Location and Travel Choice Models for the Cities of Developing Countries

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ABSTRACT: This paper initially reports the various stages of land use transportation models from aggregate to disaggregate approaches. Then the paper discusses about the importance of individual choice models for the location and travel aspects in the context of developing countries. The structure, specification and calibration of the residential location choice model using revealed preference (RP) data are discussed. The residential location choice model developed explains the decisions of households regarding residential location choice in the light of travel decisions. The calibration results of a discrete choice car ownership model, an important component of the proposed integrated land use transport framework, are also presented. The importance of revealed preference (RP) and stated preference (SP) data in the calibration of individual submodels is discussed.

RÉSUMÉ : La communication annonce tout d'abord les diverses étapes des modèles de transport d'utilisation des sols à partir d'approches globales vers des approches particulières. Puis, la communication traite de l'importance des modèles de choix individuels pour des aspects de localisation et de déplacement dans le contexte de pays en développement. Elle présente la structure, la spécification et le calibrage du modèle de choix du lieu de résidence utilisant des données de préférence révélée (RP). Le modèle de choix du lieu de résidence développé explique les décisions des ménages quant au choix du lieu de résidence prenant en compte les décisions en matière de déplacement. La communication présente également les résultats de calibrage d'un modèle de propriété de voiture de choix discret, composant important de la structure proposée de transport intégrée à l'utilisation des sols. Elle débat de l'importance des données de préférence révélée (RP) et de préférence exposée (SP) dans le calibrage de sous-modèles individuels.

1 INTRODUCTION

The major goal of urban transportation systems is to connect people with various activities. The change in the location of these activities will change travel behavior. There are evidences that land use patterns do have influences on travel patterns, such as trip, mode split, and trip generation. Combining location choice into transportation/land use analysis will make land use patterns endogenous rather than exogenous in the transportation/land use link, and it also opens door to the land use impacts of transportation, which is still an under-studied area. Decisions relating to location and travel choice have increasingly been modeled by using the discrete choice theory developed based on the concept of utility maximization. Discrete choice models have a long history of application in the economic, transportation, marketing, and geography fields, among other areas. Models of location choice are important tools for analysing urban economic policy, urban housing policy, transportation policy, and urban social spatial structure. Attempts made by many researchers to develop disaggregate location and travel choice models in the context of developed countries have proved the successful application of these models. In the context of developing countries, however, the applicability of the disaggregate choice models for location and travel has not been explored fully.

In the above context, a study has been taken up by the authors to explore the applicability of discrete choice models in arriving at realistic decision framework for the various alternative choices involved in location and travel aspects in the mega cities of the developing countries. It is assumed that each household must choose a home location in a neighborhood, a workplace location, nonwork activity locations along with travel patterns for all household members. These decisions are interrelated, and can be considered together as one joint household (HH) decision. In this study the decision making unit is taken as household. It is important to identifying the attributes of each potential alternative that the decision-maker is taking into account to make his/her decision. The variables considered in the study are land use patterns, housing unit characteristics, accessibility, travel patterns, and household socioeconomic characteristics.

The main aim of this study is to develop an integrated land use-transport model by calibrating relevant individual choice models which form the building blocks of the integrated model. It is proposed to calibrate the individual choice models using RP and SP data. The RP data set, which is mainly the home interview survey and travel data belongs to Thane city of Mumbai Metropolitan Region (MMR) of Maharashtra state, India. Towards achieving this bigger aim, in this paper, the development of residential location choice and car ownership choice models is reported. The residential location choice model developed explains the decisions of households regarding location choice in the light of travel decisions. It is also proposed to execute a suitably designed SP experiment to synthesize the residential location choice and car ownership choice of households. In addition to the individual *RP* and *SP* models, a joint *RP-SP* model is being developed to exploit the advantages of each type of data while mitigating the weaknesses. In this paper, however, the discussions are restricted to *RP* residential location choice model and the RP car ownership model only.

The various stages of land use transportation models from aggregate approaches (early) to disaggregate approaches (modern) are presented in the beginning. Then the paper discusses about the development of individual choice models for the location and travel aspects in the light of integrated land use transportation. Its applicability in the context of developing countries is discussed. The Revealed Preference (RP) and Stated Preference (SP) Techniques are briefly covered subsequently. The methodology, specification and calibration of the residential location choice model and car ownership models for Thane city using revealed preference data are discussed.

