A Sketch Planning Tool of Transportation Systems Analysis for Developing Countries: CODINA, Continuous/Discrete Network Analyzer

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Introduction

Litinas and Ben-Akiva (1980) proposed a novel approach to the development of a sketch-planning tool for urban transportation systems analysis that is based on a unique representation of the urban space and the transportation system. They used traditional network consisting of nodes and links for such portion of the system where more focused analysis is desired, while the rest of the system is represented by a set of spatial density distribution functions representing the urban activity system and the transportation system. At the heart of their approach lies the disaggregate joint choice model of destination and mode of travel that may be analytically integrated over "the continuous network" (*i.e.*, such portion of the network that is represented by density distribution functions) and numerically integrated using a sampling approach over "the discrete network" to predict aggregate behaviors of travelers.

Tsunokawa (1982) implemented the approach and developed a flexible computer model named CODINA (Continuous/ Discrete Network Analyzer). He developed a case study of the Metropolitan Area of Boston where single metro line is represented by a discrete network while the rest of the system by a continuous one. The whole urban area was divided into one primary sub-area and four secondary sub-areas and further subdivided into thirty finite elements with a large number of small elements distributed along the metro line. Analyzing the effects of the fare change of metro on aggregate shares of three modes of transport for commuters, he demonstrated the practicality of the approach as a sketch-planning tool.

Sketch planning tools are deemed suitable for the application in developing countries that are faced with severe constraints in data availability and human and technological resources. Traditional four-step procedure for urban transportation systems analysis is not often feasible due to the lack of detailed information on the activity and transportation systems and the behavior of travelers. Thus, Fatima used CODINA to analyze the urban transportation problems of Jakarta. Given the dearth of disaggregate data, she proposed a practical approach for constructing a joint choice model of the destination and mode of travel that is required by CODINA by combining a readily available gravity model with a disaggregate mode choice model with a good result. The objective of the present paper is to introduce the basic logic and operations of CODINA and the highlight of the Jakarta Case Study.

Basic Logic and Operations of CODINA

CODINA is a simplified methodology based on the combined continuous and discrete representation of the urban space and the transportation system for evaluating transportation policy impacts with small data and computational requirements. A flexible mixture of a continuous surface and discrete element is hoped to balance data requirements, computational efforts and prediction accuracy. The applications to both area-wide and local area policy analysis (e.g., analysis of a single rail route) is allowed by the mixed continuous/discrete representation.

The CODINA model employs analytical integration technique as well as Monte Carlo and finite element techniques for aggregate demand predictions. The use of analytical techniques reduces the aggregation bias and the required computational effort. This model is based on the explicit aggregation of disaggregate choice models to predict modal split, vehicle miles traveled, expected trip length and volumes of trips on the links of the discrete network (e.g., public transit line segments). Tsunokawa (op. cit.) developed a case study dealing with three modes of transportation: drive alone, shared ride and transit. While auto modes are represented solely by the movements in continuous network, the transit network is represented by a mixture of continuous and discrete segments.

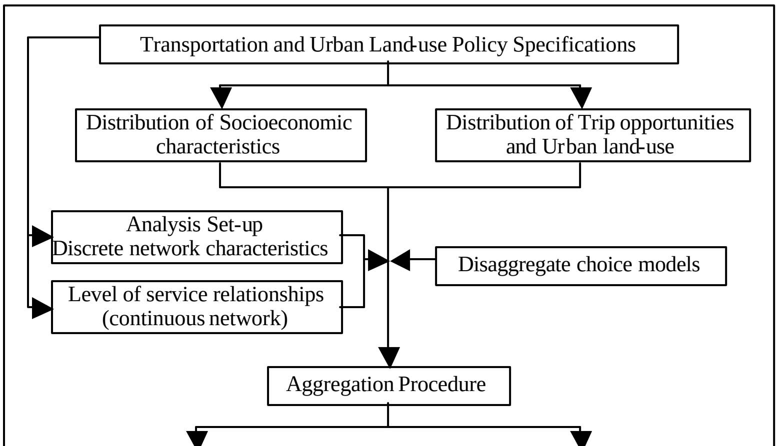

Figure 1 Basic operations of the CODINA model

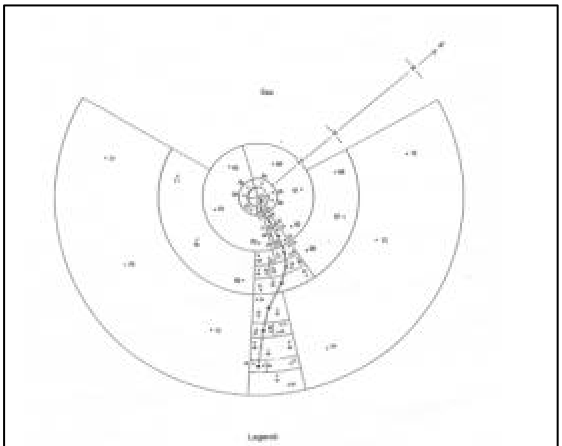

Figure 2 Finite Elements and Sampled Households

Keywords : Sketch planning tool of transportation analysis, continuous/discrete model, disaggregate model, joint choice model.

The basic operations of the CODINA model are summarized schematically in Figure 1. It accepts four sets of inputs: (1) The distribution of the households and the socioeconomic characteristics in the urbanized area, (2) The distribution of the trip opportunities and urban land-use, (3) Level of service relationships of each mode (continuous network characteristics), and (4) Analysis set-up specifications (including the finite element subdivision and description of the discrete public transit network, namely the geometric and the level of service data).

