Intercity Passenger Decision Making: Conceptual Structure and Data Implications

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Understanding intercity passenger travel behavior is important to the analysis of policies that affect intercity travel. Most studies of intercity travel behavior are based on analysis of aggregate data and lack a behavioral basis. The models developed in these studies are biased or insensitive to the effect of important policy measures, or both. A conceptual structure of the intercity passenger decision process is presented. In this behavioral framework, the first stage is to link the intercity travel decision to the individual's general process of decision making in the context of his life style and activities. In the second stage, the intercity travel decision process is grouped into four interrelated decision categories: trip generation, destination choice, mode choice, and "at-destination" decisions. Each of these categories has several dimensions, some of which have been studied in the past but not in a comprehensive framework. The conceptualization of the decision structure leads to the identification of the structure of the travel demand models needed to represent this behavior and the variables to be included in the models. The data requirements to support the proposed behavioral framework are discussed, and some methodological issues are addressed. It is concluded that the adoption of a disaggregate approach to intercity travel analysis offers substantial potential for development of improved intercity travel analysis and forecasting capabilities.

The ability to analyze intercity travel demand relationships and forecast future intercity travel is necessary to assist public agencies and private carriers in making intercity transportation service decisions. The range of public and private intercity transportation decisions that will be addressed in the future is broad, ranging from multiregional policy issues such as investment in high-speed technologies to specific improvement strategies such as adding stops to an existing rail service. The quality of these decisions depends on the quality of intercity travel analyses including the accuracy of the predicted demand and the correct identification of factors that affect the level of intercity travel demand and its distribution among the available modes. The analysis of intercity travel demand and its distribution should take account of changes in the socioeconomic and demographic environment as well as changes in intercity travel service.

A related issue is the potential impact of changes in intercity travel service on the characteristics of the metropolitan areas served. Strong positive relationships between intercity level of service and socioeconomic activity (*1*) suggest that there is a positive impact of service improvements on the activity level of metropolitan areas. This relationship is a general extension of the historical growth of cities located near waterways and rail and air hubs.

During the last two decades, substantial work has been undertaken in the development of intercity travel demand models. Both aggregate and disaggregate approaches have been used. The common denominator of all of these efforts is the absence of a behavioral framework for intercity travel analysis. That is, these efforts emphasized the estimation of statistical relationships in the available data and attempted to interpret these relationships instead of developing an understanding of the underlying behavior that determined these relationships. An overall review of these studies is given by Koppelman et al. (*2*). The main conclusions of this review are discussed here.

Initial emphasis was on development of aggregate models mostly in conjunction with the Northeast Corridor project. Several different classes of aggregate models were developed. These include direct origin-destination volume models for one and for all modes, modal share models, sequential models of total intercity volume and mode share, and models of interregional and regional demand. Although no behavioral basis supported the development of these aggregate models, they were subjected to macroeconomic reasonableness criteria and provided some insight into intercity travel behavior. The following points summarize the primary contribution of the aggregate models.

- Relevant variables: City-pair activity and attraction variables (usually population, employment, and average income) and city-pair level-of-service (travel time, cost, and frequency) were found to be statistically related to travel volume.
- Market segmentation: Segmentation by trip purpose (business and nonbusiness) and trip distance were found to be important.
- Induced demand: Trip generation and destination effects were determined to be equally important to corridor mode share in the analysis of intercity travel.
- Modal competition: Adequate forecasts of single mode volume must take account of travel service on competing modes.

Despite these contributions of aggregate intercity analysis, there are a number of issues or problems that have not been resolved. These include

- Lack of behavioral basis: The incomplete structure and specification of the aggregate models is due in part to the lack of an underlying behavioral structure.
- Unclear definition of intercity travel: There is some ambiguity about the definition of intercity travel, especially in intensely developed corridors where metropolitan regions have become contiguous.
- Deficiencies of aggregate estimation methods: Data aggregation leads to estimation bias and multicollinearity among variables; these, in turn, undermine forecast accuracy and model transferability.

