Journal of Civil Engineering
The Institution of Engineers, Bangladesh
Vol. CE 29, No. 2, 2001

A LAND USE-TRANSPORT MODEL : THE STRUCTURE AND APPLICATIONS

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ABSTRACT: The inter-relationship between land use and transport has occupied the attention of transport and urban planners for a long time. Existing models, in this field, lack consistency in forming behavioral demand elements towards development of an integrated system. This paper introduces a new type of land use-transport model with reasonable theoretical basis to overcome the major existing deficiencies and the potential for more practical application. Simultaneous equilibrium of markets and location choices is considered in the model. It provides locations and spatial interactions for urban activities, households in particular. A nested logit framework is selected for the transport model. Station choice and access mode choice models are incorporated in the transport demand forecasting process, which is expected to produce reliable forecasts for access mode and station usage. To provide theoretical consistency in the analysis, logit models are used in representation of choice decisions in both the urban activity location model and transport model. Geographical Information Systems play a major role for efficient data management, spatial analysis and colour graphical displays. A GIS function, Voronoi diagram is extensively applied to determine station domains along with other functions. The paper also includes some results of the model applications.

KEYWORDS: Land use-Transport interaction, Location surplus, Logit model.

INTRODUCTION

The inter-relationship between land use and transport has occupied the attention of transport and urban planners for a long time. The land use component has been represented as location choice of urban activities and the transport component has been represented as transport demand in this interaction process.

Urban activities may be classified into four types: (a) priority location type (e.g., large scale basic industries, higher education, government, wholesaling, regional recreation and shopping centers, culture and arts, certain fairly unique facilities such as airports or sports arenas, etc.), (b) optional location type (e.g., commerce and business,

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finance, insurance, residential development, retail, etc.), (c) subsequent location type (e.g., neighborhood stores, schools, etc.), (d) passive location type (e.g., agriculture, forestry, and fisheries). On the other hand, transport demand comprises of (a) existing traffic, (b) normal traffic growth, (c) diverted traffic, (d) converted traffic, (e) change of destination traffic, (f) development/generated traffic, and (g) induced traffic.

Existing models, in this field, lack consistency in forming behavioral demand elements towards development of an integrated system. This paper presents a new form of land use- transport model, The paper also includes a brief description of the model applications.

A BRIEF REVIEW OF THE LAND USE-TRANSPORT MODELS

Research in land use and transport studies has spawned a vast literture relating to forecasting models, Models, in this context, can be broadly grouped in the following ways.

Exogenous Input of Transport Condition

Some models forecasted land use (urban activities) with exogenous inputs of transport condition. EMPIRIC (Hill et al., 1966) and the Lowry Model (Lowry, 1964) may be the most widely used land use models (Chapin and Kaiser, 1979). However, there are many such models formulated and applied in specific situations, for example: PLUM (Goldner, 1968), BASS (Center for Real Estate and Urban Economics, 1968), Tomm (Crecine,1969), Wilson (1969), The Puget Sound Model (Brown et al., 1972), The NBER Model (Ingram et al., 1970), RURBAN (Miyamoto and Kitazume, 1989), etc.

Exogenous Input of Land use

Some models forecasted transport demand with exogenous inputs of land use. The traditional four-step transport model (trip generation, trip distribution, mode choice, and traffic assignment) has been a dominant analytical tool in such forecasting process for nearly four decades (Ton and Black, 1993). Researchers have proposed many variations to the original four sequential step model and incorporated sub-models. These include from simple aggregate sequential approach to complicated disaggregate simultaneous approach. Reviews of such variety of models and suggestions have been provided, among others, by Golob and Beckmann (1971), CRA (1972), Ruiter (1973), Brand (1973), Wilson (1973), Manheim (1973), Ben-Akiva (1974), Daly and Zachary (1976), Champernowne et al. (1976), Williams (1977), Safwat and Magnanti (1988), Nitta and Mori (1986), Harata and Ohta (1986), Preston (1991).

