TRANSPORTATION CENTER

AN ASSESSMENT OF MULTIMODAL APPROACHES TO INTERCITY PASSENGER DEMAND MODELING

by

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RESEARCH REPORT

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An intercity passenger travel demand model can be an important tool. Through it, needs in terms of equipment, facilities and routing can be ascertained. It can also reveal the impact that changes in any single travel mode, or in any socioeconomic or demographic characteristic, will have on either the whole transportation system or a particular part of it. Most of the research and modeling done in this area has tended to focus on either a single mode (air, auto, rail or bus), or has only considered the theoretical aspects of the problem (i.e., empirical testing is not undertaken). The work done on a single mode must of necessity be incomplete. Individual modes do not exist in a vacuum; the transportation system is modally interdependent. Theoretical modeling, though a useful first step, becomes more useful to the extent that a model can be put to practical use in prediction or explanation. What is needed in this area is a synthesis - - a multimodal analysis of intercity passenger demand, complete with testable empirical data. To that end, this paper will consider what has been done in this area, and consider what further research is needed.

The work that has been done in the area of multimodal intercity passenger demand has concentrated on particular regions of the country. The reason for this is the lack of general ridership data in other areas. For example, the best data on passenger volumes by modes have been collected in the Northeast

Corridor; thus, the majority of the studies are models of this area. Other works have dealt with the California Corridor and the state of Michigan. It is somewhat distressing that in a subject area as interesting and important as this, so little has been done. In preparation for assessing future research needs, the available literature will be summarized - around each available data area.

NORTHEAST CORRIDOR STUDIES

The first model of intercity travel demand in the Northeast Corridor was undertaken by the Systems Analysis and Research Corporation, SARC (24). Two objectives of the SARC study were the identification and measurement of the principal factors influencing both total intercity passenger demand and the division of this demand by mode and by purpose (business/non-business). Previous travel demand studies were surveyed and classified into three groups: urban travel demand studies, consumer behavior studies and direct demand models. The latter approach was selected, with the volume of travel (expressed as the number of round trips by mode and purpose for a city pair) being postulated as a function of both socioeconomic-demographic variables (population, income, employment and locational attractiveness) and transportation factors (travel time and cost by mode). The data for each mode were obtained as follows. Auto travel counts came from various travel surveys; air data came from the CAB. Rail data were obtained from the railroad companies in the area; however, the data suffered from no specification of trip origin. To correct this, it was assumed that rail travel between two points was proportional to highway travel. Bus data were obtained from estimates derived from schedules and other data on bus operations in the Corridor. This data were also incomplete as to origins,

and was corrected in the same manner as the rail data. It is clear that the data were somewhat unreliable and incomplete in this study. In the actual model, the preliminary relationships were tested by multiple regressions, to reduce the number of variables and measure the general effects of each variable. The final model used constrained multiple regression (to alleviate the problem of multicollinearity) with a log-linear demand function (this has constant elasticity and was used because of lack of data). The use of constant elasticity could be challenged on the grounds that the postulated relationships will certainly change over time.

The other works relating to the Northeast Corridor revolve around the Northeast Corridor Transportation Project of the U.S. Department of Transportation. Additional data sources were collected for this project by Peat, Marwick, and Livingston Co. (PML) (15) and Voorhees and Associates (25). PML reviewed and revised the SARC (and similar) data. They noted that although auto travel data were available from numerous surveys, they were not very reliable due to the nature of travel and the procedures used in the surveys. The CAB air data were one of the better sources of data, but even they contained faults. Rail data were obtained from the companies involved, while bus data were developed by the National Association of Motor Bus Owners from a review of intercity bus schedules and estimates of load factors and supplemented with certain Greyhound and Trailways data. The Voorhees data were developed from a 1969 survey on volume and characteristics of person trips by air, bus and auto between specific metropolitan areas. The auto data came from a random survey of drivers crossing particular screen lines. The air and bus data came from samples trips by questionnaires. Other corridor data sources

include the National Bureau of Standards, NBS (13).