2 THE LAND USE TRANSPORT MODELLING TRADITION

In the field of urban economics, Von Thunen (1826), Losch (1954), Wingo (1961) and Alonso (1964), among others, tried to understand the functioning of a city from an analytic point of view with as few and general assumptions as possible. The purpose was to describe the aggregate behavior of a city in terms of land prices, lot sizes, commuting patterns, location of citizens of different categories, etc. This helped planners and scientists to achieve a better understanding of what planning could accomplish and what it could not, and which kinds of measures that could improve the functioning of a city. However, this resulted in virtually no operational models. This should be no surprise, since the basic assumptions were clearly unrealistic and too far-reaching. The main contribution to the initial operational models was the possibility to model the land rent marketing in a consistent way. This idea of bid-rent approach has been successfully implemented in urban models such as MUSSA (e.g. Martinez, 1992), RURBAN (e.g. Miyamoto, 1996) etc.. The origin of the well-known aggregate spatial interaction land use models of gravity type can be said to be Hansen (1959). Some of the earliest models were developed by Lowry (1964) and Echenique (1968). It must be considered as a remarkable accomplishment that this type of models, having been operational for almost a decade, could later be ``filled with theory'' by the works of Wilson (1967, 1970), Senior and Wilson (1974), Erlander (1977), Snickars and Weibull (1977) and Smith (1978) among others. With both theory and a firm practical tradition, spatial interaction models were constructed during the 1970s that were both possible to estimate, useful for predictions and stood on a solid theoretical ground. These included the works of Wilson (1974), Putman (1973, 1975a, 1975b), Coelho and Williams (1977), Lundqvist (1975) to mention a few. Many of these models are still very much operational and under continuing development. Discrete choice models have played an important role in transportation modeling for the last 30 years. Discrete choice theory which was derived from random utility theory was first introduced in the field of travel demand by McFadden (1974), and Domencich and McFadden (1975). The first applications dealt with transport problems at a ``lower'' level, such as mode choice and destination choice, but soon the classic ``four-step model'' was reinterpreted as an individual discrete choice model (Senior and Williams, 1977), along with the generalization of the multinomial logit to the Generalised Extreme Value (GEV) model, with the nested multinomial logit model as a special case (Williams, 1977a,b; McFadden, 1978). This type of models divides the decisions involved with a trip into four steps:

whether to travel (choice of trip frequency), destination choice, mode choice and route choice. The first three steps are modeled with a random utility approach almost always as logit model. The last step is most often handled by a deterministic network equilibrium model based on the Wardrop user equilibrium condition (Wardrop, 1952). Occasionally a first step where people choose location is added (Boyce, 1980). In retrospect, it is hard to understand why it took so long to realize that the logit and the entropy approach were identical for all practical purposes (Anas, 1983; Mattsson, 1984). Today, it does not make much sense to distinguish between logit models and gravity models, the only difference being the formulation of the assumptions. The combination of the spatial interaction model with the logit transport modelling tradition has created a variety of powerful models. Some are very comprehensive, modeling as many aspects as possible of a region's development. Examples are MEPLAN (Echenique et al., 1988), TRANUS (de la Barra, 1989) and the Dortmund model by Wegener (1985, 1986) to mention just a few. While comprehensiveness may be desirable or necessary for many analyses, these models are seldom easy or

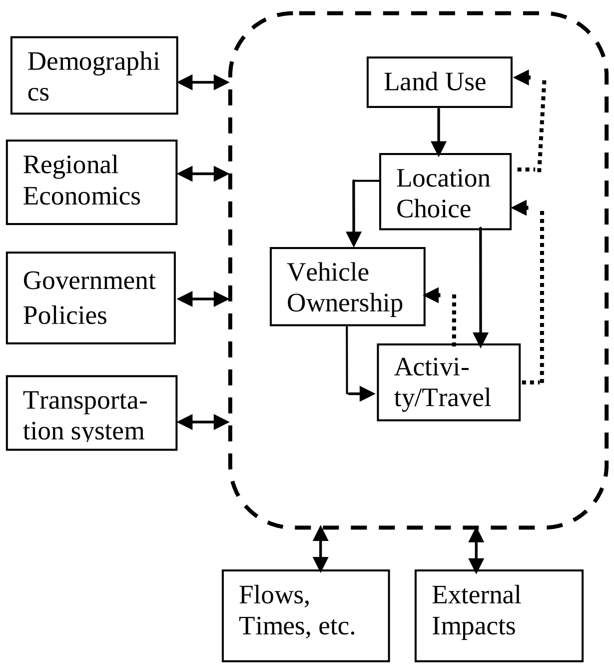

Figure 1. Idealized integrated urban modeling system

even possible to overview or evaluate for someone not deeply involved in its construction. Some modelers therefore relinquish comprehensiveness for the virtue of transparency. Some models that can be said to be examples of this are NYSIM (Anas, 1995), which also contains elements of microeconomic theory, IMREL (Anderstig and Mattsson, 1991), and the work started in Chicago by Boyce (1980). A review of the state-of-the-art of urban modeling can be found in Wegener (1994, 1998). The purpose of the study is to propose an integrated framework for location and travel choices considering the fact that the travel demand is a result of interaction of several decisions the individuals make. Such a framework considers the interactions among the various sub models of urban activity and travel, and depicts the decision hierarchies in a realistic way. These decisions usually relate to residential location choice, choice of work place, service destination choice, choice of mode, choice of time of travel, car ownership choice, etc. TRESIS is one such model developed by Hensher et al (2001) focusing on the interdependencies between land use, transport and the environment. The next session discusses about the ideal integrated land use transportation models.