Disaggregate analysis of intercity travel has been limited. These efforts, with one exception, considered only the choice of travel mode. The primary advantage of disaggregate modeling of intercity or other travel behavior results from performing the analysis at the level of the behavioral unit or decision maker: the individual, household, or firm. Analysis at this level provides a basis for

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formulating and testing hypotheses about the travel decision-making process. Thus disaggregate analysis provides a basis for improving understanding of intercity travel behavior, developing behaviorally consistent models of intercity travel behavior, and forecasting future demand with greater accuracy.

Disaggregate analyses undertaken to date have been limited by the availability of data but have, nonetheless, provided useful insights into the travel decision-making process. The single multidimensional analysis undertaken (S.A. Morrison and C. Winston, 1983) illustrates the potential of going beyond mode choice to consideration of generation, destination, and related choices. Further development of these models requires the development of a general conceptual framework, formulation of a consistently structured model system, and collection of suitable data.

CONCEPTUAL STRUCTURE OF THE INTERCITY PASSENGER DECISION-MAKING PROCESS

Introduction

A key element in the deficiencies of the existing approaches is the lack of a behavioral basis for the various models. This is an inevitable result in the development of aggregate models because the analysis is done at the level of zones, cities, or regions, whereas the behavioral unit is the individual or the household. The disaggregate models have the potential to be formulated consistently with the underlying behavioral structure. If they are not, these models also will reflect only empirical relationships with limited usefulness.

The importance of developing a behavioral framework for intercity travel is grounded in the following points:

- Identifying the relevant variables: An understanding of relevant factors and the way they affect intercity travel behavior is necessary to identify the appropriate variables and to include these factors in the models in an appropriate manner.
- Identifying the model structure: Intercity travel decisions include a number of interrelated elements that may have a hierarchical or simultaneous structure, or both. Also, intercity travel decisions may be interrelated with other decisions, though they are not pure intercity travel decisions. The behavioral framework can identify these travel and related decisions and, thereby, guide the formulation of the model system in a way that represents the underlying behavioral process and takes into account the relevant effects.
- Developing appropriate data sets: Data collection is complementary to the theoretical development. Its aim is to test the theoretical hypotheses formulated as part of the behavioral conceptualization. Because of the lack of an appropriate behavioral framework for intercity travel, travel surveys conducted in the past did not collect all of the relevant data that might be needed to test some of the more sophisticated hypotheses related to intercity travel behavior. Developing a comprehensive behavioral framework provides criteria for collecting the data needed for intercity travel analysis.
- Policy-sensitive models: If appropriate variables and a behaviorally based structure are used, the resultant models can be sensitive to many kinds of policies that directly or indirectly affect intercity travel demand. Further, not only will the models be sensitive to such policies but their predictions will be more accurate as a result of the improved representation of reality.

The balance of this section is devoted to development of a preliminary behavioral framework that can be used in the analysis of intercity travel demand.

Intercity Travel Decision Within the General Decision-Making Process

An individual's general decision-making process for activities and travel is shown in Figure 1. The inputs to this process are the characteristics of the individual and his household. These characteristics are related to the individual's needs and ability to participate in various activities. To this category belong attributes like the individual's age and education and the household's stage in the life cycle. It is assumed that the household structure is given, and decisions about household formation are not considered within the proposed framework.

Given these attributes, long-range decisions about place of residence (type, city, location), occupational level and work place, and level of automobile ownership are made. These decisions were described by Lerman and Ben-Akiva (*3*) as household mobility decisions. In the intercity context, these decisions define the environmental attributes of the individual, and, together with personal and household characteristics, they define the preferences of the individual and the system of influence acting on him.

The long-range decisions serve as the basic input to the next set of decisions that are referred to as life-style decisions. There are many definitions of life style, but, in this context, life style is represented by the various activity patterns of the individual. These patterns usually exhibit regularities that correspond to daily, weekly, and seasonal routines. The term "activity pattern" refers to the types of activities performed by an individual and their order and duration.

Individual travel decisions are derived from the various activity patterns. For the purpose of this paper, travel patterns are divided into urban and intercity travel patterns. As will be shown later, these two patterns are distinct. In some contexts, intercity travel may be further broken down into domestic and international travel.