A second demand study on the Northeast Corridor was done by McLynn and Woronka (9). The first part of this work deals with modal split regression runs - with three approaches considered. Considered first were conventional "single pair" regressions, which represented early calibrations of the modal split model. The second type were simultaneous regressions used to compensate for inherent shortcomings in the first approach. The third approach consisted of time-cost tradeoff regressions, used to cope with the collinearity of the data in the first and second approaches. The main part of the study combined a modal split model with a gravity model to obtain a single analytic model that would describe the modal demands in a competitive transportation market. This composite analytic model used socioeconomic variables such as population, income and lodging receipts and transportation variables such as time, cost and frequency. The data came from the NBS (13).

A third demand study, which used corridor data (as well as California data below) is the abstract mode approach of Quandt and others (18) (21) (26), as summarized in Young (27). Briefly, this approach suggests that modes of travel are characterised by bundles of attributes. Thus, the various parameters of travel demand are the same for all modes of travel (i.e., the demand for travel by any mode, appropriately defined, is determined by the same demand function). The explanatory variables include both modal characteristics and socioeconomic variables. Data is used to calibrate the different versions of the model and the result is evaluated, although in general, not tested. The use of this model for forecasting is discussed by Quandt (22) and Pinton (17).

Two other approaches to Northeast Corridor modeling include Monsod (12) and Blackburn (3). The Monsod (relative shares) model is a two-stage process. First, the relative share of each mode as a function of the abstract characteristics of this mode is estimated. Second, the total demand for travel is measured, considering all variables which may affect total demand. The Blackburn or probabilistic model is based on consideration of individual behavior. A further description of this model is considered below.

Two works considered the accuracy and appropriateness of the Northeast Corridor Models. In Pinton (17), the abstract mode, relative shares and probablistic models were compared as to forecasting ability. Consideration of different criteria of choice and application of tests related to these criteria led to a version of the abstract mode model being chosen as the best model for forecasting purposes. In National Bureau of Standards (14), five models were reviewed including: abstract mode, McLynn model and probabilistic model. A modification of the McLynn model was chosen as the best for four reasons: sound theoretical structure (logical, mathematic and economic), behavior with respect to changes in the transportation system, goodness of fit with the data and behavior with respect to certain scenarios. The chosen model was then calibrated using observed 2 directional travel volumes for 4 modes for 24 origin-destination pairs for 1965, and data on modal travel time, cost and frequency, and number of families with incomes greater than $10,000. Observed versus predicted volume for city pairs (by mode) was calculated for this model.

CALIFORNIA CORRIDOR STUDIES

The major California study was undertaken by Metzger and Ross for the Stanford Research Institute, SRI (10). Two objectives of this study were to project total passenger traffic between twenty high density city pair markets within the Corridor and to allocate total projected traffic among the various modes. The data were obtained as follows. Automobile figures came from counts of traffic that passed certain checkpoints, a survey for a Los Angeles Regional Transportation Study and an engineering study. It is noted that there is a very limited amount of data available as to the amount or nature of intercity highway passenger traffic. Air data were from the CAB and the California Public Utility Commission. Bus totals came from a July 1964 Greyhound summary of driver's passenger manifests in the form of total passengers by direction for all major city pairs within the Corridor. This was expanded using dollar volume of ticket sales for each month and relative frequency of Trailway's operation to get a yearly total. Rail data were obtained from Southern Pacific and Sante Fe's sample survey of passenger origin and destination. It is noted that availability of auto traffic data is the major factor limiting the number of city pairs and the time period of the study. Because of the lack of data, the study was restricted to a cross-sectional analysis. Also, because of the low number of city pairs available, the number of independent variables used to explain demand had to be kept low. The variables tested included population product, distance, travel time, income, and a "need to travel" variable. First, total travel was estimated using regression analysis. The equations containing population product and distance, and population product and travel time were the best estimators. Then, travel by mode

was projected using base year rates of participation adjusted by assumptions as to the growth and usage of each mode.

Blackburn's model (2), considered briefly above, was originally calibrated with the SRI California data. In this model, it is assumed that a choice of mode is made from a consumer's maximization of utility, taking into account the special attributes of each alternative as well as costs, time and frequency. These individual demand functions are combined by specifying the way tastes vary between individuals and by taking expectations. This taste variation is introduced by treating the parameters of the individual demand functions as observations on a set of continuously distributed random variables. Expected market demand is then taken as the product of the expected value of the individual demand functions and the number of individuals. The resulting market demand functions are mathematically complex, leading to severe problems of estimation. The parameters of the model were estimated by least squares, and the evaluation of the probability integral was carried out by Monte-Carlo methods. Observed versus predicted figures for the California city pairs presented.

