

A Critical Appraisal of Mode Choice Model of Work Trips

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Abstract: In the present scenario in world, many mode choice models have been developed to predict the travelers mode choice in the available modes of transportation system. The mode choice model is one of a very significant component in the urban transportation planning and policies, specifically in countries that are toward development and urbanization, like South Asian countries (India, Bangladesh, Nepal, etc.) the increasing horizontal spread of cities that led to increased travel demand. The aim of this review is to study the developing of mode choice model for various transportation modes. The developed models cover different modes of transportation currently employed in cities, which are Private car, Taxi, Public bus, Auto-rickshaw, Motorcycles, Shared car, Bicycles, Walking. They have been tried to be estimated for work, education, shopping and other trips. There are some factors that considerably influence the choice of transport modes are: Socio economics variables such as age, gender, car ownership, and family monthly income. Network variables are such as travel time, travel cost, comfort, reliability, employment, driving license, weather, and dust & noise. The data was collected for each of the alternative modes through questionnaire by face to face interview or by using Google form. There are different methods that can be applied for the developing a mode choice model, multinomial logit model is the easiest method with simple mathematical calculations; this method was also used by many authors for analysis and for checking the validation the likelihood ratio test. The application of mode choice model is significant to mode user to have best choice, and also such models can assist in the alleviation of traffic congestion and air pollution in the city.

Keywords: logit models, mode choice, transportation planning, utility function

I. INTRODUCTION

The transportation needs are increasing day by day due to current heavy industrialization, decentralization nature of development and increasing growth of population all over the world. The transportation planning can handle all needs of transportation through some processes.

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Basically these are four basic steps (1) trip generation, (2) trip distribution, (3) mode choice, and (4) traffic assignment. Trip generation determines the total number of trips produced from given origins and the total number of trips attracted by given destinations, while trip distribution estimates the trips between different transport zones [8].

The mode choice modeling is important for predicting the travelers' behavior for mode choice and determining the factors affecting the selection of a particular modes [6]. Finally traffic assignment designates trips to the transportation network and estimates the traffic volumes on different links of the transportation network [8]. This paper aim is to review some articles of mode choice modeling to select the suitable model for a city and the factors affect the mode modeling. The mode choice modeling approaches can be divided into aggregate and disaggregate behavioral modeling approaches. Aggregate modeling primarily focuses on the mode choices made by average individuals for trips, while disaggregate approach is based on the individual choice of the characteristics of available alternatives. Disaggregate mode choice models can be classified into three main models, namely: logit models, probit models and extreme value models [6]. Logit models are popular among the discrete models because it's simple mathematical framework. This can be classified into two main categories: (1) binary and (2) multinomial logit models. Binary choice models can be used in the individuals have only two alternatives to select from, while the multinomial logit models can be used in case of more than two alternatives [6]. Random utility theory usually derives the discrete choice logit model. It assumes that individuals choose transport modes that maximize their utility. There are three main groups of factors that affect individual's choice of transportation: (1) Factors associated with the attributes of trip maker such as age, gender, family size, car ownership and driving license, (2) Factors associated with the attributes of trip such as, time of trip, and trip purpose, (3) Factors associated with attributes of transport facilities such as travel cost, travel time and waiting time [6].

II. LITERATURE REVIEW

In this review, we focus on the literature relating to the mode choice model for the city. Some articles were studied that each of them followed almost similar methods and data collections for developing the mode choice models. During the study of literature we found some methods, case studies, data collections, and models with approximately same variables for mode choice model for different cities.



