the existing bus in-vehicle travel time in order to attract people towards bus, what could be the possible shift from other modes. These effects have been analyzed under two scenario i.e. decrease of bus in-vehicle time ten percent and twenty percent (fig. 6.1)
- If certain actions are taken in terms of increasing bus frequency or any other for decreasing the existing bus out-of-vehicle travel time in order to attract people towards bus, what could be the possible shift from other modes. These effects have been analyzed under two scenario i.e. decrease of bus out-of-vehicle time ten percent and twenty percent (fig. 6.2)
- If certain rickshaw movements are restricted in important links/roads, what could be the possible shift towards other modes. In this case, rickshaws will have to travel more distance than the prevailing situation and this will eventually increase the rickshaw travel cost. These effects have been analyzed under two scenario i.e. increase of rickshaw travel cost ten percent and twenty percent.
- The combined effects (combined effect 1) of the decrease of bus in-vehicle travel time and bus out-of-vehicle travel time have been analyzed under ten percent and twenty percent scenario (fig. 6.4).
- The combined effects (combined effect 2) of the decrease of bus in-vehicle travel time and bus out-o-vehicle travel time and the increase of
Rickshaw travel cost have been analyzed under ten percent and twenty percent scenario (fig. 6.5).

Figure 6.1 Change of modal share due to change of bus in-vehicle travel time

Figure 6.2 Change of modal share due to change of bus Out-of-vehicle travel time

Figure 6.4 Change of modal share due to decrease of combined effect 1

Figure 6.5 Change of modal share due to change of combined effect 2
The issue of mode choice is probably the single most important element in transport planning and policy making. Developing of models sensitive to those attributes of travel that influence individuals choices plays a paramount role in this regard. In this paper, two discrete mode choice models of multinominal logit type have been proposed and subsequently one of these models are used to analyze the influence of different policy on existing modal share under changed scenario. Policy analysis reveals that the out-of-vehicle time is more sensitive that the in-vehicle travel time in changing the modal share of the mass transit (bus). The combined effect of policies manifest that a significant amount of modal shift can be expected. Model interpretation reveals that people perceive roughly three out-of-vehicle minutes per minute of in-vehicle time and the rate of substitution approximates 30 taka (.05 US dollar) per hour of in-vehicle time.

It has long been recognized that there is a need for more research about transport mode choice behavior to understand the urban transport policy and planning context that could accommodate traveler’s demand. In this research, I developed a multinominal logit ---model for mode choice considering three widely used mode for the case study. The model is primarily developed with observed factors and later a methodology for incorporating latent factors in the model is proposed.

Further improvement in mode choice behavior analysis will contribute to help both public and private organizations to address specific problems more quickly and efficiently in the context of transportation demand and planning of transport investment.

References