Finally, certain early versions of the abstract mode models of Quandt and Young were calibrated with the SRI California data. In (18), the model was calibrated using air, bus and auto data. In (19), the model was calibrated using only the air and auto data, with predicted versus actual modal splits being calculated.

MICHIGAN STUDY

A final study was undertaken by Billheimer (1). He developed a segmented (by population) mathematical model designed to represent the demand for travel

between cities of various sizes in and around Michigan. Initially, auto travel between fifteen origin-destination city pairs were selected and used to test five existing demand models (including two multimodal models, (9) and (10)). Poor results ensued, highlighting the difficulty of predicting intercity passenger demand for a wide range of distances and city sizes. It was decided that the chosen model should have the following attributes: simplicity, sound theoretic structure, ability to reflect the intermodal consequences of systems changes, and the ability to reproduce observed travel data in Michigan. The model selected was a modification of the McLynn model (9); the variables considered were travel time, out of pocket (per capita) cost, service frequency and number of families with income greater than $10,000. To calibrate the model's parameters, observed one way travel volumes by air, rail, bus and auto were obtained for twenty city pairs along with cost, time, frequency and access time and cost data. The demand model was calibrated by means of a constrained search technique, since calibration by log-linear regression analysis proved unsuccessful. Two objections could be raised against this technique. First, the use of parameter constraints may negate the theoretical design of the model. Second, a segmented model can lead to abrupt changes in travel for small changes in the segmented variable. In theory, a continuous function for segmentation would be preferred. The model was then checked for its sensitivity it was determined what a 10% change in each variable would do to modal demand and total intercity travel demand. Also, the effect of parameter changes was considered.

MODEL SUMMARY AND CRITIQUE

A survey of current forecasting techniques was compiled by Lansdowne of

the Rand Corporation (7). The demand models are divided into the following categories: Market Analysis Methods (travel market surveys, generally not used for predicting intercity modal demand volumes), Sequential Trip-Generation and Modal Split Models (see Monsod's model above), Joint Trip-Generation and Modal Split Models (see SARC, above), Implicit Abstract-Mode Models (deals implicitly with underlying individual utility functions, see Quandt and Young models above) and Explicit Abstract Mode Models (see Blackburn's model, above). The first four types of models are descriptive, the final one is behavioral. Lansdowne formulates a behavioral demand forecasting model, which can make forecasts for major transport improvements - although it is not calibrated or tested.

It seems obvious that the biggest limitation to construction and use of these demand models is the lack of reliable data. Whether a particular region is to be analyzed, or the whole country, suitable data must be available. Probably the best available data is on air travel volumes between city terminals. Nevertheless, this data is not true origin-destination data but simply terminal to terminal data. In the last year or two, it appears that comprehensive origin-destination rail data is being collected by Amtrak, for all cities served by that corporation. Since this data is not publically available at this time, no comments can be made on its appropriateness. The final common carrier, the bus, appears to keep little record of origin-destination data. However, it is my feeling that the raw materials necessary for obtaining this data (ticket stubs, drivers records, etc.) are certainly kept, if not processed. Probably the most difficult data problem is auto travel. For any national survey, only a study of the scope of the U.S. Census could possibly get accurate

national origin-destination data. The difficulty of regional data gathering is itself apparent. Cordon counts cannot reveal accurate data; some sort of regional surveying (similar to the Census) would be needed. It might be easier to eliminate the auto from consideration, but this would compromise the effectiveness and accuracy of the model.

Reliable data for one period of time would allow construction of a cross-sectional model. However, it must be realized that the parameters that result will not remain constant over time. Thus, it would be desirable to obtain data over time - to allow use of time series methods, as well.

National intercity passenger travel demand would certainly be a fruitful and invaluable area of research. But in view of the massive difficulties involved, it might be worthwhile to consider only a particular region.

BIBLIOGRAPHY

1. Billheimer, John W. (Stanford Research Institute). "Segmented Multimodal Intercity Passenger Demand Model". Highway Research Record #392, 1972.