3 IDEAL INTEGRATED LAND USE TRANSPORTATION MODELS

The ideal integrated model system consists of four interrelated components; Land development, location choice, activity/travel and automobile ownership. The land development models the evolution of the build environment and includes the initial development of previously vacant land and the redevelopment over time of existing land uses. This component could also be labeled "Building supply," because building stock supply functions are included. The location choice includes the location choices of households (for residential dwellings), firms (for commercial locations), and work places (for jobs). The activity/travel models involve predicting the trip making behavior of the population, ultimately expressed in terms of Origin and Destination flows by mode and by time of day. Finally the automobile ownership component models household auto ownership levels, an important determinant of household travel behavior. Figure 1 presents a highly idealized representation of land use transportation modeling system. The behavioral core of this system consists of four interrelated components. As explained, an integrated land use transport model consists of several sub-models that explain the decisions of households/individuals relating to location, travel, vehicle ownership, etc. Each sub- model is a discrete choice model calibrated with either RP or SP data or both. The calibrated sub-models can be integrated using micro-simulation. Stated Preference techniques may be very handy in building the sub-models of an integrated disaggregate land use transport model.

4 REVEALED AND STATED PREFERENCE TECHNIQUES

The most frequent type of choice data corresponds to revealed preference (RP) information which is the data about actual or observed choices made by individuals. In the case of stated preference (SP) individuals are asked about what they would do in a hypothetical situation. As the opportunities for undertaking real life controlled experiments within transport systems are very limited, SP surveys, a quasi-experiment based on hypothetical situations set up by the analyst, provide an approximation to this. The degree of artificiality of these situations may vary according to the rigour and needs of the exercise. A very basic problem with this type of information is how much faith we can put on individuals actually doing what they stated they would do when the case arises. In fact, experience in the 1970's was not very good in this sense, with up to 100% differences between predicted and actual choice found in many studies (Ortuzar, 1980). The situation improved considerably in the 1980's and recently good agreement with reality has been reported from models estimated using SP data (Louvier, 1988). However, this has occurred because SP data collection methods have improved enormously and are now very demanding, not only in terms of survey design expertise, but also in terms of their requirements for operational resources. Table 1 gives the clear difference between stated preference and revealed preference data.

Table 1. Difference between Stated Preference and Revealed Preference Data

Revealed Preference data	Stated Preference data
• Based on actual market behavior	• Based on hypothetical scenarios
• Attribute measurement error	• Attribute framing error
• Limited attribute range	• Extended attribute range
• Attributes correlated	• Attributes uncorrelated by design
• Hard to measure intangibles	• Intangibles can be incorporated
• Cannot directly predict response to new alternatives	• Can elicit preferences for new alternatives
• Preference indicator is choice	• Preference indicators can be rank, rate or choice
• Cognitively congruent with market demand behavior	• May be cognitively non-congruent

Stated preference data collection methods have improved enormously and are now very demanding, not only in terms of survey design expertise but also in their requirements for trained survey staff and quality assurance procedures (Pearmain et al, 1991). The main features of an SP survey may be summarized as follows.

- It is based on the elicitation of respondents' statements of how they would respond to different hypothetical (travel) alternatives.
- Each option is represented as a 'package' of different attributes like travel time, travel cost, headway, reliability and so on.
- The individual effect of each attribute can be estimated using experimental design techniques that ensure the variations in the attributes in each package are statistically independent from one other.
- The respondents state their preferences towards each option by ranking them in order of attractiveness, rating them on a scale indicating strength of preference, or simply choosing the most preferred option from a pair or group of them.

5 DISAGGREGATE RESIDENTIAL LOCATION CHOICE MODELS: REVIEW

The integrated analysis of land-use and transportation interactions has gained renewed interest and importance with the passage of the Inter-modal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21). In this context, one of the most important household decisions is that of residential location, especially because residential land-use occupies about two-thirds of all urban land and home-based trips account for a large proportion of all travel (Harris, 1996). The household residential location decision not only determines the association between the household and the rest of the urban environment, but also influences the households' budgets for activity travel participation. To be sure, there is a substantial and rich body of literature related to household residential choice. One stream of research on residential location modeling is based on a discrete choice formulation. Sermons and Koppelman (2001) identify at least two appealing characteristics of such a formulation for residential location analysis. First, the discrete choice approach is based on microeconomic random utility theory and models the residential location choice decisions as a tradeoff among various locational attributes such as commute time, housing costs, and accessibility to participation in activities. Second, the discrete choice approach allows the sensitivity to locational attributes to vary across sociodemographic segments of the population through the inclusion of interaction variables of locational characteristics with demographic characteristics of households. The early applications of the discrete choice formulation to residential location analysis include the works of McFadden (1978), Lerman (1975), Onaka and Clark (1983), Weisbrod et al. (1980), Quagley (1985) and Gabriel and Rosenthal (1989). More recent applications include Timmermans et al. (1992), Hunt et al. (1994), Waddell (1993, 1996), Abraham and Hunt (1997), Ben-Akiva and Bowman (1998), Sermons (2000), and Sermons and Koppelman (2001). Some of the above studies have focused only on residential location choice (for example, McFadden, 1978; Gabriel and Rosenthal, 1989; Weisbrod et al., 1980; Hunt et al., 1994; and Sermons and Koppelman, 2001), while others have focused on residential choice as one element of a larger mobility-travel decision making framework (for example, Lerman, 1975; Quagley, 1985; Waddell, 1993, 1996; Abraham and Hunt, 1997; and Ben-Akiva and Bowman, 1998). Similarly some studies have focused on location choice for specific demographic groups (such as single worker and Caucasian households), while others have been more inclusive.