Land use-Transport Interaction

The simple land use models and traditional four-step transport models are incapable of modeling the complex interaction between land use and transport in the scene of gradual urban development and provide only an incomplete picture of what might happen if certain policies are pursued (Webster et al. 1988). So the trend to consider the Interaction between land use and transport has started. Webster et al. (1988) and Webster and Paulley (1989) have reviewed the report of the international Study Group on Land-use/transport Interaction (ISGLUTI) which included nine such land-use/ transport integrated models: TOPAZ (Brotchie et al. 1980). DORTMUND (Wegener 1985), CALUTAS (Nakamura et al. 1983), OSAKA (Amano et at. 1983), AMERS-FOORT (Floor and de Jong 1981), SALOC (Landqrist and Mattsson 1983), LILT (Mackett 1983), MEP (Geraldes et. al. 1978), and ITLUP (Putman 1983). Some further developments in this field are: Miyamoto et al. (1986), Matsuura and Numada (1989), Martinez (1992), and Roy and Marquez (1993).

Deficiencies in the Models

In most land use models or in land use component of land-use/ transport interaction models, mentioned above, different types of activities are located by different modeling techniques such as: spatial interaction, utility maximization, market mechanism, input-output technique, etc. Supply side of housing does not represent both land owner's and developer's behavior in such models.

Similarly, in most transport models or in transport component of land-use/ transport interaction models, mentioned above, transport demand forecasting process composed of a mixture of aggregate and disaggregate approaches.

Most of the land-use/transport interaction models gave more emphasis on land use. So comprehensive information on trip behavior is not available. To overcome these deficiencies the concepts of a land use-transport interaciton model is proposed in the following sections.

THE MODEL STRUCTURE

Basic Elements

Basic elements and their interaction according to the model are shown in Fig.1. Urban activities, termed as locators, are the forecasting elements for the urban activity location model, considering the housing market. In turn, these locators who are considered to be the typical transport users in the transport market, reflect the demand, forecasted by the transport model. Housing markets are adjusted by a price mechanism, whereas the transport markets are primarily adjusted by time penalties through travel disutilites towards equilibrium.

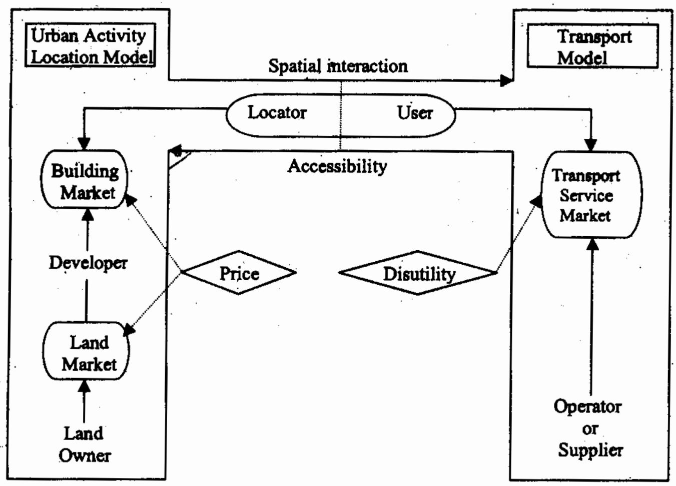

Fig 1. Basic Elements of the Model Structure

Operational Structure

The operational flow diagram for the model systems is explained in Fig.2. The subsystem for urban activity location model forecasts the locations of activities on the basis of an activity location pattern and the disutilities from the transport model. Which further produced the distribution of home-based work trips. The sub-system for transport model forecasts the transport demand for the desired routes using this forecasted interaction and calculates the disutilities, which are input to the urban activity location model for the next time period. They are the measures of accessibility among zones that influence future spatial choice (such lags in the adjustment of the system is also explained among others, by Barra and Rickaby 1982, Hunt and Simmonds 1993). The order of such model operation considering "time period" is shown in Fig. 3. The theoretical concepts underlying these sub-systems for forecasting of urban activity location and transport demand are explained in the following sections.

URBAN ACTIVITY LOCATION FORECASTING

Major Assumptions

Major assumptions considered in the model are summarized as follows:

1) There are i= 1 to I zones in the spatial coverage of the model. Each zone has one land market and one building market.

2) Economic agents considered in the model are, several types of locators, developers, and land-owner. The locator population consists of k= 1 to K types with N_{kT} locators. Total number of k= 1 to K type locators N_{kT} is given. Hence, an urban system in the model is a closed city in a sense of urban economies'. There is only one representative developer and one land-owner in each zone. Each representative developer can supply floor service and demand for land service only in its own zone. Also, each land-owner can supply land service in its own zone. Hence, subscript i=1 to I labels developers and land-owners as well as zones.