A wide range of policy options which can be analyzed by the model encompass transit line extensions, fare and other operation policies, the effects of higher gasoline prices, and so forth. Effects of the change in lad-use such as the location of new business centers can also be simulated.

Jakarta Case Study

A case study of the Jakarta Metropolitan Area was conducted to examine the applicability of the CODINA model in the developing countries situation. A section of Jabotabek transit railway system (between Jakarta City and Bogor consisting of 10 stations) is represented as a discrete network. In this case study only two modes of transportation are considered, auto and transit. A circular symmetric distribution of employment density is assumed to represent the distribution of trip opportunities. 77 households are sampled from the similar circularly symmetric distribution of population. The whole urbanized area (a radius of 20 km) is divided into one primary sub area and four secondary sub areas and further subdivided into 29 of finite elements. 21of these are within the primary sub area. Sub-areas and discrete transit network are illustrated in Figure 2.

A joint choice model of the destination and mode of travel for commuting trip was derived by combining a readily available disaggregate mode choice model with a gravity model. Disaggregate mode choice model, which is not available for Jakarta, was transferred from the model originally developed for Metro Manila. Aggregate data collected from Jakarta were used to estimate trip production and trip distribution. They are furthermore used to calibrate the gravity model of Jakarta's work trip distribution. A function representing the probability of location (destination) choice is then obtained from the gravity model. The joint choice model was expressed as a product of the functions representing the probability of mode and location (destination) choice.

Simulation was run for three alternative cases, the Base Case and two other cases representing different policy conditions. In order to compare the result with available observation, the situation as of 1990 was simulated as the Base Case. Uniform fare of 400 rupiah was assumed for the Jabotabek Line. The impact of a fare increase of Jabotabek Line was assessed by comparing Base Case with Alternative 1, where a uniform 1,000 rupiah was assumed. To examine the effect of network density , a denser network of the continuous transit was assumed for Alternative 2.

Predictions of the modal split and the ridership of the Jabotabek Line by market segments were summarized. Overall modal split of the commuter in Jakarta Metropolitan Area as of 1990 was 52.5% vs. 47.5% for public transit and auto, respectively, while Jabotabek user was predicted as 1% of the overall ridership. The simulation result of Base Case gave a comparable shares prediction for all modes. As is expected, the transit share is high for the low-income group while the auto share is very high for the high-income population. The effect of the fare increase in the Jabotabek Line is almost negligible in terms of the overall modal share, while the Jabotabek Line ridership decreased by 60.08%. As the network became denser, the transit share increased because the denser network provided new connections between some origin -destination pairs for which the public transit had not been available before. The change in the Jabotabek Line ridership by direction is depicted in Figure 3 for each case.

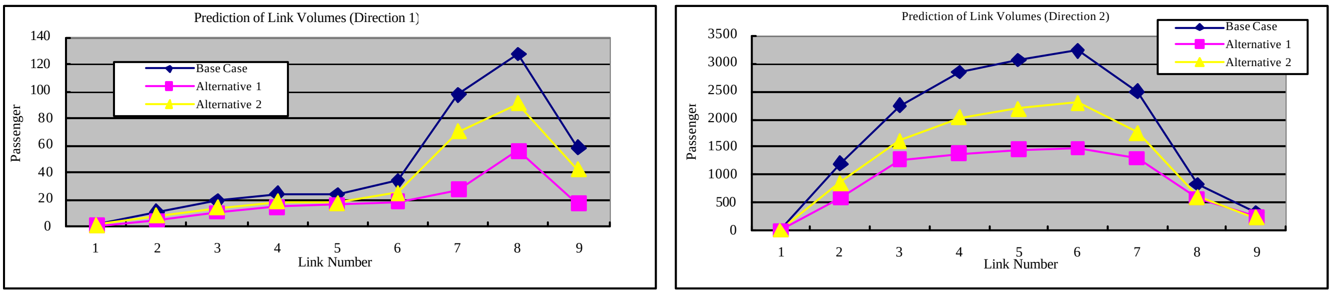

Figure 3 Predicted Link Volumes by Direction

Conclusions

The Case Study has led to the conclusion that CODINA is applicable in the analysis of urban transportation systems in developing countries. Necessary component relationships of CODINA were developed using information readily available in these countries. Policy analysis with the emphasis on the focused discrete network segments was made possible by the combined continuous/discrete representation of the urban space and the transportation system. To further improve the predictive capability of CODINA, more studies will be required on the representation of the density of transportation network and the equilibration procedure in the continuous network.

Reference: (1) Litinas, N., and Ben-Akiva, M.E., (1982), "Simplified Transporation Policy Analysis Using Continuous Distributions", Transportation Research, Vol. 16A, No. 5, Pergamon Press, Ltd. (2) Tsunokawa, K., (1980), "An Application of Continuous Modeling Approach for Transportation Policy Analysis: A Preliminary Case Study of Boston Using Policy I, A Continuous/Discrete Network Model Implemented in Apple Pascal", MIT. (3) Fatima, I., (1999), "Simplified Transportation Systems Analysis Method for Developing Countries Based on A Continuous/Discrete Network Representation: A Case Study of Jakarta Metropolitan Area", Saitama University.