The current study focuses only on residential location choice behavior of households. However, it accommodates measures of accessibility for participation in different purposes as explanatory variables. Thus, the research bears some similarity with earlier studies that have considered residential location within the context of broader mobility and travel decisions. The research is confined to single worker households. The current research may be distinguished from earlier studies in several respects. First, the research considers the residential location choice decisions of households, accessibility and travel aspects. The MNL model used for residential location choice, which is unable to accommodate full set of spatial alternatives in the estimation process.

6. RESIDENTIAL LOCATION CHOICE MODEL FOR THANE

6.1 Model Structure

Despite the development of a large number of aggregate location choice models, many authors have worked with disaggregate models that are structurally more stable compared with aggregate models and are better able to capture the causal relationship between residential location determinants and residential location levels. As a result, disaggregate methods have become a very popular approach to modeling residential location choice. Most discrete choice models are based on the random utility maximization (RUM) hypothesis. Within the class of RUM-based models, the multinomial logit (MNL) model has been the most widely used structure for residential location choice. The random components of the utilities of the different alternatives in the MNL model are assumed to be independent and identically distributed (IID) with a type I extreme value (or Gumbel) distribution (Johnson and Kotz, 1970). In addition, the responsiveness to attributes of alternatives across individuals is assumed to be homogeneous after controlling for observed individual characteristics i.e., the MNL model maintains an assumption of unobserved response homogeneity. These foregoing two assumptions together lead to the simple and elegant closed-form mathematical structure of the MNL. However, the assumptions also leave the MNL model saddled with the ‘‘independence of irrelevant alternatives’’ (IIA) property at the individual level (Luce and Suppes, 1965; Ben-Akiva and Lerman, 1985). As per this framework, the utility of any alternative (residential location choice) can be expressed as

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (1)$$

Where,

U_{in} = the true utility of household (or individual) n for choosing residential location i

V_{in} = a deterministic component of utility and a function of variables, and it can be written as

$$V_{in} = \alpha_i + \beta X_{in} \qquad (2)$$

Where, α_i = constant specific to the alternative i,

β = Vector of parameters to be estimated, and X_{in} = vector of attributes for the individual n and the alternative i

ε_{in} = a random component / error term

The assumption that the error terms are independently and identically distributed as a *weibull* distribution and the application of RUM framework results in the well-known multinomial logit (MNL) model. The model used in the present work is an MNL model of the form,

$$P_n(i) = exp\,(V_{in}) \,/\, \sum_j exp\,(V_{jn}) \qquad (3)$$

Where, $P_n(i)$ = probability of household n choosing residential location i.

Using the RUM principle to estimate residential location choice may be appealing especially because it does not place any restrictions on the effect of household characteristics across residential locations.

6.2 Data-set and Methodology

The data set for the study was mainly derived from the data of home-interview survey conducted as a part of Preparation of Detailed Project Report (DPR) on the proposed Mass Rapid Transit System (MRTS) for Thane city of Mumbai Metropolitan Region (MMR), Maharashtra floated by the Maharashtra State Road Development Corporation (MSRDC). The city of Thane is located about *19 km* in the interior from main seacoast and on the northern extremity of Greater Mumbai. The physical development of Thane is circular, as the city has grown around the Central Business District (*CBD*) in the western area adjoining the Thane Railway Station. The Central Railway’s main north-south corridors pass through the city. The Thane Municipal Corporation (TMC) is spread over an area of around *128.23* km^2 and a number of industrial estates are located in the region. The area covered under TMC was taken as the study area. As per the MRTS study there were 115 zones and 11 sectors in study area. The 115 TAZ are aggregated in to 38 wards based on revenue records of Thane for this study. It contained a population of 0.46 million in 1981, *0.80* million in *1991* and has increased to 1.3 million as per 2001 census. The average HH size of 4, average HH income of 5000 rupees per month, average working adults in HH of 1.5, average school going children in HH of 1.1 and average HH expenditure of less than Rs. 2000 were observed from the data. The motor vehicle population has increased rapidly from 1990 *to 1999.* The maximum growth rate of *26.44 %* is observed for auto rickshaws and *7.17%* for cars during *1995-1999.* The residential growth was also very rapid during this period.

The home interview survey data contained socioeconomic and travel information on 3500 households. This constitutes a sample size of 1.5 per cent. The *RP* data set for the development of residential location choice model was extracted from this home interview survey data. This resulted in 3500 valid samples, which were used for the calibration of the residential location choice model in this study. The travel time, travel cost and travel distance for the public transport were obtained from the network information of Thane. The average rental values for each zone were collected. The average rental values were used to determine the modified accessibility index, which is based on gravity type accessibility originally developed by Hansen (1959). Accordingly, the choice set considered for the disaggregate residential location choice model contained thirty-eight geographical residential locations (Zones) in the study area namely, 1 to 38 aggregated zones or eleven sectors namely 1 to 11 sectors, depending upon the level of aggregation. The methodology adopted for the development of the revealed preference residential location choice model is presented as a flow chart in Figure 2.