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Developing of a mode choice model for Mansoura city in Egypt, Marwa.E, Usama.E.S, and Sherif M.El-Badawy [4], collected around 10000 online questionnaires using Google Forms. Two-thirds of the data were randomly selected and used in developing model and the remaining one-third data was used in validating the developed model for accuracy purpose. Their model covers five main modes of city, which are private car, Taxi, Microbus, Walking, and others. The result of model is 85% accuracy and exhibits a good fit for the data. Moreover, the model shows that travel time, total cost, car ownership gender, personal income, occupational status are the prime factors that significantly affect the mode choice. They used logit models for developing the model and chi-square test for goodness of fit [4]. In their paper, the authors collected data using online questionnaire in Google Forms between March and July 2015 that each questionnaire represented a household. The questionnaire was divided into four sections (respondent's residency information in city, the information about respondent building, socio economics condition of family, and choice of alternative modes). After collecting the data, it was analyzed by descriptive statistics and the preference of mode choice of trip maker. The authors measured the strength between the mode choice behavior and traveler's socioeconomics used "CRAMERS V" test. "CRAMERS V" value varies between 0-1. If the value close to zero considered as weak relationship between variables while close to one indicated strong relationship. The model calibration was preceded by using logit model estimation software based on iterative process until the desired result achieved. Each utility function had to be specified until satisfactory results and then a model was calibrated. The descriptive statistics percentage shows that bicycles, motorcycles, work car, three wheeler were very low. Thus, considered in one mode, final modes for analysis were "taxi, private car, microbus, walking". After the result of statistics, they selected multinomial logit model for developing the model. After that they used the easy logit modeling software for calibrating of the developed model, and then they evaluated the calibrated model by four tests. The first was logicity of the model variables. The second test was significance of variable in model. The T-statistic applied to check each variable at 95 significance level. The third test was the "Goodness of fit" test by adjusted rho-square " p^2 ". The fourth test they used was for comparing the models [4].

Case study of Kolkata city on mode choice modeling of work trips was studied by Ram Chanda, Saptarshi and Sudip Kumar Roy [7], that there are two criteria for variables which may be classified as quantitative (includes, travel time, travel cost, waiting time etc.) and qualitative (includes, reliability, comfort, convenience, etc.). Their article considered the India work trips as Transit, Para-transit and personal vehicles, and the utility for each alternative mode was collected through questionnaire survey. They used in their paper logit model including utility function formulation [7]. The authors used the primary data from field. Thus, the data collection methods included face to face interview of individual trip makers traveling along the selected route through questionnaire survey. Random sampling method was adopted for sampling technique. The prime technique adopted for mode choice analysis is logit model method. In

order to use logit model utility function is necessary to develop. They presented some attributes for formulation of utility function such as travel cost, travel time, convenience, comfort, reliability and dust and noise. The individual trip maker in the forming of rating converted to weight vectors. The weight vectors designate the importance of an attribute to a trip maker. They used psychometric technique for finding weight vector of each variable [7].

Gaza city work trips mode choice was studied by Essam Almasri and Sadi Alraee [1]. Their main concentration was on the effect of socio elements on mode choice model such as income, vehicle ownership, distance, age as significant factors and their developed model had 95% confidence level validity. They indicated that the transport system in Gaza city is classified into private and public transport. The public transport serves effectively around the city and satisfies the majority of the population mobility. The public transport has three modes which are taxi, shared taxi and buses. They used logit model based on utility theory. The validation of model was tested by likelihood ratio test and formulated the null hypothesis [1]. The authors presented six stages for their research paper completion. Literature review was considered in first stage. The second stage was the selection of travel attributes that involved designing of initial questionnaire and analysis of data to determine the attributes. The third stage was to design the final questionnaire and conducting of survey to select the sample size and attributes. They designed the questionnaire into three sections. These includes: socio economic factors, factor effect mode choice, trip characteristics (travel cost, travel time, fuel consumption, license, and maintenance cost etc.). The fourth stage had calibration and estimation of the utility functions for the models based on the utility functions formula. The accurate model was preferred with their overall goodness of fit. The fifth stage was to validate the models by Likelihood Ratio Test (LRTS) and null hypothesis formulation. They applied the Likelihood Ratio Test and chi-square test with a specific degrees of freedom named k . If Likelihood Ratio Test result became less than critical chi square value at the rate of 95% confidence level and degree of freedom equals to k than for that case the null hypothesis ($H_0: \beta_i = \beta_j$) can be accepted otherwise it is rejected [1]. The last stage of their paper was findings and conclusions. They calibrated the model based on the descriptive statistical analysis of data; also considered six modes for modeling. The modes were private car, shared taxi, taxi, motorcycle, bicycle, and walking. Their first built model included travel time (TT) and travel cost (TC) as basic variables. If in case one variable increases one unit that has the same impact on the entire model utility of modes available. Moreover, the distance variable was considered as a specific variable for bicycle and walking modes and the private car mode was considered as a base mode when adding constants for the mode utilities. The following utility formulations used for different modes while developing the models for each mode [1]. Ling Ding and Ning Zhang presented a research paper the title of mode choice model using individual grouping based on cluster analysis in Nanjing city in Chain [3].

