Transpn. Res.-A Vol. 19A, No. 5/6, pp. 460–464, 1985
Printed in the U.S.A.

0191–2607/85 $3.00 + .00

STATE OF THE ART AND RESEARCH OPPORTUNITIES IN TRAVEL DEMAND: ANOTHER PERSPECTIVE

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INTRODUCTION

The objeetive of this brief paper is to extend and enhance the state-of-the-art review and discussion of research opportunities in travel demand analysis prepared by Horowitz. Thus, this paper should be read as a complemcnt to that of Horowitz, although some of the important points he raises are reiterated here.

Travel demand analysis aims to understand travel behavior and thus inform transportation policy development and decision-making. In many cases, travel demand analysis results in a mathematical model that may be used to prediet travel behavior under specified circumstances. However, the development of a predictive model is not inherent to travel demand analysis, and substantial insight may be gained without the development and estimation of a mathematical model of travel demand. A good example is the work of Burns (1979), which shows that the accessibility of urban dwellers can be increased more by relaxing time constraints on activity participation than by increasing the speed of travel. This finding has substantial implications for the development of transportation and related policies. Thus, this paper is not limited to the development and application of mathematical models of travel behavior.

The remainder of this paper is organized as follows. First, a brief overview is presented of the state of the art in one stream of travel demand analysis research; namely, the activity-based approach. Second, a number of research opportunities and needs in travel demand analysis are identified and discussed. Third, data needs for advancing the state of the art in travel demand analysis are examined. Fourth, some concluding thoughts are presented.

AN OVERVIEW OF THE STATE OF THE ART IN THE ACTIVITY-BASED APPROACH

Horowitz argues correctly that discrete choice random utility models are the only operational travel demand modcls consistent with an explicit theory of choice behavior, and he provides a very comprehensive review of the state of the art in the estimation and testing of these models. However, he tends to overlook a substantial body of recent travel demand analysis research commonly referred to as the "activity-based approach" or "activity analysis." The objective of this section is to provide an overview of the state of the art in the activity-based approach.

Activity-based approaches use many methodologies and theoretieal concepts. In a number of cases, researchers have used discrete choice random utility models to operationalize their activity-based research efforts (see, e.g. Damm, 1980; Hirsh *et al.*, 1984, 1985). Such applications represent an important confluence of these two streams of research, thereby illustrating their complementary nature. In effect, the random utility model formulation has allowed some activity-based research to be operationalized. At the same time, research in random utility models has been enhanced by being informed by the ideas and results of the activity-based research. For example, the recent interest in extending discrete choice random utility models to incorporate eonstraints on individual behavior (Kitamura and Lam, 1984) can be ascribed, at least in part, to the findings of activity-based research concerning the existence and potential importance of constraints on travel behavior.

The activity-based rcsearch spans a very wide range of concerns, methods, and theoretical concepts. However, a number of themes recur in this body of work. These themes include (a) analysis of the demand for activity participation (and the analysis of travel as a derived demand), (b) the scheduling of activities in time and space, (c) the constraints (spatio-temporal and interpersonal) on activity and travel choice, (d) the interactions between activity and travel decisions over the day (or longer time period), as well as interactions between different individuals, and (e) the structure of the household and the roles played by the various household members. These themes are interdependent, and thus many studies address more than a single topic. As a result, any attempt to cite references for each theme would result in considerable repetition. A representative, but eertainly incomplete, selection of recent references is as follows: Clarke and Dix (1983), Damm (1980, 1983), Golob (1985), Hanson and Burnett (1981), Hanson and Huff (1982, 1985), Hirsh *et al.* (1985a, 1985b), van der Hoorn (1983 a,b), Jones *et al.* (1983), Kitamura (1983, 1984), Kitamura and Kermanshah (1984), Landau *et al.* (1981); Koppelman and Pas (1985), Pas (1982, 1983), Recker and McNally (1985), Recker, McNally and Root (1983), Recker *et al.* (1983).