It follows from this brief description that intercity travel analysis should take account of individual and household characteristics, residential and work location, automobile ownership, and developmental and service characteristics of an individual. Further, when analyzing intercity travel, special attention should be given to the potential for substituting urban travel for intercity travel. At a minimum, this means that the alternative of not making an intercity trip should be present in the analyzed individual choice set. As can be seen from Figure 1, many factors affect intercity travel decisions. Neglecting them may lead to misrepresentation of an individual's decision-making process. A critical modeling issue is the identification of those elements that can be excluded from the analysis of intercity travel without undermining the interpretational and predictive usefulness of the resultant model system.

Dimensions of Intercity Travel Decisions

The intercity travel decision has many dimensions, which means that more than one decision precedes the execution of an intercity trip. Figure 2 shows the dimensions associated with the intercity decision-making process. These dimensions are categorized under the traditional classification of the travel decision process: trip generation, distribution, and mode choice. To these are added another class, "decisions at the destination."

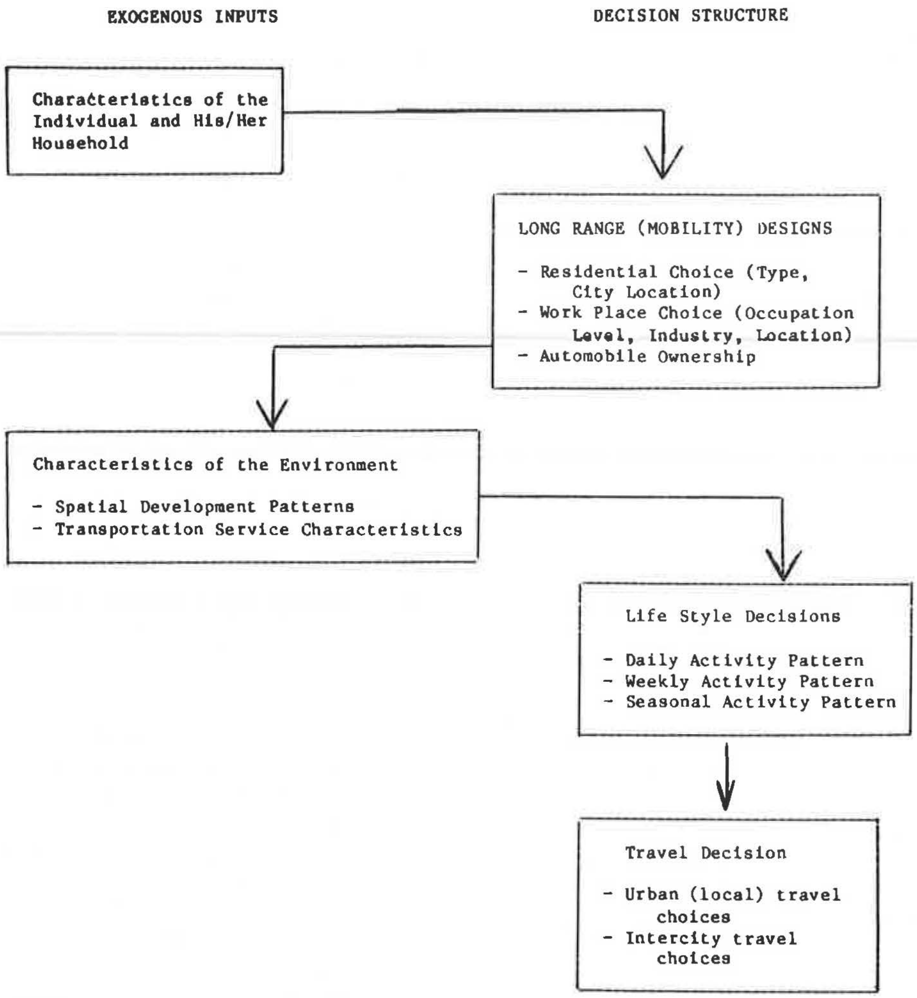

FIGURE 1 Intercity travel decisions within the general decision-making process.

