１．発展途上都市での通勤交通手段選択行動のモデル化

ーダッカ市の事例ー

Modeling mode choice behavior for work-trip of a developing city

-A case study of Dhaka City-

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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.

1. Introduction

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. If few current transit riders switch to other modes because of the fare increase, transit revenues will increase proportionally to the increase in fare. But if many riders switch to other modes, revenues will increase less than proportionally to the fare increase and may decrease.　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. In most situations, planners must choose among a variety of fare schedules and service designs.　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.

The choice of transport mode is probably one of the most important classic models in transport planning. This is because of the key role played by the public transport in maintaining congestion at reasonable levels. Almost without exception public transport modes make use of road space more efficiently than the private car. Furthermore, underground and other rail-based modes do not require additional road space (although they may require a reserve of some kind) and therefore do not contribute to congestion. Moreover, if some drivers can be persuaded to use public transport instead of cars, the rest of the car users would benefit from improved levels of service. It is unlikely that all car owners are willing to use their cars could be accommodated in urban areas 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 fundaments 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.

2. Literature Review

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-Akiava 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.

3. Research design and data collection

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.

4. Discrete choice model using objective factors

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

Variable name	Coefficient estimate	Standard error	t-statistic
Const_r	1.23	0.42	2.89
Const_b	0.94	0.67	1.39
IVT	-0.06	0.02	-2.75
OVT	-0.11	0.045	-2.55
TC	-0.043	0 .018	-2.36

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

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

$V_{rickshaw}$=1.23213-0.060054*IVT-0.115455*OVT-0.043684*TC

V_{bus}= .945505-0.060054*IVT-0.115455*OVT-0.043684*TC

V_{taxi}= 0.060054*IVT-0.115455*OVT-0.043684*TC

Where, IVT=In-vehicle travel time, OVT=out-of-vehicle travel time, TC= Travel cost,

Interpretation of estimation results, Const_r =alternate specific constant for rickshaw choice, Const_b=alternate specific constant for bus choice.

- 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 β_1 through β_5 and the subsequent columns represent the coefficient estimates and their statistical information.

Table 4.2 (Model two)

Trinomial logit model using two alternative-specific constants, two travel attributes and one mixed travel-socioeconomic attribute

Variable name	Label of the coeffi-cients	Coefficient estimate	Standard error	t-statistic
Const_r	β_1	0.086	0.44	0.19
Const_b	β_2	-1.64	0.99	-1.65
IVT	β_3	-.068	0.024	-2.80
OVT/OWD	β_4	-1.42	0.35	-4.00
TC/HI	β_5	-2211.55	373.22	-5.92

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 ($\hat{\beta}$) = -107.579

First likelihood ratio, -2[L(0)- L($\hat{\beta}$)] = 180.34

Second likelihood ratio, -2[L(c)- L($\hat{\beta}$)] = 135.69

Rho-square, ρ^2 = 1- L($\hat{\beta}$)/L(0) = .46

Modified rho-square, $\bar{\rho}^2$= 1 - [L($\hat{\beta}$)-K]/ L(0) = .44

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

$V_{rickshaw}$=.086528-0.068734*IVT -1.4295*OVT/OWD-2211.55*TC/HI

V_{bus}=-1.64464-0.068734*IVT -1.4295*OVT/OWD-2211.55*TC/HI

V_{taxi}=-0.068734*IVT-1.4295*OVT/OWD-2211.55*TC/HI

Where, IVT=In-vehicle travel time, OVT=out-of-vehicle travel time, TC= Travel cost, OWD=One Way Distance, HI=Household Income, Const_r =alternate specific constant for rickshaw choice, Const_b=alternate specific constant for bus choice.

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

$$1+ \frac{\beta_4}{\beta_3(one-way-disatance)} = \frac{20.8}{one-way-distance},$$

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

$$\left[\frac{\beta_3}{\beta_5} + \frac{\beta_4}{\beta_5(one-way-dis\tan ce)}\right] \times$$

(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.

5. Portrayal of mode choice behavior using latent factors

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

	Rickshaw	Bus	Taxi
Relax	.74	.59	.39
Safety	.59	.59	.48
Reliability	.70	.77	.50
Security	.65	.52	.63
Privacy	.66	.51	.48
User-friendliness	.63	.60	.21

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.

