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Mode Choice Modelling of Work Trips: A Case Study of Kolkata

(URBAN TRANSPORTATION PLANNING)

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***Abstract*— In developing countries, like India, the increasing horizontal spread of the cities and the decentralized nature of development have led to the increased travelling demand. In order to suffice the people's need for travelling, various transportation modes, having different attributes, have been introduced gradually in the transportation system viz. public city bus, taxi/cab, auto-rickshaw, private vehicle, etc. The trip makers decide the suitability of a mode with respect to his/her criteria which may be classified as quantitative (includes, travel time, travel cost, waiting time etc.) and qualitative (includes, reliability, comfort, convenience, etc.). In this study, the modal share of the Garia-Park Circus corridor in Kolkata, India has been tried to be estimated for work trips only. Transit, Para-transit and Personal vehicles are considered here. The criteria selected for the modeling are Travel Time (TT), Travel Cost (TC), Comfort, Convenience (Waiting Time), Reliability and Dust& Noise. The utility perceived by the trip makers for each of the alternative modes is collected through questionnaire survey and the scaling of the stated preferences is done by psychometric scaling technique.**

Keywords— ***Mode Choice Modeling, Utility function, Logit Model, Theory of Successive Category.***

I. INTRODUCTION

The transportation needs are increasing day by day due to heavy industrialization, decentralized nature of development and increasing growth of population all over the world. There are many alternate modes of transport available nowadays. Thus, a trip maker needs[2] to decide which alternate mode is suitable for his/her travelling on the basis of certain criteria for any particular trip purpose. Some of these criteria are qualitative and some are quantitative.

In Indian cities, a large variety of public transport modes are available such as, Air Conditioned Bus, Ordinary Bus, Auto-Rickshaw, Taxi and Private Vehicle, available for long as well as short distance work trips. Metro system is also running in some major corridors at some of the cities. The choice of the modes by the trip makers depend on many factors. Some of the factors are Travel Time, Travel Cost, Comfort, Convenience (in terms of Waiting Time), Reliability, Pollution etc. The aim of the present study is to prepare any simple method to assess the share of different passenger transport mode of a large Indian city, particularly of Kolkata, the third largest metropolitan city of India.

Many research works on mode choice modeling have already been done in past years.A number of previous journal papers regarding mode choice analysis have been studied in order to fulfill the objectives of this study.Thamizh et al (1996) [1]presented study about trip characteristics ofdifferent groups of travelers in an urban area. The mode choice of this group in Tiruchirapally, a medium sized city in India is modeled for work trips using a binary logit model. The tripdistance is identified as the major factor influencing mode choice.Tae younjang (2003) [3] studied on causal relationship among travel mode, activity and travel pattern in Korea and concluded that individual activities are classified into obligatory and discretionary activities. In another paper by Singh (2003) [10] studied the application of behavioral simulation approach in formulation of transport policy in an Indian city.Lena et.al (2003) [6] studied factors influencing the choice of mode and to find measures that could attract car drivers to Park & Ride. The results indicate that security at the Park & Ride facility is important.Ewing et.al.(2004) [2]examined the relationship between mode of travel to school and the full range of factors that might affect mode choice in a medium sized city of Florida. Students with shorter walk or bike times to school proved significantly more likely to walk or bike.Ravi et.al. (2014) [9] made this study to carryout detailed review on various modeling methods of mode choice. He emphasized on statistical mode choice models such as multinomial logit and probit models as well as recent advanced soft computing techniques such as Artificial Neural Network models and

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Fuzzy approach model. Most of these literatures and many other studies have been carried out in small or medium sized cities. There are fewer studies on modal choice behavior of the trip makers of Kolkata city. One such study is by Mandal and Roy (2007) [5]. They assessed users' preference for public transport modesin a simplified way in the city of Kolkata.
It is observed from literature that very few studies on modal choice is done in Indian perspective, particularly for the city of Kolkata.

II. Study Objectives and Scope

The specific objective of the study is to assess modal choice of the regular work trip makers of the city of Kolkata. The scope of the study includes:

- Determination of Weight Vector of different attributes.
- Development of Utility function.
- Determination of the modal share using Logit Model.

The inputs of the model are generated from specific field data collected from an important arterial of Kolkata.