6.3 *Specifications and Calibration of the MNL Model*

The choice of variables for the potential inclusion in the residential location choice *RP* model was guided by previous theoretical and empirical work on residential location choice modeling, intuitive arguments regarding the effects of exogenous, endogenous variable, statistical significance of the variables and data availability. A number of variables representing household socio-economic, accessibility and travel characteristics were included. The complete list of variables considered in the present study is listed in Table 2. The description of these variables and their categorization is also presented in Table 2. The socio-economic variables considered in this study are built-up area, house ownership level, family size, number of males, number of females, number of working adults, number of non working adults, number of school going children, number of business persons, number of service persons, number of people engaged in agriculture and labourers, number of persons of age more than forty, number of persons of age equival to or less than forty, number of retired persons, household travel expenditure, car license holders in house hold, number of persons education more than SSC and number of persons education equal to or less than SSC and age of household head. The travel attributes considered are travel time, travel distance and travel cost by public transport. In addition to these, zonal accessibility index developed by incorporating the average rental values and considering the population and employment was also used. The details of accessibility index can be presented here two/three alternatives of incorporating rental values in accessibility measure could also be suggested. With these variables, several specifications of the simple MNL model as in Equation (3) were tried before selecting the final model. As a starting point all the household and socioeconomic variables were used along with the alternative-specific constants and travel variables were used along with generic constants in defining the utility of different residential location choice. The attention was given to the use of different alternative-specific and generic variables in utility function of different residential location choice models. The variables were eliminated if found statistically not-significant or having illogical signs. The variables so eliminated were then used in the utility function of other residential location choice model and again the same checks were made.

Factors considered in selecting the specification were overall goodness of fit measures, the significance of variables entered, and multicollinearity. The parameters of the logit models specified were estimated using maximum likelihood method. The software, ALOGIT was used for this purpose. The goodness-of-fit of the models was assessed with the help of the likelihood-ratio index. The results of calibration in terms of coefficient estimates and statistical validation of the *RP final* model are not computed due to time constraints.

7 DISCRETE CHOICE CAR OWNERSHIP MODEL

The choice of variables for the potential inclusion in the car ownership *RP* model was guided by previous theoretical and empirical work on car ownership modelling, intuitive arguments regarding the effects of exogenous variable, statistical significance of the variables and data availability. A number of variables representing household socio-economic characteristics were included. The variables considered in this study are built-up area, house ownership level, family size, number of males, number of females, number of working adults, number of non-working adults, number of school going children, number of business persons, number of service persons, number of people engaged in agriculture and labourers, number of persons of age more than forty, number of persons of age equival to or less than forty, number of retired persons, household travel expenditure, car license holders in house hold, number of persons with education level more than SSC and number of persons with education level equal to or less than SSC. Variable definitions are shown in Table 2. With these variables, several specifications of the simple MNL were tried before selecting the final model. As a starting point all the household and socioeconomic variables were used along with the alternative-specific constants in defining the utility of different car ownership levels. The attention was given to the use of different alternative-specific variables in utility function of different car ownership level. The variables were eliminated if found statistically not significant or having illogical signs. The variables so eliminated were then used in the utility function of other car ownership level and again the same checks were made.