6. Policy analysis under different scenario

Since the review of the correlation coefficients among different variables of model one and model two (table 4.1 and table 4.2) developed in section four manifests significant correlation at least between two variables (IVT and TC) of model one, model two has been chosen for policy 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:
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)

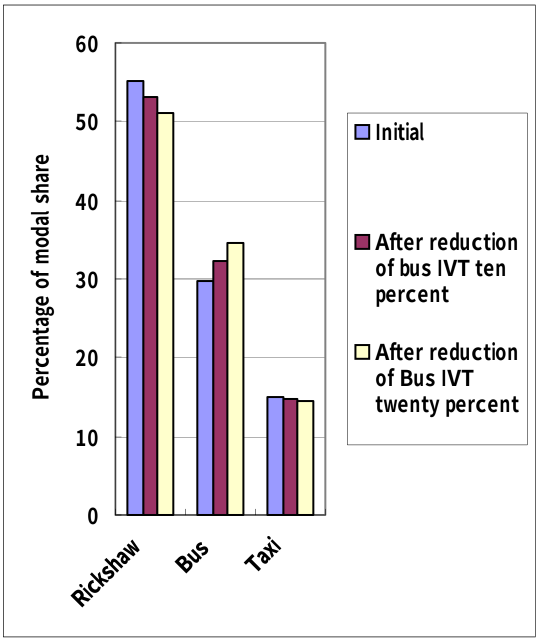

Figure 6.1 Change of modal share due to change of bus in-vehicle travel time

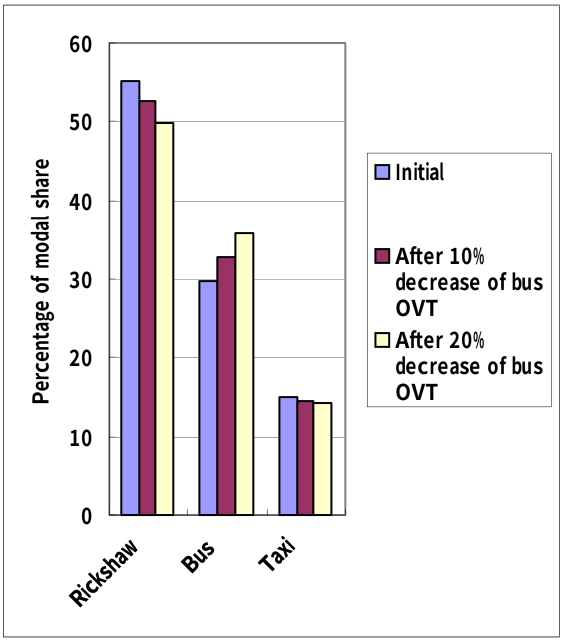

Figure 6.2 Change of modal share due to change of bus Out-of-vehicle travel time

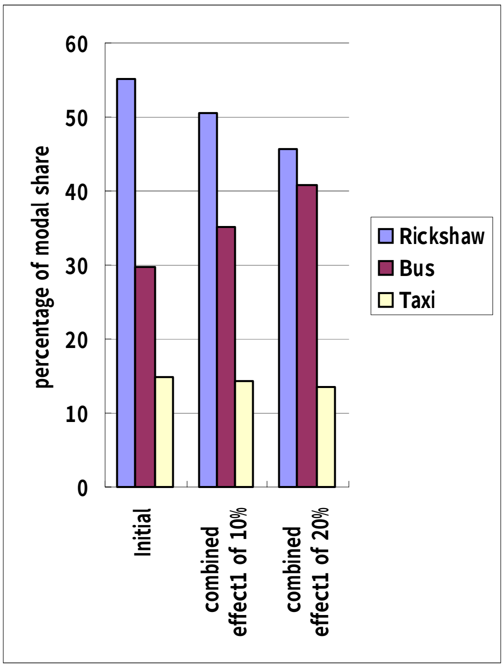

Figure 6.4 Change of modal share due to decrease of combined effect 1

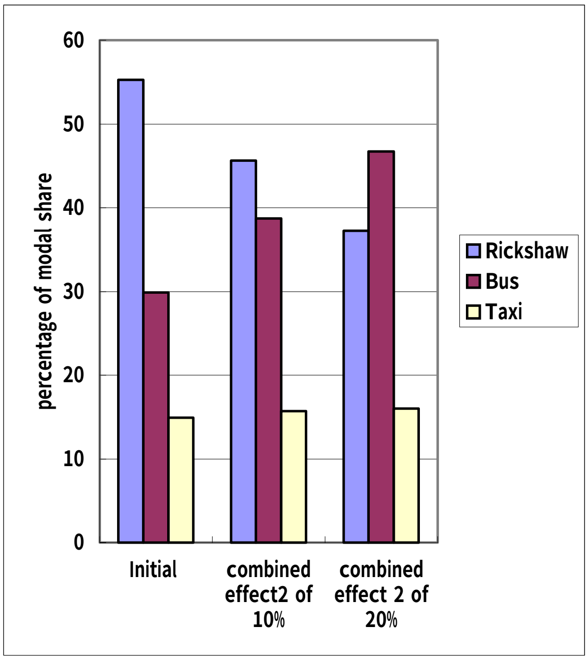

Figure 6.5 Change of modal share due to change of combined effect2

7. Conclusion

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 multinomial 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 multinomial 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.

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