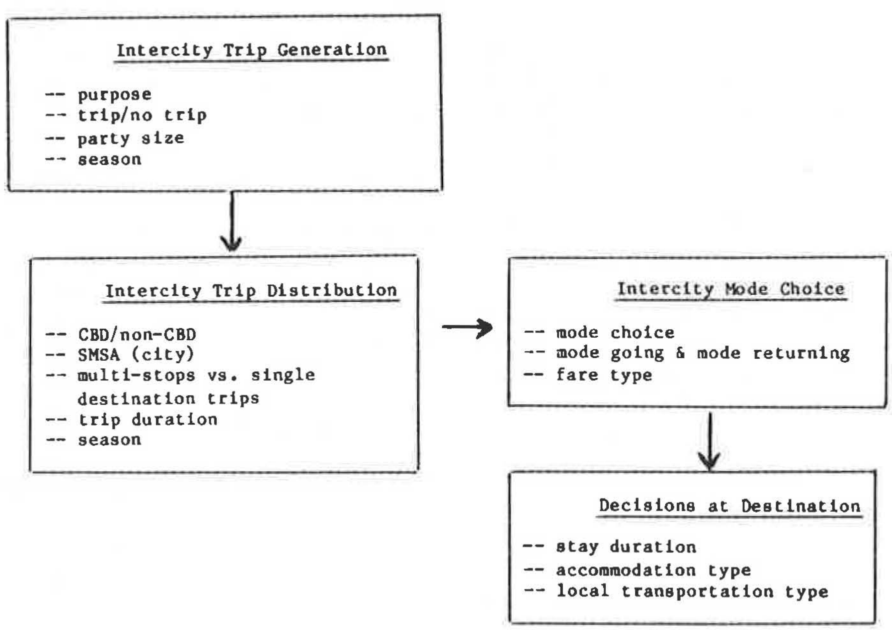

FIGURE 2 Dimensions associated with intercity travel decision making.

The first step in the suggested decision-making process is the trip generation phase. Here, the individual first decides whether or not to make an intercity trip. Given that a positive decision to undertake an intercity trip is made, several related decisions have to be made. Traditionally, only the trip purpose dimension is considered at this stage and, usually, the models deal with trip purpose by means of market segmentation (*4, 5*). Such segmentation implies that trips are generated explicitly for different purposes, which appears to be appropriate in many contexts; however, it ignores the potential of combining business and recreational travel. Further, there are other dimensions that are important at this stage. Party size has been identified and used in two studies as an explanatory variable for mode choice [Direnzo and Rossi (*6*) and Morrison and Winston, 1983]. However, neither of these studies attempts to estimate size. Another determinant that appears to be relevant is the time-of-the-year dimension of the intercity trip. Travel during the winter may be different from travel during the summer. Significant seasonal variations in trip generation have been identified in some data sets (*7*).

The second stage of the decision-making process is trip distribution or destination choice. Most models do not address this stage separately but combine it with the trip generation or the mode choice step, or both, to form a direct demand model (*8, 9*). Few studies, however, treat the destination choice separately or explicitly consider competition among destinations. Some studies in this category develop trip generation or mode choice models for specific destination segments, such as central business district (CBD) versus non-CBD destinations (*6*); stratify models according to distance (*10*); or develop models for specific corridors (*11, 12*). Only one disaggregate study (Morrison and Winston, 1983) actually modeled the destination choice for recreational travel using a choice set that was composed from several specific metropolitan areas.

In all of these studies, however, only one destination is considered for the intercity trip. This restriction limits the usefulness of the analysis because intercity trips may have multiple stops. Another dimension of destination choice is trip duration. Because this dimension may be an important input to the mode choice stage, it should be studied explicitly. Further, it is reasonable to hypothesize that trip distribution has a seasonal component.

The third stage in the decision-making process, mode choice, is the most extensively and, in many cases, the only aspect analyzed. All of the mode choice models developed to date considered only the origin-to-destination mode for the trip and implicitly assumed that the same mode is used for the return trip. The models are formed as either binary choice or multinominal choice models. In the latter case, a violation of the independence of irrelevant attributes (IIA) assumption may exist because the automobile mode may be treated differently than the common carrier modes. Future research should address this problem. Another important issue in the mode choice stage is the distinction between the mode going and the mode coming back. In this respect, automobile travelers are usually captive to the chosen mode and common carrier travelers have more freedom.