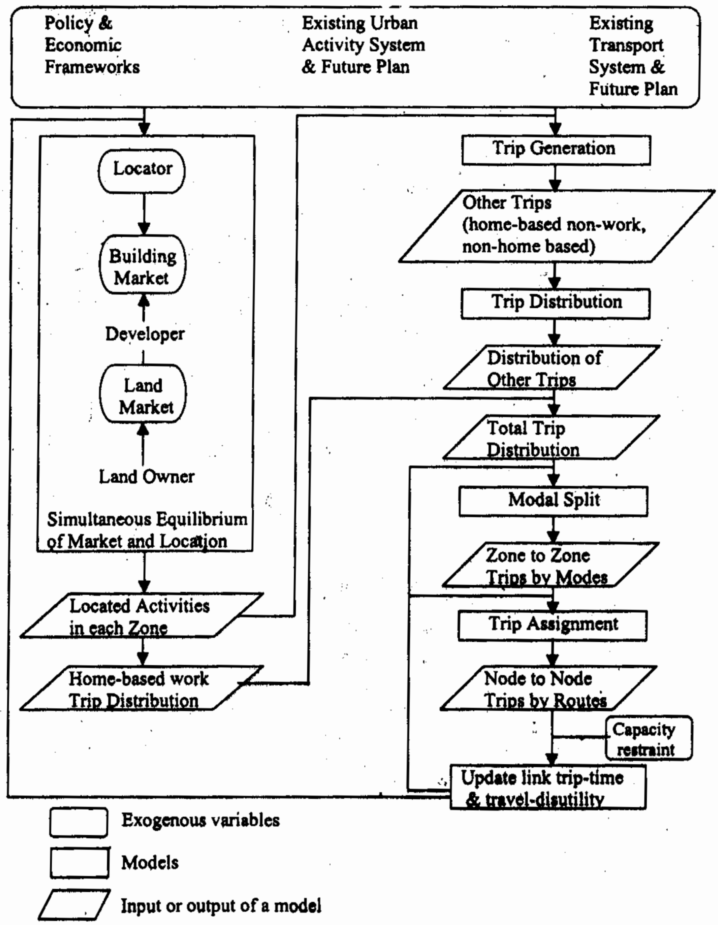

Fig 2. Structure of the Land use- Transport Model

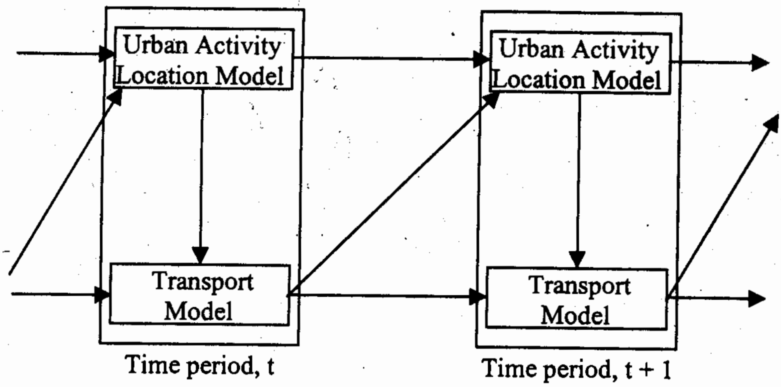

Fig 3. Order of Model Operation

3) Location choice behavior of locators is modeled as logit model, which gives choice probabilities as a function of variables denoting attractiveness of zones. The attractiveness of zone for locators is called "location surplus" (V_{ki}), and it is defined as surplus of floor consumption.

4) In the framework of Walrasian (general) multimarkets eqilibrium (see Anas, 1982), all land and building markets should be cleared. All of locators should be allocated so that none of them can have an motivation to relocate. The former state is "market equilibrium", and the latter "location equilibrium". The state of "simultaneous equilibrium" for both of them is simulated in each time period. These mechanisms of markets and location choice are shown in Fig. 4.