The activity-based approach has required travel demand analysts to (a) reconsider the definition of the phenomenon being modeled, (b) give more explicit recognition to the derived demand nature of travel and (c) pay more attention to the sociodemographic characteristics of

individuals and households that affeet the demand for aetivity participation (and hence travel) and that often constrain activity and travel choices. The activity-based approaeh to travel demand analysis has made considerable progress in the past deeade and has made substantial contributions to the understanding of travel behavior.

RESEARCH OPPORTUNITIES AND NEEDS IN TRAVEL DEMAND ANALYSIS

Horowitz identifies and discusses a number of research opportunities and needs, mainly relating to the estimation and statistical testing of discrete choice random utility models. The following discussion is organized around four topics: behavioral theory, measurement, model development and model application. These are clearly interdependent topics; however, it is useful to structure the discussion along these lines.

Behavioral theory

Utility theory has been operationalized in the form of discrete choice random utility models, and considerable research (and application) in travel demand aualysis has employed these models, particularly in the case of work trip mode choice models. However, as Horowitz notes, no empirical studies of the usefulness of this theory in the description and prediction of travel demand have beeu undertakcn. Thus an important area of research in travel demand analysis relates to thc examinatiou of the applicability of utility thcory to travel choice behavior.

Many of the devclopments in the activity-based approach are based on theoretical concepts and frameworks, in contrast with the purely empirical basis underlying the first generation aggregate travel demand models. Damm (1983) notes these developments and argues for the need to develop an integrated, comprehensive theory using the theoretical coneepts and frameworks developed in earlier research. The development of such a theory of travel (and related) behavior is a major research opportunity in travel demand analysis. At the same time, a number of the components of a comprehensive theory of travel behavior are particularly relevant research topics curreutly. These topics are discussed iu the following paragraphs.

First, there is the issue of interpersonal interdependencies in travel behavior. There is considerable evidence (both direct and indirect) in the literature that the behaviors of members of the same household are not independent (Allaman *et al.*, 1982; Damm, 1980; Heggie and Jones, 1978; Jacobson, 1978; Kostyniuk and Kitamura, 1982; Landau *et al.*, 1981; McGinnis, 1978; Pas, 1984; Pas and Koppelman, 1984). The question of intrahousehold interdependencies in travel behavior is becoming more important because of recent and on-going changes in the structure of households. These changes include: increased single adult households, fewer children per household and more women in the labor force.

A second, and related issue, is the question of interdependencies in travel and activity behavior over the course of the day, week or longer time period. Again, there is considerable evidence in the literature that such interdependencies exist (Damm, 1980; Hauson 1979; Heggie and Jones, 1978; Hirsh *et al.*, 1985a, 1985b; Kitamura and Kermanshah, 1984; Landau *et al.*, 1981; etc.).

A third issue relates to the dynamie aspects of travel and related behavior. That is, understanding how individuals and households adapt in response to changes in the transportation and related environment. Existing theories and methodologies deal almost exelusively with the travel and related behavior of individuals and households at a particular point in time. However, it is increasingly being recognized that understanding travel and related behavior requires the development of models of the process by which travel and related behavior change in response to changes in the external environment and as a result of changes in the sociodemographic characteristics of the travelers (Dix and Layzell, 1985; Hensher and Wrigley, 1985).

A fourth issue relates to the examination of the rules by which individuals identify, evaluate and compare alternatives. Existing models of travel choice behavior generally assume compensatory decision-making. However, the validity of this assumption ueeds to be examined, and alternatives, such as the elimination-by-aspects model (Tversky, 1972), should be evaluated. Young (1985) reviews the role of thresholds in the travel choice process and concludes that they are possibly important in the determination of choice sets, the perception of the importance and satisfaction of attributes, as well as the determiuation of choice.

Measurement of travel and related variables

A major impediment to travel demand analysis research is the lack of suitable data. It is important to differentiate between the data needed for travel behavior research, in order to develop an improved understanding of the phenomenon, and the opportunities for research on data collection for travel demand analysis. The former question is addressed separately below. In this seetion we deal with issues of sample design, the measurement of behavior and changes iu behavior, and the measurement of household structure and lifestyle.