III. Methodology

A. Utility Function

One of prime techniques adopted for modal choice analysis is Logit Model. Logit model is used in this study as well. A utility function is necessary to be developed in order to use it in the logit model. This leads to the formulation of a utility function. The utility function, in general, is in the form[4, 7]:

$$u = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \cdots + a_nx_n \quad (1)$$

Where,
u is the utility function
x_1, x_2,…x_n are the criteria for mode choice considered in the study
a_0 is the mode specific attribute
a_1,a_2…$a_n$are the weight vectors of each criteria.
The criteria included in this study are

- Travel cost (TC): includes the expenditure incurred for travelling.
- Travel time (TT): represents In-vehicle travel time.
- Convenience (WT): represents the accessibility of mode e.g. time of walk at origin and destination stop and waiting time at the stop to avail a mode.
- Comfort: represents the perception of users' satisfaction while travelling in the mode considering in vehicle jerking, crowding, cleanliness etc.
- Reliability: indicates chances of arrival of vehicles in schedule time and reach destination at right time.
- Dust and Noise: indicatesthe level of pollution created by a particular mode as perceived by the trip makers.

B. Weight Vector

The trip makers perceive different attributes of the modes differently. These perceptions are extracted from the trip makers individually in the form of rating through a structured questionnaire survey. The ratings are converted to weight vectors using some psychometric technique. The weight vectors indicate the perceived importance of an attribute to a trip maker in a numerical form. In the present study, the psychometric technique used to obtain the weight vectors is the Theory of Successive Categories, proposed by L.L.Thurston(1927) (Quantification of Psychology by William L.Hays). A sample of the ratings provided by the respondents when transit is used as the mode of travel is shown in Table Isection V.

C. Mode Choice Modeling

The mode choosing probability of a particular mode is obtained by using the logit model. This model uses the utility function of a particular mode to estimate the probability of choosing a particular mode by a trip maker.

$$P_i = \frac{e^{u_i}}{\sum e^{u_i}};\ i=1,2\ldots n \quad (2)$$

Where,
P_i denotes the probability of choosing the 'i'th mode as the trip makers' mode of travel
u_i denotes the utility function of the 'i'th mode
Factors like Reliability, Comfort and Dust & Noise are subjective in nature and their cardinal values are not easy to assess. However, these are considered indirectly through mode specific attributes (a_0). Thus, the input criteria for developing utility equations are:

- In-vehicle Travel time (in Minute).
- Cost incurred to make the travel (in Rupees).
- Waiting time to access the mode (in Minute).

The final form of the utility function for this study is as follows:

$$u = a_0 + a_1x_1 + a_2x_2 + a_3x_3 \quad (3)$$

Where,
u=Utility of a particular Mode.
a_0 = mode specific attribute.
a_1 = weight vector for in-vehicle travel time.
x_1= In-vehicle Travel Time (in Minute).
a_2 = weight vector for Cost of Travel.
x_2= Cost of Travel (in Rupees).
a_3 = weight vector for Waiting time to access the vehicle.
x_3= Waiting Time to access the Vehicle (in Minute).
The study area and the data collection procedure are described in the next sections.

IV. Study Area

Kolkata is the third largest metropolitan city in India and the capital city of West Bengal state. It has a huge population, mostly residing at the suburban regions. It has wide variety of modes of transport plying on its streets. The corridor from Garia to Park Circus seven points was selected as the study area. Garia lies in the suburban region with many residential complexes and Park Circus, an important intersection, lies near the central part of Kolkata. The connecting corridor of approximately 9.5 km length (Fig 1) exhibits the

heterogeneous traffic of the city. Vehicles plying on this corridor include ordinary buses, Air Conditioned buses, auto rickshaw, taxis and private vehicles. The modes are classified into 3 types in this study, viz. Transit (t) which includes ordinary buses and Air Conditioned buses; Para-transit (pt) which includes auto rickshaw and taxi and Personal vehicles (pv) includes self-owned vehicles. The survey process and the data collection procedure are described in the following section.

Fig. 1: Route Map showing the Survey Area
Source: Google Map

V. SURVEY AND DATA COLLECTION

In the absence of any secondary data on attitude studies, collection of primary data from field survey for the study was essential to understand the attitude of the commuters towards selecting a particular mode. Thus, the data collection method included face-to-face interview of individual trip makers travelling along the selected route through questionnaire survey. Random sampling method was adopted for sampling technique. A total of 106 trip makers were interviewed. A sample of the ratings provided by the respondents when transit is used as the mode of travel is shown below in Table 2.