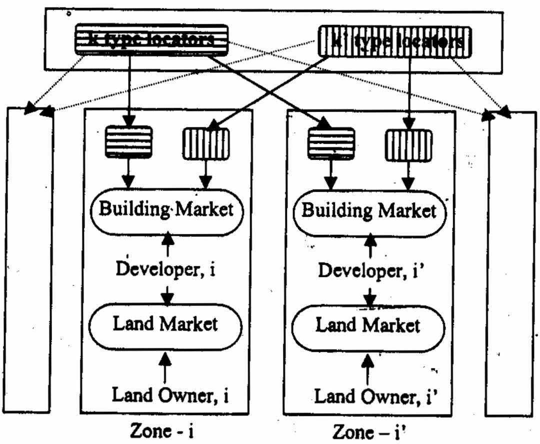

Fig 4. Mechanism of Markets and Location Choices

Definition of Surplus Functions

Location surplus :

Since a locator demands for floor space, the level of utility realized by 'k' type of locator in zone 'i', termed as location surplus can be directly measured as consumer's surplus (see also Ueda et al., 1993).

$$V_{ki}(R_i, A_{ki}) = \int_{R_i}^{\alpha} q_k(m)dm + A_{ki}$$

Where,

V = level of location surplus

R = floor rent

A = utility term dependent on location attribute

q = individual floor demand

m = a dummy in integral

Floor demand functions can be derived from surplus functions, from Hotelling's lemma if the locator is a firm and from Roy's identity (for example, see Varian, 1992) if the locator is a household.

$$\frac{\partial V_{ki}}{\partial R_i} = -q_k(R_i)$$

Developer's profit:

A representative developer in zone 'i' has a profit π_i^D, which is a function of floor rent R_i and land rent P_i,

$$\pi_i^D = \pi^D(R_i, P_i)$$

From Hotelling's lemma, floor supply Q_i^S is

$$Q_i^S = \frac{\partial \pi^D(R_i, P_i)}{\partial R_i} = Q^S(R_i, P_i)$$

and land demand L_i^d is

$$L_i^d = \frac{\partial \pi^D(R_i, P_i)}{\partial P_i} = L^d(R_i, P_i)$$

Landowner's profit:

Profit of a representative landowner in zone 'i' is

$$\pi_i^L = \pi^L(P_i)$$

Also from Hotelling's lemma, land supply L_i^S is a function of land rent as,

$$L_i^S = \frac{\partial \pi^L(P_i)}{\partial P_i} = L^S(P_i)$$

Equilibrium of Markets and Location Choice

Number of locatiors N_{ki} affects R_i and P_i through eq.4 and eq. 5 and inversely R_i and P_i affect N_{ki} through eq.1, eq.2 and eq.3. The system of equations listed below, give conditions for solution of simultaneous equilibrium of markets and location.

$$V_{ki}(R_i, A_{ki}) = \int_{R_i}^{\alpha} q_k(m)dm + A_{ki} \qquad \text{for all } i = 1 \text{ to } I \quad \text{and } k = 1 \text{ to } K \qquad (1)$$

$$a_{ki} = \frac{\exp(\theta V_{ki})}{\sum_{i=1}^{I} \exp(\theta V_{ki})} \qquad \text{for all } i = 1 \text{ to } I \text{ and } k = 1 \text{ to } K \qquad (2)$$

$$N_{ki} = N_{kT}\, a_{ki} \qquad (3)$$

$$\sum_{k=1}^{K} N_{ki} q_k(R_i) - Q^S(R_i, P_i) = 0, \; R_i \in [0, R_i^{max}] \qquad \text{for all } i=1 \text{ to } I \qquad (4)$$

$$L^d(R_i, P_i) - L^s(P_i) = 0, \qquad P_i \in [0, P_i^{max}] \quad \text{for all } i = 1 \text{ to } I \qquad (5)$$

Where, a = choice probability

θ = a parameter

Choice Probability

Probabilistic choice or random utility theory provides a very flexible approach to the problem of representing, within a modeling framework, how people behave and make choices by assuming that individuals make their decision so as to maximize their utility or satisfaction subject to probabilistic variation in their knowledge and perceptions, and tastes and preferences (Webster et al., 1988). Nested multinomial logit model is thus, introduced in the proposed transport demand forecasting model to represent this probabilistic choice.

Moreover, by integrating the access mode and station choice models in the demand forecasting process, reliable forecasts are expected for access mode and station usage.