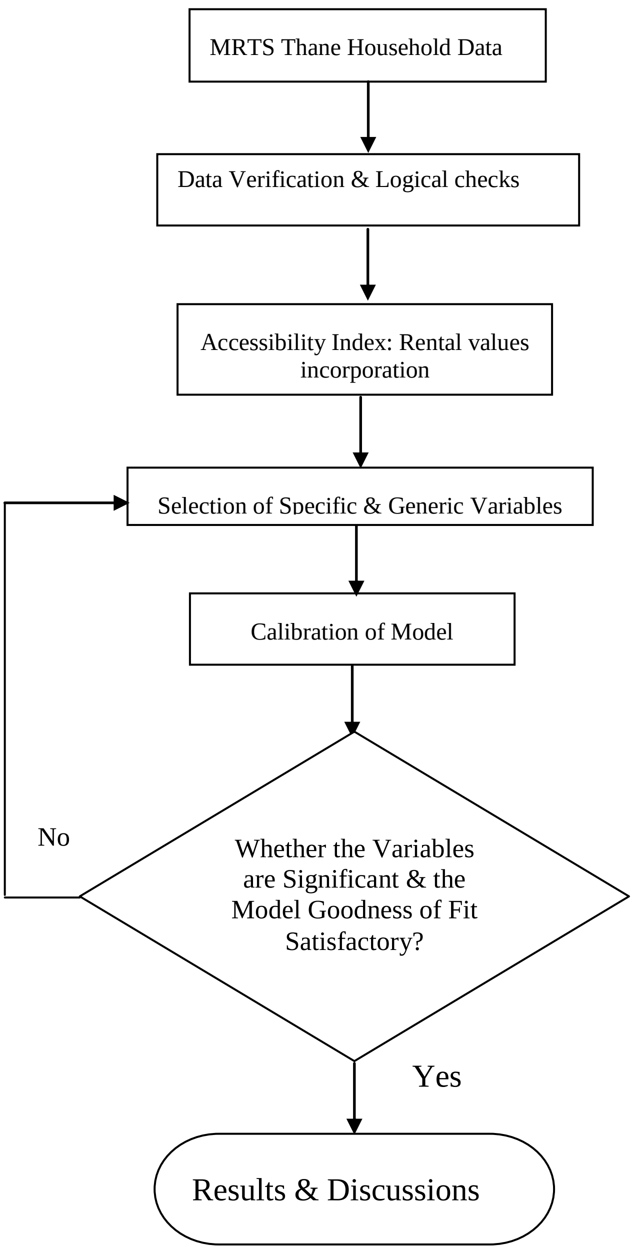

Figure 3. Flow chart for Methodology

Factors considered in selecting the specification were overall goodness of fit measures, the significance of variables entered, and multicollinearity. The variables built-up area, number of people with education more than *SSC*, family size, household income, number of car license holders and number of business persons were found to be significant at *95%* confidence level and having logical signs for one car ownership utility. The variables household income, household level and family size were found to be significant at *95%* confidence level and having logical signs for two car ownership level. Whereas the variables built-up area and number of business persons were found to be significant at *90%* confidence level and having logical signs for two car ownership level. The other variables under consideration got eliminated during the process. The parameters of the logit models specified were estimated using maximum likelihood method.

Table 2. Definition of Variables

Code	Definition
BA	Built up area: categorical variable classified as less than 250 sq.ft – 1; 250 to 500 – 2; 501 to 750 – 3, 751 to 1000 – 4; and more than 1000 – 5.
HOL	House ownership level: categorical variable classified as own house 1, rented 2, Govt. quarter 3, company quarter 4.
NM	Number of males
NF	Number of females
FS	Family size
NCHH	Number of cars in HH
AGHD	Age of the head
NPEMSSC	Number of persons education more than SSC
NPELESSC	Number of persons education lee-than SSC
NBPHH	Number of business persons in HH
NSPHH	Number of business persons in HH
NSGC	Number of school going children
NRPHH	Number of retires persons in HH
HHINC	Household Income: categorical variable classified as, up to Rupees 2000-1; 2001 to 5000-2; 5001 to 10000 – 3; 10001 to 15000 – 4; 15001 to 20000 – 5; 20001 to 30000 – 6; 30001 to 40000 – 7; and more than 40000-8.
AMTE	Average monthly Travel Expenditure
TT	Travel time between O & D
TC	Travel cost between O &D
TD	Travel distance between O & D
AIZ	Accessibility Index of the zone

Table 3. Statistical validation of RP model

* Not significant at 95 percent level but significant at 90 percent confidence level

The software, ALOGIT was used for this purpose. The goodness-of-fit of the models was assessed with the help of the likelihood-ratio index. estimates and statistical validation of the *RP* model are presented in Table 3.The prediction success table is then obtained by cross tabulating the predicted and observed values. The prediction success table for the car ownership model is shown in Table 4.

The prediction success tests indicate that the predictions are better in the case of zero car and one car ownership. In the case of zero ownership level, *88.61%* choices were predicted correctly and in the case of one car ownership level, *84.23 %* choices were predicted correctly. As the number of samples with two and more than two-car ownership level is very less, the prediction success in this ownership level is not satisfactory.

Table 4. Prediction success table

	0 car	**1 car**	**2 car**	**Observed**	**% Observed**
0 car	568	73	0	641	69.44
1 car	38	203	0	241	26.11
2 car	6	35	0	41	4.44
Predicted	612	311	0	923	100
Prediction %	66.30	33.69	0	100	-
PCP*	88.61	84.23	-	-	-

*PCP: Percentage Correctly Predicted

8 CONCLUSIONS

There is a need to examine the working of an integrated land use transport model made up of behavioural sub models in the context of developing countries. In this paper the attempts made towards literature and framework for an ideal integrated model was suggested. The skeleton structure of residential location choice model are discussed. The discrete choice model calibrated using RP data for car ownership model was discussed. The Revealed preference car ownership model developed for Thane, Mumbai Metropolitan Region has shown good results. Therefore, it can be concluded that the model specification developed for the above studies is acceptable. The results clearly indicate that the disaggregate modelling approach can be successfully used for modeling location and travel decisions of households.