TABLE I: Ratings of the attributes by the transit users (in %)

	Extremely Not Important	Not Important	Immaterial	Important	Extremely Important
Time	17.50%	20.00%	5.00%	30.00%	27.50%
Cost	15.00%	12.50%	10.00%	22.50%	40.00%
Comfort	20.00%	12.50%	20.00%	30.00%	17.50%
Convenience	20.00%	27.50%	20.00%	20.00%	12.50%
Reliability	20.00%	25.00%	17.50%	20.00%	17.50%
Dust & Noise	22.50%	27.50%	27.50%	12.50%	10.00%

Source: Field Survey

Similarly, different ratings were obtained for the other two modes and the weight vectors were estimated.The weight vectors as obtained by the psychometric scaling theory using the ratings provided by the respondents are exhibited in table III section VI A.

Some of the characteristics of the commuters interviewed like Vehicle Ownership (Fig 2), Monthly Income Characteristics (Fig 3), Age of Commuters (Fig 4) and Distance Travelled (Fig 5), are provided below. The mean perceived Travel Time, Travel Cost and Waiting Time as perceived by the commuters along the route are shown in Table II.

TABLE II.Perceived Travel Time, Travel Cost and Waiting Time for the three different modes

Transit			*Paratransit*			*Personal vehicle*		
TT (Min)	*TC (INR)*	*WT (Min)*	*TT (Min)*	*TC (INR)*	*WT (Min)*	*TT (Min)*	*TC (INR)*	*WT (Min)*
50	10	25	30	115	13	25	250	0

Source: Field survey

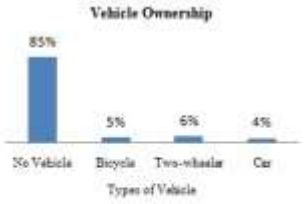

Fig 2: Vehicle Ownership Characteristics
Source: Field Survey

Fig 3: Monthly Income Characteristics
Source: Field Survey

Fig. 4: Age Characteristics of Commuters
Source: Field Survey

Fig 5: Trip Distance Characteristics
Source: Field Survey

Fig 2 indicates that 85% of the respondents do not have their Personal vehicle. This implies that they rely upon public transit system or the para-transit system. Fig 3 exhibits the income characteristics of the commuters. About 73% of the trip maker's monthly income lies between Rs. 5000 to Rs. 50000 i.e. low to mid income group. This may lead most of the trip makers to prefer the transit system rather than the para-transit system. Fig 4 shows that the age of the commuters varies from 18 to 60 years with maximum commuters in the range of 25 to 45 years. The trip distance characteristics (Fig 5) show that maximum commuters travel 3 to 5 Km.

VI. Data Analysis and Result

The data recorded from the questionnaire survey is analyzed. It is exhibited under the following three heads.

A. Quantification of Attitudinal Variables

The Theory of Successive Categories, proposed by L.L.Thurston(1927) (Quantification of Psychology by William L.Hays) is used here to quantify the qualitative variables that affects mode choice. The weight vectors (i.e., a_1, a_2, etc.) for the different attributes are shown in Table III below. The comparison of these weight vectors for the different modes is shown in Figure 6.

TABLE III Weight Vectors for different Modes along Garia-Park Circus Corridor

Mode / Attribute	Transit	Paratransit	Personal vehicle
Travel Time(TT)	0.1988	0.1877	0.0385
Travel Cost(TC)	0.2138	0.1464	0.0211
Comfort	0.1575	0.1758	0.3475
Waiting time(WT)	0.1447	0.1825	0.2091
Reliability	0.1535	0.1656	0.0382
Dust & Noise	0.1317	0.1659	0.3478