An important aspect of mode choice, especially for policy analysis purposes, is the choice of fare and service type. Intercity carriers offer a range of fare types associated with the level of service and the amenities offered. The existence of several fare classes is especially true in the airline industry, which may offer many different fare classes for the same flight (e.g., first class, business class, coach fare, excursion fare, and one or more restricted discount fares). From the point of view of the carrier, the number of seats to be allocated to each class (or the introduction of a new class) is one of the most important marketing decisions because changes in travel time between city pairs are limited and changes in service frequency incur substantial cost differences. Similar service class options may be important in intercity rail and bus marketing programs. Because of the potential importance of the service class decision, an individual's choice of fare type should be addressed explicitly in future analyses.

The three stages discussed so far form the conventional decision-making process associated with travel behavior. However, for a comprehensive analysis, intercity travel choices should not be separate from local activity pattern at the destination. The precise location of the intercity destination and the need for mobility at the destination may influence intercity travel choices. Of all the related decisions made at the destination, three dimensions appear to be most important. These are duration of stay at the destination, arrangements for accommodation, and transportation available at the destination. A recent study (Morrison and Winston, 1983) found statistically significant relationships between the decision to rent a car at the destination and the mode chosen for nonbusiness intercity trips.

A preliminary proposal for a behavioral framework of intercity travel has been presented. Developing a fully comprehensive framework requires the development of a system of corresponding models to test the various hypothesis implied in this structure.

DATA IMPLICATIONS

Requirements for the Data Set

An appropriate data set is needed to validate and refine the model system described previously. A data set should satisfy the following requirements to accomplish this objective.

- Fully disaggregate data: The data have to be gathered at the individual or the household level. This task is accomplished by interviews at the residence or work place. However, the interviews may need to be supplemented from other sources especially for the data that describe the level of service supplied by the nonchosen modes. Supplementing the data by using average city-to-city values for the missing information is equivalent to an error in measurement that may substantially undermine the effectiveness of the model.
- Compatibility with behavioral framework: Testing and supporting the behavioral framework can be done only with data that are relevant to the conceptualized decision-making process. This means that the candidate data set should include the following items: (*a*) personal and familial characteristics of the individual; (*b*) actual behavior in intercity travel over a substantial period of time; (*c*) full description of all of the intercity trips undertaken during this period (i.e., purpose, party size, time of the year); (*d*) relevant information about the destinations visited (i.e., city, specific areas visited, number of stops, trip duration); (*e*) attributes of the modes chosen for the trip as well as the corresponding attributes of the nonchosen modes; for any mode that offers several alternatives for service, all of the alternatives should be included in the data; and (*f*) description of the local activity pattern at the destination (i.e., length of stay, accommodations, and transportation arrangements).
- Compatibility of definitions of data items from various sources: Usually, a complete intercity travel data base contains information from various sources. Definition of city bounds, intercity distances, and level of service for the various modes should be

consistent. Attention should be given to eliminating ambiguous and confusing definitions from the data.

In light of these criteria, none of the existing data sets include all of the desired information. Most of the available data sets are in aggregate form. So-called disaggregate studies have used the 1977 National Personal Transportation Study (NPTS) (*13*) or the 1977 National Travel Survey (NTS) (*14*). These provide disaggregate data on individual trips of 75 or 100 mi and longer during a recall period of 14 days or a full year for the NPTS and the NTS, respectively. There are three major issues that limit the usefulness of these data sets:

- The data sets do not include accurate information on the place of residence of the respondents (this is to satisfy privacy restrictions). Thus access and egress time and cost for the trips cannot be constructed and used in the models.
- The specific origin and destination cities are not identified in some cases because of the use of standard metropolitan statistical area (SMSA) codes for both the origin and the destination. Hence, if one of the trip ends is not within an SMSA, the location of that trip end is not known. Also, the SMSA usually covers a large geographical area.
- The fare class used for common carrier trips is not given. Because many fare classes may exist for the same trip, this eliminates the ability to model fare class choice and limits the usefulness of the mode choice models because of error in travel cost variables.