Demand Elements

The transport demand forecasting procedure is based on a model system that estimates in stages with each stage affecting the following stage (the nested logit model, for example see Talvitie, 1992). This general model system provides the probabilistic consistency in aggregation method by utilizing the "log sum" term and also satisfies the condition of structuring of demand functions appropriate to additive, separable utility functions (Williams, 1977). However, the trip generation element is formulated as a regression function. Demand elements are described below:

Trip Generation (Trip origin)

$$q = \beta_0 + \sum_i \beta_i * X_i$$

Trip Distribution (Destination choice)

$$P_D = \frac{\exp(U_D + \beta_M U_M^*)}{\sum_D \exp(U_D + \beta_M U_M^*)}, \quad U_M^* = \ln \sum_M \exp(U_M + \beta_R U_R^*)$$

Modal Split (Mode choice):

$$P_M = \frac{\exp(U_M + \beta_R U_R^*)}{\sum_M \exp(U_M + \beta_R U_R^*)} \quad U_R^* = \ln \sum_R \exp(U_R + \beta_A U_A^*)$$

Trip Assignment (Route choice):

Station/Intersection/Interchange Choice

$$P_R = \frac{\exp(U_R + \beta_A U_A^*)}{\sum_R exp(U_R + \beta_A U_A^*)}, \qquad U_A^* = ln \sum_A \exp(U_A)$$

Access Mode Choice

$$P_A = \frac{\exp(U_A)}{\sum_A \exp(U_A)}$$

where,

q	= trip generation
X	= explanatory variables
Subscript I	= number of variables
β	= coefficients
P	= choice probability of an individual
U	= utility function
	$= \theta_0 + \sum_i \theta_i . ln(X_i)$
θ	= coefficients
subscript D	= at trip distribution level
subscript M	= at modal split level
subscript R	= at station choice of trip assignment level
subscript A	= at access mode choice of trip assignment level

INTEGRATION OF GIS

Geographical Information Systems (GIS) has been defined in many ways by the experts in the field. Schweiger (1992) quoted as, "A GIS is a tool that provides data base management capabilities (including capture, selection, storage, editing, querying, retrieval, and reporting functions) for and display of spatial data, and provides the ability to perform analysis of geographic features (points, lines, and polygons) based on their explicit relationship to each other".

Transport projects, especially in the context of urban areas, involve much spatial details at different plan levels to represent enormous and varied project and policy variables. Geographical Information Systems play a major role in the model for efficient data management and spatial analysis of such spatial data. GIS features and functions, such as point, are, polygon, node, link, grid, aggregation and disaggregation and voronoi diagram are extensively applied in the system.

MODEL APPLICATIONS

The Joban New Railway Line Project

In order to test the possibilities of practical application of the model, it was used to analyse the impacts for the Joban New Railway Line project in Tokyo, Japan. The Joban New Line is proposed to build from Akihabara to Tsukuba, with a total length of 58.3 kilometer and 19 stations on it. The implementation of the project would reduce the travel time to 45 minutes from Akihabara to Tsukuba, from travel time by existing Joban line of 85 minutes and travel time by bus of 65 minutes. Various urban development projects are also proposed along the new line. This would increase the existing population in the area and would contribute as generated traffic to the Joban New Line.

For model application, the total Tokyo metropolitan area was sub-divided into six employment zones. Zones were, 1) Tokyo municipality, 2) Kawasaki and Yokohama, 3) South-west of Tokyo metropolitan area, 4) North-west of Tokyo metropolitan area, 5) East of Tokyo metropolitan area, and 6) The Joban New Line area. The Joban New Line area was then further sub-divided into one hundred and three small residential areas representing all the relative station domains in the area (see Fig. 5).

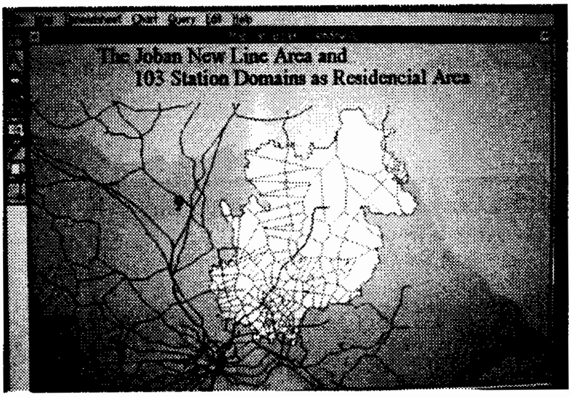

Fig 5. 103 station domains, existing lines, and the new line in Joban new line area.