Variable	Coefficient	t-value	Specific to
BA	0.5746	4.4	1 car
NPEMSSC	0.2376	3.0	1 car
NCLH	1.4960	7.7	1 car
HHINC	0.5057	7.8	1 car
FS	-0.2870	-3.8	1 car
NBPHH	0.2262	1.5*	1 car
HHINC	0.8367	7.9	2 car
BA	0.2738	1.3*	2 car
HOL	-1.7410	-3.0	2 car
FS	-0.2802	-2.4	2 car
NBPHH	0.3427	1.8	2 car
0 car constant	4.4030	10.6	0 car
Structural Parameters			
L (0)	-1014.0191		
L (c)	- 685.0074		
L (θ)	- 426.2742		
χ^2	1175.4898		
ρ^2 (0)	0.5796		
ρ^2 (c)	0.3777		
Adjusted ρ^2	0.5687		

9 REFERENCE

Abraham, J.E. & Hunt, J.D. 1997. Specification and estimate

on of a nested logit model of home, workplace and commuter mode choice by multiple worker households. *Transportation Research Record* 1606: 17–24.

Alonso, W. 1964. Location and Land Use. *Harvard Univ. Press*, Cambridge: MA.

Anas, A. 1983. Discrete choice theory, information theory and the multinomial logit and gravity models. *Transportation Research B* 17:13-23.

Anas, A. 1995. Capitalization of urban travel improvements into residential and commercial real estate: simulations of a unified model of housing, travel mode and shopping choices. *Journal of Regional Science* 35: 351-375.

Anderstig, C. & Mattsson, L.G. 1991. An integrated model of residential and employment location in a metropolitan region. *Papers in Regional Science* 70: 167-184.

Ben-Akiva, M. & Bowman, J.L. 1998. Integration of an activity-based model system and a residential location model. *Urban Studies* 35 (7): 1131–1153.

Ben-Akiva, M. & Lerman, S. 1985. Discrete-Choice Analysis: Theory and Application to Travel Demand. *MIT Press*, Cambridge: MA.

Boyce, D.E. 1980. A framework for constructing network equilibrium models of urban location. *Transportation Science* 14: 77-96.

Coelho, J.D. & Williams, H.C.W.L. 1977. On the design of land use plans through locational surplus maximization. Presented at The 17th Congress of the European Regional Science Association.

De la Barra, T. 1989. Integrated Land Use, Transport Modeling. *Cambridge Univ. Press*: Cambridge.

Domencich, T.A. & McFadden, D. 1975. Urban Travel Demand: A Behavioral Analysis. *North-Holland:* Amsterdam.

Echenique, M.H. 1968. Urban systems: towards an explorative model. *In: Land Use and Built Form Studies*: Cambridge.

Erlander, S. 1977. Accessibility, entropy, and the distribution and assignment of traffic. *Transportation Research* 11: 149-153.

Gabriel, S.A.& Rosenthal, S.S. 1989. Household location and race: estimates of a multinomial logit model. *The Review of Economics and Statistics* 17 (2), 240–249.

Hansen, W.G. 1959. How Accessibility Shapes Land Use. Journal of American Institute of Planners, 25, pp 73-76.

Harris, B. 1996. Land use models in transportation planning: a review of past developments and current practice. avilable *www.bts.gov/other/MFD_tmip/papers/landuse/compendium/dvrpc_appb.htm>*.

Hensher, D. A. & Ton, T. 2001. TRESIS: A Transportation, Land Use and Environmental Strategy Impact Simulator for Urban Areas. *9th World Conference on Transport Research*, July 2001, Seoul: Korea.

Hunt, J.D., McMillan, J.D.P. & Abraham, J.E. 1994. Stated preference investigation of influences on attractiveness of residential locations. *Transportation Research Record* 1466: 79–87.

Johnson, N. & Kotz, S. 1970. Distribution in Statistics: Continuous Univariate Distributions. Chapter 21, *John Wiley:* New York.

Lerman, S.R. 1975. A disaggregate behavioral model of urban mobility decisions, *Ph.D. dissertation*, Massachusetts Institute of Technology.

Losch, A. 1940 Die raumliche Ordnung der Wirtschaft, Jena. Translation, 1954. The Economics of Location. *Yale Univ. Press*, New Haven: CT

Louviere, J. J. 1988. Conjoint analysis modeling of stated preferences – A review of theory, methods, recent developments and external validity. *Journal of Transportation Economics and Po*licy 22(1): 93-119.

Lowry, I.S. 1964. A Model of Metropolis. *Rand Corporation*: Santa Monica.

Luce, R.D. & Suppes, P. 1965. Preference utility and subjective probability. In: Luce, R.D., Bush, R.R., Galanter, E. (Eds.), Handbook of Mathematical Psychology. *John Wiley and Sons*: New York.

Lundqvist, L. 1975. Transportation analysis and activity location in land use planning- with application to the Stockholm region. In: Karlqvist, A., Lundqvist, L. and Snickars, F. (Eds.), Dynamic Allocation of Urban Space. *Saxon House*: Westmead.

Martinez, F. 1992. The bid-choice land use model: an integrated economic framework. *Environment and Planning A* 24: 871-885.

Mattsson, L.G. 1984. Equivalence between welfare and entropy approaches to residential location. Regional Science and Urban Economics 14: 147-173.

McFadden, D. 1974. Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (Ed.), Frontiers in Econometrics. *Academic Press*: New York.