They searched on two travel modes: the transit (bus and metro) and private car. They collected two information, traveler's personal information and travel information were collected through a reveal preference survey and a stated preference survey. The personal information includes gender, occupation, income, and car ownership, while the travel information includes the mode choice, walking time, waiting time, vehicle time, fare, comfort, etc. The factors that contribute to travel behaviors mainly fall into two categories: the macroscopic (economic level, land use) and the microscopic factor (age, income, travel time, travel cost, etc.) [3]. In their study, the authors performed two survey. Revealed Preference and Statistical Preference. The revealed preference and statistical survey were collected from 524 respondents. The revealed preference collected respondent's social- economical information including gender, occupation, income, and car ownership. The age was not regarded as attribute because all respondents' ages fall in to the range of 20 to 45 years. The statistical preference survey collected the information of preferred mode to the CBD. The data was classified based on cluster analysis for the classification of samples or indexes. The main objective of cluster analysis is to collect data for their similarity of the study object. They preferred to use statistical analysis system software which is widely used for hierarchical clustering analysis and software applied on the individual grouping. A simple Multinomial Logit (MNL) model was applied in their study for the travel choice analysis. The variables used in the utility functions include: walking time, waiting time, in-vehicle time, fare, comfort, travel time cost [3]. Travel to school mode choice modeling in Dresden city in Germany, Sven Muller, Stefan and Knut Haase [10], described that students might switch from low cost transport modes for instance cycling and public transport. They indicated the most influencing factors that affect the mode choice are: distance, car availability and weather. They modeled using a multinomial logit approach. Their study focused on secondary schools students aged 10 and 19 years that create 45% students are in this age in Dresden city (City Council of Dresden, 2003). They have presented a method utilizing GIS to disaggregate travel survey data. Particularly for travel to school analysis this could be a useful procedure to gain better and even more realistic modeling results. The authors used two pages questionnaire to obtain information of each student home district, the school attended, age, sex, car availability, driver license as well travel to school mode choice and the preferred transport mode from home to school and school to home. Moreover, the total travel time from school to home or home to school is related to the most preferred transport in three weather conditions summer, winter and bad weather were the important factors in questionnaire. They presented, that mode is a categorical variable. They suggested that a student chooses the transport mode with high utility. So they reverted to multinomial logistic regression since this is based on utility theory and appropriate for categorical data analysis. The result of model is 81% correctly predicted for all cases [10]. Development of intercity mode choice models for Saudi Arabia, Hasan M. Al- Ahmadi [2], and the main purpose was to develop intercity mode choice models for Saudi Arabia. The required data was collected through

comprehensive questionnaire at the airport terminals, bus terminals, train terminals. The mode choice model was for work, Aumera (Pilgrimage) and social trips. The factors studied in their article are socio economics, travel distance, travel time, nationality of the traveler, out of pocket cost and etc. They also prioritized, that another important factor affects the trip maker in choosing a mode is the weather due to very hot weather in summer, the trip makers to use his car or use ground transportation in intercity trips. In their study the focus was only on men as trips maker because women are not allowed to drive or travel [2]. The authors categorized three variables: socioeconomic variables (income, car ownership, license, group size, family, age, nationality) level of service (in vehicle travel, access time, egress time, waiting time, total travel time, travel cost) and trip regarding variables (trip purpose, duration of stay). A questionnaire form designed in two languages Arabic and English due to different countries residents in Saudi Arabia. The questionnaires were distributed in terminals departure for respondents; they interviewed the trip makers who were travelling at gas stations. Different model specifications were tested based on the various model utility functions. Some of the models tests presented poor statistical goodness of fit and/or opposite signs and were not accepted, however some models results were a very good fit, thus concluded as:

Some variables with insignificant coefficient and those variables that had "wrong" signs were not considered, and there were few who had relation with level of service were also considered, few sets of variables were with high correlation were not dropped, included in the analysis. The most satisfactory models were for work trips as compared to social and Aumra (pilgrimage). After doing t-statistics, the values for the variables that the null hypotheses that the true value of each coefficient is zero can be rejected at least at the 0.1 significance levels. The goodness - of -fit measure rho-square for the work model, Aumra model, social models, the rho statistics for these models represent a very good fit. Different data was used for model validation other than calibration data. Likelihood Ratio Test statistics were used to conduct validation tests. Chi -square tests distributed with degrees of freedom equal to the number of model parameter. The validation determined that there is no significance difference between the observed and predicted behavior for mode choice [2]. Jayesh Juremalani and Krupesh A. Chauhan [11] studied for comparing the mode choice model by collecting 224 respondents behavior for analysis proposes in Vadodara city. They considered socio economics characteristics (age, house hold size, employment, income) and trip attributes (travel time, travel cost) as independent factors affect the mode choice model. They considered four transportation modes. These include, private cars, motorcycle, bus, and shared auto. They applied Chi square test to check the effect of variable on mode choice, and found that the independent factors influence the mode choice behavior. Their paper compared three models, which are boost tree model, multinomial logit model and SVN model by using mining process in statistical software.

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Finally they found that the superior model is boost tree model because the error percentage was lesser than other two [11]. Minal and ChRavi Sekhar[12] presented in their paper for models for mode choice analysis, the factors that affect the mode choice and the methods of collecting travel behavior data. They mentioned that mode choice is affected by social, economic, environmental and cultural factors such as: travel time, travel cost, waiting time, number and ease of transfers, comfort, etc. The travel time is widely influencing and is considered in the transportation planning importantly. Many researchers considered the travel time as effective parameter in mode choice analysis. Researchers have found that the value of travel time for work trips is completely close to the wage rate of commuters. For non-work trips this value is found to be clustered around 25% of the wage rate. They collected some methods for collecting the data through survey like face to face survey, workplace survey, destination survey, online survey and intercept survey. After doing survey by any method, sampling selection is significant and should be attempt with caution. Personal interview survey is where the pollster holds the questionnaire, reads to the respondents and fills up their answers. This type of interview can have high chance of error as compared to computer assisted interviewing. Computer assisted interviewing method is that the respondents directly answer by computer without using the papers and pen. This can also be conducted through face to face interview by using the portable computers, this interviewer data goes to the central computer. Online survey is other research tool that can be performed by mail assisted or commuter assisted telephone survey. Recently, GPS survey is deployed that second by second data of location, speed, position can be collected. Moreover, the two reliable techniques of revealed preference and stated preference are used as complementary tools stimulate the preference of the decision maker. Revealed choice data describes current observed travel patterns and costs and hence gives very accurate picture of current modal choice. However, the use of Stated Preference (SP) data had often been and still is sometimes rejected due to their unknown reliability. They also explained on some models for mode choice. If the mode choice information is based on zonal and inter-zonal the model is known as aggregate. If the information is based on individual data or household is called disaggregate model. The aggregate model deals with the overall average behavior of a set of individual's travelers rather than individual traveler. There are a number of aggregate models like the direct demand models, sequential models, Trip-end modal split, Trip-interchange modal split models, aggregate transportation planning models and etc. These models implementation mostly hard due to time consuming and more costly but provide accurate result such as direct demand and sequential models. The aggregate transportation planning model was criticized for their inflexibility and inaccuracy. On the contrary, disaggregate approach is individual choice responses as a function of the characteristics of available attributes of each individual. Efficiency is more than aggregate approach in terms of reliability of data. Disaggregate model is mainly classified into three models, namely: logit models, probit models, and extreme value models. Statistical models classifications