Berkson's method (Berkson 1953, Berkson and Hodges 1961), extended by Theil (1969) has been applied for calibration of logit models. Models have been validated using part of the data available for calibration and data from reports of preliminary studies on the Joban New Line project.

The land use-transport model forecasted the land prices and trips generating from each residential zone to each employment zone in the project area considering both without and with the project situation for the years 2000, 2010 and 2020. Finally station-to-station traffic were determined for the new line for these years. SPANS, a GIS package, was used for the coloured graphic outputs. For example, Fig. 6, Fig. 7 and Fig. 8 show the forecasted land prices, trips generated and station to station traffic for the year 2020 respectively (for detail please see Ahsan, 1994).

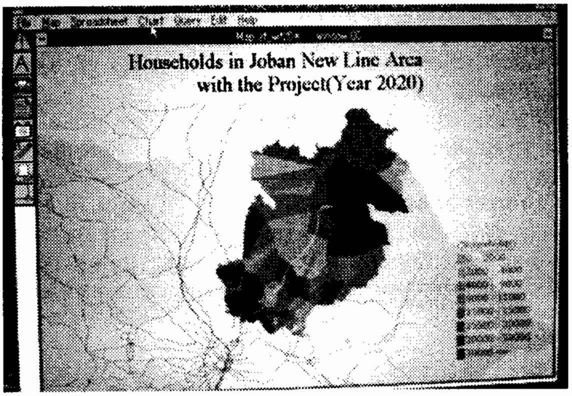

Fig 6. Land prices (¥/m²) in Joban new line area with the project (Year 2020).

Fig 7. Trips (households) originating from Joban new line area, with the project (Year 2020).

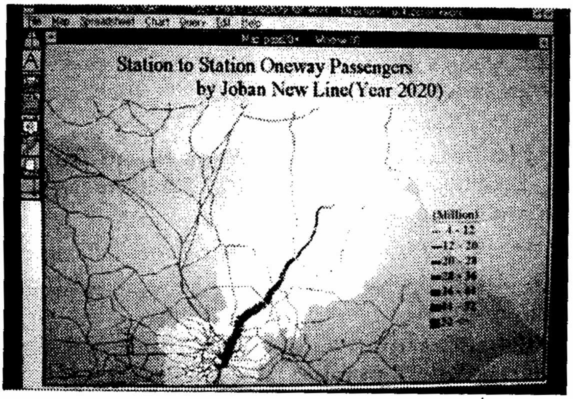

Fig 8. Station to station one-way passengers by Joban new line (Year 2020).

Dhaka Urban Transport Plan

Various development schemes to improve the road traffic situation in Metropolitan Dhaka are planned to be implemented phase by phase in the Dhaka Urban Transport Plan. Such road transport development would certainly have an impact on land use. In relation to this, housing projects prepared by developers are increasing in Dhaka. So the mechanism of markets and location choice incorporated in the model would be useful to represent the residential sector in Dhaka. Moreover, the interaction process in the model would enable to forecast the changes in land use due to transport development.

For model application, Dhaka is divided into ninety municipal wards. Relevant transport, land use and socio-economic data collection is in progress. Initially it is intended to use published data from relevant departments. Results would be prepared for publication in the near future.

CONCLUSION

This paper introduced an integrated land use-transport model, which considered simultaneous equilibrium of markets and location choices, and logit models are used in representation of choice decisions in both the urban activity location and transport demand sub-systems. Results of the model application revealed the potentiality of the system for practical application in urban transport planning.

REFERENCES

Ahsan. H.M. (1994). An Integrated Evaluation System for Urban Railway Projects. Doctor of Engineering Thesis, University of Tokyo, Japan.

Amano.K., T.Toda, and H. Abe (1983). A Hierarchical urban model and its application to the Osaka Metropolitan Area. Paper presented to the 23rd European Congress of the Regional Science Association, Poitier, France.

Anas, A. (1982). Residential Location Markets and Urban Transportation: Economic Theory, Econometrics, and Policy Analysis with Discrete Choice Models. Academic Press.

Barra. T.de la, and P.A.Rickaby (1982). Modelling regional energy-use: a land-use, transport, and energy-evaluation model. Environment and Planning B, Vol.9, pp. 429-443.