Sample design. An area of research that could yield substantial benefits is the use of alternative sampling procedures to improve estimation efficiency. The work of Daganzo (1980) and Sheffi and Tarem (1983) in connection with optimal sample design appears to be promising, but needs to be investigated with real data. These researchers have been concerned with improving estimation precision by optimal selection of respondents from prespecified segmeuts of the population. Another approach eoncerns the possibilities for improved estimation efficiency, without increasing data collection costs, by the use of repeated measures of the behavior of given individuals. Pas (1985) has undertaken some initial work in this area in the context of linear regression models, and the early results are very encouraging.

Measurement of behavior and changes in behavior. The colleetion and analysis of longitudinal data is essential in our efforts to understand how individuals and households adapt their travel and activity behavior in response to ehanges in the transportation-related environment. However, the design and exeeution of longi-

tudinal surveys raises issues not encountered in the collection of cross-sectional data. In particular, the problem of non-response bias is likely to be a greater problem in the case of a longitudinal survey than in the case of a cross-sectional survey (Golob, Schreurs and Smit, 1985). Important research areas are the development of procedures for reducing non-response bias, the formulation of procedures for estimating such bias, and the development of methods to adjust for such bias during model estimation.

An interesting research opportunity exists in the exploration of alternatives to the interview and questionnaire survey approaches commonly used in the collection of travel and related data. The Household Activity Travel Simulator (HATS) developed at the Transport Studies unit at Oxford University (Jones, 1979) is an example of an innovative approach to the collection of information about household decision-making and adaptation in the face of changes in the transportation-related environment. Such open-ended, yet structured, techniques have proved valuable in identifying the range of possible responses to a particular change in the environment. The further development and creative use of such devices in increasing our understanding of travel behavior is a potentially productive area of research; particularly with the use of modern electronic technology.

A number of researchers have attempted to measure complex travel-activity patterns (daily or weekly) by classifying these behaviors into a set of discrete classes (Hanson and Huff, 1985; Koppelman and Pas, 1985; Pas, 1982, 1983; Pas and Koppelman, 1985; Recker, McNally and Root, 1983). These classes may be used to study the relationships between hypothesized explanatory variables and complex travel-activity behavior (Pas, 1984) and to estimate the effects of alternative policies (Recker, *et al.*, 1980). These efforts have generally been successful in identifying a small number of "representative patterns." An area for future research is the refinement of these methods and the development of alternative methods for measuring complex travel-activity patterns. Furthermore, the development of methodologies for identifying representative complex travel-activity patterns perceived to be distinct by individuals is an important research area.

Measurement of household structure and lifestyle. Considerable research effort has been expended on defining and employing a variable, generally termed *household lifecycle*, which is used to describe household structure. There is considerable evidence in the literature that household lifecycle is an important explanatory variable with respect to travel and related behavior (e.g. see Allaman *et al.*, 1982; Clarke and Dix, 1983; Kostyniuk and Kitamura, 1985; Pas, 1984). However, two related issues require further investigation. First, there is no common agreement on the measurement of lifecycle, either with regard to the specific variables to be used in describing lifecycle nor with respect to the categories to be used. Second, the validity of the conventional view of a household progressing through a series of "standard" lifecycle stages has been questioned recently (Murphy and Staples, 1979).

The characteristic often referred to as lifestyle has received less attention than lifecycle. However, Salomon and Ben-Akiva (1983) report pioneering work in the measurement and use of lifestyle in travel demand analysis, and show the usefulness of the concept. Further research is needed in the area of measuring and employing descriptions of lifestyle in travel demand analysis.

Model development (estimation and testing)

Horowitz provides a very comprehensive review of the state of the art and research opportunities in estimation and testing of discrete choice random utility models. There are, however, two additional research opportunities.