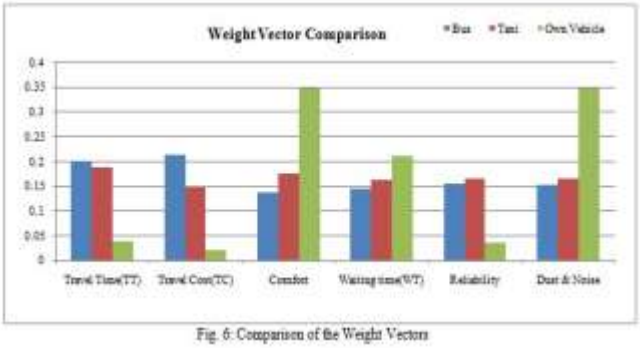

Fig. 6: Comparison of the Weight Vectors

The graph shows that, the trip makers give more importance on travel time while travelling by transit and para-transit. The travel cost is most important to the commuters who travel by transit and least important for personal vehicle users. This is because mostly the low-medium income group people avail the transit service and tries to minimize their travel cost. Whereas, the weight of comfort, waiting time and dust & noise criteria is higher for the personal vehicle users with respect to the other two modes.

B. Utility Function Formulation

The mode specific attribute for each of the modes i.e. a_{0t}, a_{0pt} and $a_{0pv}$are estimated by regression analysis. The trip makers' stated mode preference is equated to the utility function using the logit model to obtain the unknown values of a_0 for each of the modes. The input values for x_1, x_2 and x_3(3) for all three alternative modes is obtained from questionnaire survey.

The mean values of mode specific attribute for different modes obtained from the regression analysis are shown in Table IV.

TABLE IV.Mean Values of the Mode Specific Attributes from Regression Analysis

Mode Specific Attribute (a_0)	Values obtained
For Transit	15.6
For Paratransit	22.8
For Personal vehicle	1.1

The final form of the utility function for the three different modes along the Garia-Park Circus corridor is as follows:

$$U_t = 15.6 - 0.1988 \times x_{1t} - 0.2138 \times x_{2t} - 0.1477 \times x_{3t} \quad (4)$$

$$U_{pt} = 22.8 - 0.1877 \times x_{1pt} - 0.1464 \times x_{2pt} - 0.1625 \times x_{3pt} \quad (5)$$

$$U_{pv} = 1.1 - 0.0385 \times x_{1pv} - 0.0211 \times x_{2pv} - 0.2091 \times x_{3pv} \quad (6)$$

C. Estimation of Modal Share

The mode choice of the trip makers along the Garia-Park Circus corridor is estimated using Logit Model. The utility functions (4, 5 and 6) are used. The input values of the variables in the utility functions are shown in Table II section V. The Mode choice is shown in Fig 7.

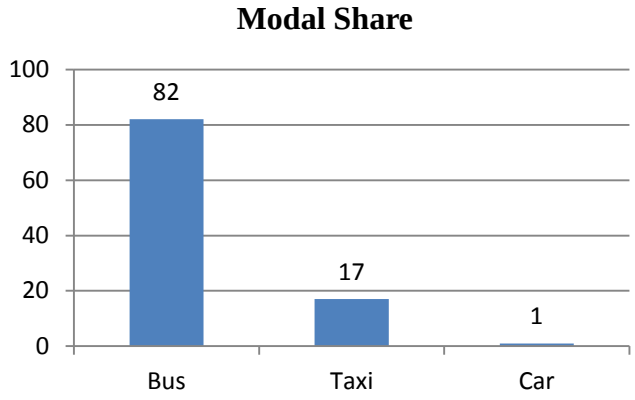

Fig 7: Modal Share as obtained from the Formulated Utility Function

VII. Conclusions

The weight vector (Table III) of each of the six criteria was calculated using the Theory of Successive Category by L.L.Thurstone. It shows that personal vehicle users are giving maximum importance to comfort, dust & noise and waiting time. Whereas, the transit users try to minimize their travel cost and travel time and hence gives more importance to these two criteria. The weight of all the attributes as perceived by the paratransit users, fall in between the transit and personal vehicle users.Travel Time, Travel Cost and Waiting Time only have been picked in the utility function development. The mode specific attribute (a_0) for the different modes i.e. Transit, Paratransit and Personal vehicle were estimated by regression analysis (Table IV). Finally, the utility function for each of the modes (4, 5 and 6) was formulated which was used in Logit model to providean overview of the modal share along the

Garia-Park Circus corridor in Kolkata (Fig 7). It is found out that, 82% of the work trip makers prefer transit for their travel over the other two modes, 17% prefers paratransitas their travel mode and only 1% chooses personal vehicle.

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