Nonetheless, the 1977 NTS data set was used in a disaggregate study (Morrison and Winston, 1983) and revealed the potential usefulness of the disaggregate approach in exploring further aspects of intercity behavior; specifically, the development of interrelated multidimensional choice models.

Issues in Developing a New Data Base for Intercity Travel

In preparing a new intercity travel data base, several methodological issues should be addressed:

- Clear and unique definitions of relevant terms: The complexity of the intercity travel phenomenon necessitates the establishment of a well-defined terminology before data are collected. Special attention should be given to the definition of intercity travel especially in intensely developed corridors.
- Population frame and sample design: Because no disaggregate intercity travel data set was collected in the past to support a comprehensive study, basic issues such as population frame (i.e., region size), sample size, and sampling procedure have to be addressed. Also, attention should be given to the data collection strategy. Because time of the year may affect intercity travel, it would be desirable to collect data during the entire year. Also, because bias may result from omitting households that are absent for a long period during the data collection stage, a careful protocol for follow-up contact should be developed.
- Design of questionnaire: The data needed from the interviewee are more complex and extensive than the data collected in most urban travel surveys and the individual is required to supply information for an extended time period. There is a need to establish procedures that minimize dependence on long-term recall.
- Combining various data sources into one data base: In preparing an intercity travel data base, information needs to be extracted from several sources, especially for the level of service supplied by the nonchosen modes. Combining data should be done carefully to ensure uniqueness of definitions and compatability among data items. Also, attention should be given to the possible mixture of reported level of service with measured level of service data.
- Exploiting existing data sets: Because of the complexity of the intercity travel phenomenon, collecting a new data base can be a costly project. It may be more cost-effective to use various existing data sets or to coordinate this effort with other data collections.
- Updating the data base: When an intercity travel data base has been established, methods should be developed to update the information. Changes that occur in the general environment and in the transportation system need to be continuously incorporated into the data base so that it is not out of date when it is needed.

SUMMARY

A conceptual structure of the intercity passenger decision-making process has been presented and some of the implications for data base needs and data preparation have been noted. Accurate, policy-sensitive analysis is especially important for purposes of policy evaluation. Undertaking such analysis at the aggregate level is ineffective for policy evaluation; therefore a disaggregate approach is recommended. A key element in analysis of intercity travel is the development of an appropriate behavioral framework. Such a framework is needed for identifying the relevant variables and the correct model structure and is important to the development of a suitable intercity travel data set.

The first stage in the suggested behavioral framework is to link the intercity travel decision to the individual's general decision-making process. These linkages show that intercity travel can be interchanged with other decisions, so intercity models should include the alternative of no intercity trip in the individual's choice set.

The suggested decision-making process is categorized under four successive but interrelated decisions: trip generation, distribution, mode choice, and decisions at destination. Each of these categories has several dimensions, some of which have been studied in the past.

The establishment of a firm and detailed behavioral framework requires an appropriate data set. The data set should be fully disaggregate and contain information that is relevant to testing the underlying behavioral assumptions. In preparing the data set, several methodological issues have to be addressed. These include population frame, sample design, questionnaire design, combining various data sources, exploiting existing data sets, and updating the data.

Adoption of a disaggregate approach to intercity travel analysis and use of a suitable data base offer substantial potential for development of an improved intercity travel analysis and forecasting capability.

REFERENCES

1. A. H. Meyburg. "An Analysis of the Relationship Between Intercity Passenger Transportation and the Socio-Economic Characteristics of Metropolitan Areas." *Proc., Transportation Research Forum*, 1972.
2. F. S. Koppelman, G. K. Kuah, and M. Hirsh. *Review of Intercity Passenger Travel Demand Modelling: Mid-60's to the Mid-80's.* The