McFadden, D. 1978. Modelling the choice of residential location. In A. Karlquist, L. Lundquist, F. Snickars and J.W. Weibull (eds), Spatial Interaction Theory and Planning Models, North-Holland: Amsterdam.

Miyamoto, K. 1996. An analysis system for integrated policy measures regarding land- use, transport and the environment in a metropolis. In: Hayashi, Y., Ro y, J. (Eds.), Transport, Land-Use and The Environment. *Kluwer Academic Publishers:* Dordrecht.

Onaka, J. & Clark, W.A.V. 1983. A disaggregate model of residential mobility and housing choice. *Geographical Analysis* 19: 287–304.

Ortuzar, J.de D. 1980. Mixed-mode demand forecasting techniques. *Transportation Planning and Technology* 6: 81-95.

Pearmain, D., Swason, J., Kroes, E & Bradley, M. 1991. Stated Preference Techniques: A Guide to Practice. *Steer Davis Gleave and Hague Consulting Group*: London.

Putman, S.H. 1973. The interrelationships of transport development and land development. Department of City and Regional Planning, *University of Pennsylvania:* Philadelphia.

Putman, S.H. 1975a. Calibrating a disaggregated residential allocation model DRAM: the residential sub-model of the Integrated Transportation and Land Use Model Package, ITLUP. Presented at *The Eighth Annual Conference of The British Section of the RSA:* London.

Putman, S.H. 1975b. Further results from, and prospects for future research with, the Integrated Transportation and Land Use Model Package, ITLUP. Presented at *The Annual Conference of the Southern RSA*: Atlanta.

Quagley, J.M. 1985. Consumer choice of dwelling, neighborhood and public services. *Regional Science and Urban Economics* 15: 41–63.

Senior, M.L. & Williams, H.C.W.L. 1977. Model-based transport policy assessment. Traffic Engineering and Control 18: 402-406.

Sermons, M.W. 2000. Influence of race on household residential utility. *Geographical Analysis* 32 (3): 225–246.

Sermons, M.W. & Koppelman, F.S. 2001. Representing the di.erences between female and male commute behavior in residential location choice models. *Journal of Transport Geography* 9: 101–110.

Smith, T.E. 1978. A general efficiency principle of spatial interaction. In: Karlqvist, A., Lundqvist, L., Snickars, F. and Weibull, J. (Eds.), Spatial Interaction Theory and Planning Models. North-Holland: Amsterdam.

Snickars, F. & Weibull, J. 1977. A minimum information principle. *Regional Science and Urban Economics* 7: 137-168.

Timmermans, H., Borgers, A., Dijk, J. & Oppewal, H. 1992. Residential choice behavior of dual earner households: a decompositional joint choice model. Environment and *Planning A* 24: 517–533.

Von Thunen, J.H. 1826. Der Isolierte Statt in Beziehung auf Landwirtschaft und National okonomie. Hamburg. Translation, 1966. Von Thunen's Isolated State. *Pergamon Press:* London

Waddell, P. 1993. Exogenous workplace choice in residential location models: is the assumption valid? *Geographical Analysis* 25: 65–82.

Waddell, P. 1996. Accessibility and residential location: the interaction of workplace, residential mobility, tenure, and location choices, presented at the *Lincoln Land Institute TRED Conferenc*e. Available at: <http://www.odot.-state.or.us/tddtpan/modeling.html>.

Wardrop, J.G. 1952. Some theoretical aspects of road traffic research. In: Proceedings of the Institute of Civil Engineers 1(part-II): 325-378.

Wegener, M. 1985. The Dortmund housing market model. A Monte Carlo simulation of a regional housing market. In: Stahl, K., (Ed.), Microeconomic Models of Housing Markets. Springer: Berlin.

Wegener, M. 1986. Integrated forecasting models of urban and regional systems. *London Papers in Regional Science* 15.

Wegener, M. 1994. Operational urban models- state of the art. *Journal of the American Planning Association*. 60: 17-29.

Wegener, M. 1998. Applied models of urban land use, transport and environment: state of the art and future developments. In: Lundqvist, L., Mattsson, L.-G., Kim, T.J. (Eds.), Network Infrastructure and the Urban Environment. Springer: Berlin.

Weisbrod, G., Lerman, S. & Ben-Akiva, M. 1980. Tradeoffs in residential location decisions: transportation vs. other factors. *Transportation Policy and Decision Making* 1: 13–26.

Williams, H.C.W.L. 1977a. Generation of consistent travel demand models and user-benefit measures. In: Bonsal, P., Dalvi, W., Hills, P. (Eds.), *Urban Transportation Planning*, Abacus Press: London.

Williams, H.C.W.L. 1977b. On the formulation of travel demand models and economic evaluation measures of user benefit. *Environment and Planning A* 9: 285-344.

Wilson, A.G. 1970. Entropy in Urban and Regional Models in Geography and Planning. *John Wiley & Sons*: Oxford.

Wilson, A.G. 1974. Urban and Regional Models in Geography and Planning. Wiley: Chichester.

Wingo, L. 1961. Transportation and Urban Land. *Johns Hopkins Univ. Press*, Baltimore: MD.