Recent research by Koppelman and Chu (1983) finds that the sample sizes required to obtain reasonably precise parameter estimates in multinominal logit mode choice models are substantially larger than the sample sizes commonly considered adequate for model estimation. Two research opportunities arise from this finding. First, it is necessary for this finding to be verified and examined in the context of models of other choices. Second, it is important that research be undertaken to develop estimation procedures which use data more efficiently. (Some possibilities relating to sample design are described previously.) A potentially productive area of research appears to be the development of procedures for the consistent estimation of models with data from different sources (home interview surveys, roadside interviews, on-board surveys, cordon counts, census data, etc.). Some initial work in this area is reported by Ben-Akiva, Gunn and Pol (1984) and by Daly and Gunn (1985). Similarly, the estimation of models with data describing the behavior of individuals in both actual and hypothetical situations (revealed and stated preference data) appears to be a promising area of development. Both of these approaches could allow the estimation of models with smaller data collection budgets.

As noted earlier, an important research direction is the examination of travel and related behavior as a dynamic process. In addition to the development of a theoretical model, research is needed in the development and application of estimation procedures that account for heterogeneity, state dependence and non-stationarity (Hensher and Wrigley, 1985). Lyon (1984), for example, reports the development of a methodology for estimating a dynamic structural equation model of the attitude-behavior relationship.

Model application

The use of a travel demand model to predict travel behavior in a particular situation requires an estimated model and estimates of the exogeneous variables in the model. The use of a model to predict behavior in a context different from the estimation context is termed model transfer, and the ability of a model to provide useful information about behavior in the application environment is termed transferability (Koppelman and Wilmot, 1982). The application and estimation environments may be different either spatially, temporally or both.

A number of studies have examined the transferability of various travel demand models. Some of these studies

have shown that model transferability is substantially enhaneed by making some adjustments to the estimated parameters based upon some information about the application environment (Gunn *et al.*, 1985; Koppelman *et al.*, 1985). The further development and testing of these "updating " procedures is an important area for future research. In particular, future rescarch should incorporate thc costs of collecting the various types of data needed for thc different updating procedures so as to develop "optimal" updating procedures.

A second important issue in model transfer is the selection of a "donor model," assuming a number of models are available. That is, given a number of potential donor models, as well as information about the estimation and application contexts, the problem is to predict which model is most suitable for modcl transfer.

DATA NEEDED FOR TRAVEL DEMAND ANALYSIS RESEARCH

Existing data sets can be used in imaginative and creative ways in advancing the state of the art in travel demand analysis and in providing improved nnderstanding of travel behavior. However, there is an urgent need for the collection of new data sets to snpport the potential advances in travel demand analysis. This section discusses some of the general characteristics of data needed for travel demand analysis research, although it should be recognized that advances in the state of the art in travel demand analysis will require the collection of a number of specialized data sets.

First, the importance of a carefully collected longitudinal data set to advancing our understanding of travel behavior cannot be overestimated. Second, the collection of activity data, as opposed to travel data, is most important if we are to enhance our understanding of travel as a derived demand. That is, we require information concerning both in-home and out-of-the home activities, in order to understand the trade-off between in-home and out-of-the-home activity participation (where the latter requires travel). Third, the acitivity data should be recorded for each member of the household to allow examination of intrahousehold interdependencies in travel and related behavior. Fourth, the use of techniques other than interviews and questionnaires needs to be considered in the collection of data for state-of-the-art research in travel demand analysis. In particular, enhanced understanding can be obtained from the use of devices sueh as HATS (Jones, 1979) and the use of carefully designed laboratory simulations (Mahmassani and Chang, 1985).

CONCLUSIONS

The state of the art in travel demand analysis has made substantial advances in the past 15 years. The field is rieh with concepts and methodologies but many interesting problems are yet to be solved. This paper provides a brief overview of the state of the art in travel demand analysis and identifies a number of important and potentially productive researeh areas.

Inevitably, this paper reflects my own perspective on the state of the art and researeh opportunities. Furthermore, it is designed to complement the paper prepared by Horowitz. Together, these papers represent a broad perspective on travel demand analysis, and it is the author's hope that these papers will be useful in guiding future basic research in travel demaud analysis.

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