refer to discriminant model technique analysis. Discrete choice models are derived from random –utility maximization and are widely used in transportation related application particularly in the urbanization part. There are three different main categories of models, namely: logit model, probit model, and general extreme value. Logit model is most widely used and applicable on complicated problems, and its calculation is quite simple to resolve that issue, which they have ability to analyze complex travel behavior of any data with simple mathematical framework; it is based on the theory of utility maximization. Logit models are classified in three types depending on whether the data or coefficients are chooser-specific or choice-specific. These models are used since many years for the development of mode choice models. Discrete models analyses choices separately, are so named discrete models of mode choice. These models follow the rules of disaggregate models, means that the trip maker is presumed to be an individual, not by a group or traffic analysis zones. The data is directly refers to the level of a person, household, or firm. This model framework is associated by four elements with the choice process which are Decision maker, Alternatives, Attributes, Decision rule [12]. Random utility model underlying the hypothesis, when faced with choice situation. The individual prefers to each alternative by utility measures. The utility function creates a numerical value on the basis of available attributes of mode for the trip and also the characteristics of the trip makers. The decision will be taken for the highest utility. Utilities, however, cannot be observed directly. The word random means that the trip maker has ability to choose the mode choice, that is, the expert is supposed to have inadequate information about the individual's choice decisions. Therefore, uncertainty must be accounted in the utility function. Four sources of uncertainty are identified: unobserved alternative attributes, unobserved individual attributes, measurement errors and incomplete information, and instrumental variables. Moreover, studied that multinomial logit models are the basic member of general extreme value. This model formulation is on the basis of three assumptions. The different alternatives of random components of utilities are independent and identically distributed, multinomial nested logit model sustains homogeneity in responsiveness to attributes of alternatives across individuals. The error variance-covariance structure of the alternatives is identical across individuals. Nested logit model allows estimation among selected sub – modes, it processes earlier between modes. Random component is distributed identically; dependently with type one extreme value by the nested logit model. The multinomial probit model is harder than it, the major disadvantages of nest logit model are first, if the alternative increases the structure of search increases rapidly. Second, alternative might be continued by the actual competitive structure which cannot be accurately represented by separating the alternatives into mutually exclusive subsets. Multinomial probit model is the main alternative to general extreme value –based values in discrete choice analysis.

The major disadvantage of this model is the requirement to use a normal distribution for representing random test heterogeneity, causing losses in terms of flexibility. Due to this the transport planners prefer to logit models as this is simple mathematical framework and can give accurate result. Probit models need lots of calculations due to their alternative specific utility structure; this involves the calculation of the error distribution for every alternative mode. This model is on the basis of stochastic utility function. It is a closed form distribution that allows for various levels of correlation among the unobserved part of utility across alternatives [12].

III. CONCLUSIONS & RECOMMENDATIONS

This literature review can be concluded that the basic variables (travel time, travel cost), vehicle ownership, age, distance, license, occupation, residence status, weather, and family income are the factors that can significantly effect on the behavior on traveler mode choice in a city. Many of authors considered gender is statically insignificant. Thus, most of the papers excluded from model. These studies present a multinomial logit mode choice behavioral model for individual trips based on the utility functions theory. Each model was then validated after calibration with a separate data which was not used in calibrating. The developed models covered different modes such private cars, taxi, walking, motorcycle, share taxi, bicycle with high accuracy prediction. The models exhibits a good fit for the data, the tests of likelihood ratio, chi square and rho-square were applied for goodness of fit. During the study of literature, some recommendations are emerged. 1) regular public awareness campaigns should be planned and executed to provide the advantages of non-motorized transport or public transport for trip makers; 2) it is necessary to develop models for social, study, and recreational trips other than work trips; 3) the captive travelers effect of on mode choice models should be studied; 4) generalized extreme, probit modeling methods can be used other than logit model; 5) Data should be collected for mode choice from different places such as universities, commercials, hospitals, transport stations, offices, etc. 5) it is very important to cooperate with university researchers in developing such models or any transportation related planning and technology. With their support, research will become more productive and useful.

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