Ben-Akiva, M.E. (1974). Structure of passenger travel demand models. Transportation Research Record number 526, pp. 26-42.

Berkson, J. (1953). A Statistically Precise and Relatively Simple Mothod of Estimating the Bioassay with Quantal Response, Based on the Logistic Function. Journal of American Statistics Association, Vol. 48, pp. 565-599.

Berkson,J., and Jr.J.L. Hodges (1961). A minimax estimator for the logistic function. Proceedings of the 4th Berkeley Symposium, Vol. 4,pp.77-86.

Brand, D. (1973). Travel demand forecasting, some foundations and a review. Urban Travel Demand Forecasting special report 143, Highway Research Board, Washington, DC.

Brotchie.J.F., J.W.Dickey, and R.Sharpe (1980). TOPAZ planning technique and applications. Lecture notes on Economics and Mathematical Systems Series, Vol.180, Springer-Verlag, Berlin.

Brown. H.J., J.R. Ginn, F.J.James, J.F.Kain, and M.R. Straszheim (1972). Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organization. Exploratory Report 6. New York: National Bureau of Economic Research.

Center for Real Estate and Urban Economics (1968). Jobs, People and Land: Bay Area Simulation Study (BASS). Berkeby: The Author, Institute for Urban and Regional Development, University of California.

Champernowne, A.F., H.C.W.L. Williams, and J.D.Coelho (1976). Some Comments on Urban Travel Demand Analysis, Model Calibration and The Economic Evaluation of Transport Plans. Journal of Transport Economics and Policy, pp. 267-285.

Chapin,J.F.S., and E.J.Kaiser(1979). Urban Land Use Planning, Third Edition. University of Illinois Press, Chicago.

CRA (1972). A disaggregate behavioural model of urban travel demand. Charles River Associates, Federal Highway Administration, US Department of Transportation, Washington, DC.

Crecine, J.P. (1969) Spatial Location Decisions and Urban Structure: A Time-Oriented Model, Discussion Paper No.4. Ann Arbor: Institute of Public Policy Studies, University of Michigan.

Daly, A. J., and S. Zachary (1976). Improved multiple choice models. Urban Traffic Models, PTRC Summer Meeting, University of Warwick, Coventry, England.

Floor,H., and T.de Jong (1981). Testing a disaggregate residential location model with external zones in the amersfoort region. *Environment and Planning* A, Vol.13, pp.1499-1514.

Geraldes, P., M.H.Echenique, and L.N.Williams (1978). A Spatial economic model for Bilbao, Proceedings of the PTRC Summer Annual Meeting, Stream M, pp.75-94.

Goldner, W. (1968). Projective Land Use Model (PLUM): A Model for the Spatial Allocation of Activities and Land Uses in a Metropolitan Region. BATSC Technical Report 219. Berkeley, Calif.: By Area Transportation Study Commission.

Golob,T.F., and M.J. Beckmann (1971). A utility model for travel forecasting. Transportation Science. Vol.5-1, pp. 79-90.

Harata, N., and K. Ohta (1986). Some Findings on the Application of Disaggregate Nested Logit Model to Railway Station and Access Mode Choice, Proceedings of the World Conference on Transport Research, Vol.4

Hill, D.M., D.Brand and W.B. Hansen (1966). Prototype Development of Statistical Land Use Prediction Model for Greater Boston Region. Highway Research Record 114, Washington, D.C.: Highway Research Board.

Hunt, D., and D.C. Simmonds (1993). Theory and application of an integrated land-use and transport modelling framework. Environment and Planning B, Vol.20,pp. 221-244.

Ingram,G.K., et al. (1970). The NBER Urban Simulation Model. Springfield, Va.: National Technical Information Service.

Lowry,J.S. (1964). A Model of Metropolis. Memorandum RM-4035-RC. Santa Monica, Calif.: RAND Corporation. August.

Lundqvist,L., and L.G. Mattson (1983). Transportation systems and residential location. European Journal of Operational Research, Vol. 38.

Mackett,R.L. (1983). The Leeds Integrated Land-Use/Transport model (LILT). Supplementary Report 805. Transport and Road Research Laboratory, Crowthorne, Berkshire.

Manheim,M.L. (1973). Practical implications of some fundamental properties of travel demand models. Highway Research Record number 422, Highway Research Board, Washington, DC, pp. 21-38.