Transportation Center and Department of Civil Engineering, Northwestern University, Evanston, Ill. 1984.
3. S. R. Lerman and M. E. Ben-Akiva. "Disaggregate Behavioral Model of Automobile Ownership." In *Transportation Research Record 569*, TRB, National Research Council, Washington, D.C., 1976, pp. 34–55.
4. C. A. Lave, S. Mehring, and R. Kuzmyak. "Price Elasticites of Intercity Passenger Travel." *Proc., Transportation Research Forum*, 1977.
5. G. S. Cohen, N. S. Erlbaum, and D. T. Hartgen. "Intercity Rail Travel Models." In *Transportation Research Record 673*, TRB, National Research Council, Washington, D.C., 1978, pp. 21–25.
6. S. F. DiRenzo and L. P. Rossi. "Diversion Model for Estimating High-Speed Rail Use." In *Highway Research Record 369*, HRB, National Research Council, Washington, D.C., 1971, pp. 15–25.
7. A. Stachurski and R. Rice. "Development of Direct Intercity Rail Passenger Demand Models." *Proc., World Conference on Transportation Research*, London, England, April 1980.
8. G. Kraft. *Demand for Intercity Passenger Travel in the Washington-Boston Corridor.* NTIS: PB166–884. Systems Analysis and Research Corporation, Boston, Mass., 1963.
9. R. E. Quandt and W. J. Baumol. The Abstract Mode Model: Theory and Measurement. *Journal of Regional Science*, Vol. 6, No. 2, 1966, pp. 13–26.
10. S. E. Eriksen. *Demand Model for U.S. Domestic Air Passenger Markets.* Flight Transportation Report R78–2. Massachusetts Institute of Technology, Cambridge, June 1978.
11. P. L. Watson. "Comparison of the Model Structure and Predictive Power of Aggregate and Disaggregate Models of Intercity Mode Choice." In *Transportation Research Record 527*, TRB, National Research Council, Washington, D.C., 1974, pp. 59–65.
12. G. R. Leake and J. R. Underwood. Comparison of Intercity Bi-Modal Split Models. *Transportation Planning and Technology*, Vol. 5, 1978, pp. 55–69.
13. *1977 National Personal Transportation Study, User Guide for Public Use Tapes.* FHWA, U.S. Department of Transportation, 1980.
14. *National Travel Survey—Travel During 1977.* Bureau of the Census, U.S. Department of Commerce, Oct. 1979.

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Constraints on Individual Travel Behavior in a Brazilian City

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In this paper the statistical and predictive performance of two disaggregate choice models that incorporate probabilistic choice set formation are compared with a standard logit specification. The empirical work is conducted with work mode choice data from a Brazilian city. For the type of travel demand analyzed it is found that, although statistically inferior to the probabilistic choice set specifications, the standard logit specification, allied with market segmentation, is a robust formulation in both statistical and predictive terms. Recommendations for future research work in probabilistic choice set modeling are presented.

The principal issue addressed by this paper is the appropriateness of choice theory, as it is now interpreted, for modeling travel demand. In a highly constrained environment, such as can be found in low-income areas, observed choice may well be the result of the elimination of alternatives through active constraints, as opposed to the exercise of a choice prerogative by the decision maker.

The effect of constraints on travel behavior is particularly important for analyses in developing nations. Swait et al. *(1)* present an extensive discussion of a disaggregate travel demand model system for a medium-sized Brazilian city. Because of its unique nature, many substantive conceptual and modeling issues have arisen during the course of the study. These issues highlight fundamental differences between developed and developing countries in terms of travel demand. These practical experiences and conceptual concerns have led to the investigation and formulation of a number of probabilistic choice set formation models and to empirical testing of these to investigate their performance with respect to choice models with fixed choice sets.

The overall methodology and the alternative models that incorporate probabilistic choice sets are described in Ben-Akiva and Swait *(2)* and in Swait and Ben-Akiva *(3)*. In this paper two of these models are implemented with data for work mode choice from Maceió, Brazil, and their statistical fit and forecasts are compared with those of a standard logit model.

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HYBRID APPROACH TO MODELING CHOICE SET GENERATION

The approach used in this work is based on the following two-stage choice process: first, constraints (of a personal, household, and social nature) act on the individual to define his choice set; second, the individual exercises choice according to some decision rule.

From the perspective of an analyst who normally does not know either the specific alternatives that constitute an individual's choice set or the exact decision rule used to make a choice, the two-step choice paradigm leads to the following probability of observing alternative j being chosen by individual n *(4)*:

$$P_n(j) = \sum_{C \in G_n} P_n(j|C)\, P_n(C) \tag{1}$$