Martinez, F.J. (1992). Towards the 5-Stage Land Use-Transport Model. Proceedings of the World Conference on Transport Research, Vol.4.

Matsuura, Y., and M. Numada (1989). Normative Model of Land Use/Transport Interactions. Proceedings of the World Conference on Transport Research, Vol.4, pp.1-15.

Miyamoto, K., H. Nakamura, and E. Shimizu (1986). Land use model based on disaggregate behavioral analyses. Proceedings of the World Conference on Transport Research, Vol. 2, pp. 1535-1550.

Miyamoto, K., and K. Kitazume (1989). A Land-Use Model Based on Random Utility/Rent-Bidding Analysis (RURBAN). Proceedings of the World Conference on Transport Research, Vol.4,pp.107-121.

Nakmura. H., Y. Hayashi, and K. Miyamoto (1983). A land-use/transport model in metropolitan areas. Papers of the Regional Science Association, Vol.51.

Nitta, Y., and M. Mori (1986). Station Choice Models Incorporating Generalized Time. Proceedings of the World Conference on Transport Research.

Preston, J.(1991). Demand forecasting for new local rail stations and services. Journal of Transport Economics and Policy, Vol.25, No.2, pp. 183-202.

Putman, S.H. (1983). Integrated urban models: policy analysis of transportation and land use. Pion, London.

Roy, J.R., and L.O. Marquez (1993). SUSTAIN-A Model Investigating Sustainable Urban Structure And Interaction Networks. Paper for International SIG[1] `Seminar 'Environmental Challenges in Land-Use Transport Coordination', Blackheath, NSW, Dec. 6th-10th.

Ruiter, E. (1973). Analytic Structures. Urban Travel demand Forecasting, special report 143, Highway Research Board, Washington, DC.

Safwat, K.N.A., and T.L. Magnanti (1988). A Combined Trip Generation, Trip Distribution, Modal Split, and Trip Assignment Model, Transportation Science,. Vol.22,No.1,pp.14-30.

Schweiger,C.L. (1992). Current Use of Geographic Information Systems in Transit Planning, Transportation Research Record 1349, Washington, D.C., pp. 93-105.

Talvitie, A. (1992). How To Code the Generalized Cost of Accessing a Transit System. Transportation Research Record 1357. Washington, D.C.

Theil, H. (1969). A Multinomial Extension of the Linear Logit Model, International Economic Review, Vol. 10, pp. 251-259.

Ton, T.T., and Black,. J.A. (1993). An. Object-Oriented Approach for Implementing an Integrated Four-Step Transport Model, Paper prepared for the Third international Conference on Computers in Urban Planning and Urban Management, Atlanta, Georgia, July 23-25.

Ueda, T., H. Nakamura and E. Shimizu (1993). CIS Integrated System for Urban Transport and Development Planning. Paper for SIGI seminar on Environmental Challenges in Land use and Transport Coordination, Blackheath, NSW, Australia.

Varian, H.R. (1992). Microeconomic Analysis. Third edition, Norton.

Webster, F.V., and N.J. Paulley (1989). An International Study to Compare Land-Use/Transport Models and Evaluate Urban Polices. Proceedings of the World Conference on Transport Research, Vol.4,pp.31-45.

Webster, F.V., P.H. Bly, and N.J. Paulley (1988). Urban Land-use and Transport Interaction: Policies and Models. Report of the International Study Group on Land-use/Transport Interaction (ISGLUTI). Avebury, England.

Wegener, M. (1985). The Dortmund housing market model: a Monte Carlo simulation of a regional housing market. In K. Stahl (ed.): Microeconomic models of housing markets. Lecture Noes in Economics and Mathematical Systems 239. Springer Verlag, Berlin/Heidelberg/New Youk, pp. 144-191.

Williams, H.C.W.L. (1977). Travel Demand Models, Dually Relations and Benefit Analysis, Journal of Regional Science, Vol. 16, pp. 147-166.

Wilson, A.G. (1973). Travel Demand forecasting: achievements and problems. Urban Travel Demand Forecasting special report 143, Highway Research Board, Washington, DC.

Wilson, A.G.(1969). Disaggregating Elementary Residential Location Models. Working Paper Number 37. London: Center for Environmental studies.