2. Blackburn, Anthony J. A Non-linear Model of Passenger Demand. Ph.D. Dissertation, M.I.T., 1966.

3. _____. "Estimation of the Behavioral Model." Chapter 3 in Studies in Travel Demand, Vol. 5, MATHEMATICA, 1969.

4. Brown, David A. An Intercity Passenger Transportation Demand Model. Ph.D. Dissertation, Stanford University, 1969.

5. Crow, R. T., Young, K. H., and Cooley, T. Models of Intercity Travel Demand, Part I. MATHEMATICA, 1971.

6. Gupta, M. and Young, K. H. "Statistical Testing of the Abstract Mode Model," Chapter 5 in Studies in Travel Demand, Vol. 4, MATHEMATICA,1968.

7. Lansdowne, Z. F. Analysis of Intercity Transportation Improvements: Forecasting Demand and Evaluating User Benefits. Santa Monica: The Rand Corporation, 1970.

8. Lave, Lester. "The Demand for Intercity Passenger Transportation," Journal of Regional Science, April, 1972.

9. McLynn, J. M. and Woronka, T. (Arthur B. Young and Co.) Passenger Demand and Modal Split Models. Northeast Corridor Transportation Project Report # NECTP-230, 1969.

10. Metzger, Willan L. and Ross, Howard R. An Analysis of Intercity Passenger Traffic Movement Within the California Corridor Through 1980. Stanford Research Institute, 1966.

11. Miller, Ronald. "A Survey of Demand for Travel Studies". Chapter 1 in Studies in Travel Demand, Vol. 1, MATHEMATICA, 1965.

12. Monsod, Solita. "Relative Shares Model." Chapter 3 in Studies in Travel Demand, Vol. 5, MATHEMATICA, 1969.

13. National Bureau of Standards, Technical Analysis Division. The Assimilation of an Interim Set of Demand, Socioeconomic and Transportation Data for the Northeast Corridor, 1968.

14. _____. Modeling for the Northeast Corridor Transportation Project. NECTP report #213, 1969.

15. Peat, Marwick, Livingston and Co. Access and Demand Data Used in the Development and Calibration of the Northeast Corridor Transportation Models. NECTP report #217, 1969.

16. _____. National Intercity Travel: Development and Implementation of a Demand Forecasting Framework, 1970.

17. Pinton, Michael R. "Tests and Comparison on Demand Models." Chapter 4 in Studies in Travel Demand, Vol. 5, MATHEMATICA, 1969.

18. Quandt, R. E. and Baumol, W. "The Abstract Mode Model: Theory and Measurement," Journal of Regional Science, Vol. 6, No. 2, 1966. Reprinted in 20.

19. _____. "Estimation of Modal Splits," Transportation Research, Vol. 2 (1968). Reprinted in 20.

20. _____. (ed.) The Demand for Travel: Theory and Measurement. Lexington: D.C. Heath and Co., 1970.

21. _____ and Young, K.H. "Cross-Sectional Travel Demand Models: Estimates and Tests," Chapter 2 in Studies in Travel Demand, Vol.3, MATHEMATICA, 1967. Reprinted in Journal of Regional Science, Vol.9, No. 2, 1969 and 20.

22. _____. "Tests of the Abstract Mode Model," Chapter 2 in Studies in Travel Demand, Vol. 2, MATHEMATICA, 1966.

23. Rose, Mark. "Some Problems and Prospects in Collecting Data on Travel Demand," Chapter 6 in Studies in Travel Demand, Vol. 2, MATHEMATICA, 1966.

24. Systems Analysis and Research Corporation. Demand for Intercity Passenger Travel in the Washington-Boston Corridor, 1965.

25. Voorhees, Alan M. The Northeast Corridor Intercity Travel Survey on Air, Auto, and Bus Modes, 1971.

26. Young, K. H. "The Abstract Mode Travel Demand Models: Estimation and Forecasting," Chapter 1 in Studies in Travel Demand, Vol. 4, MATHEMATICA, 1968.

27. _____. "An Abstract Model Approach to the Demand for Travel," Chapter 1 in Studies in Travel Demand, Vol. 5, MATHEMATICA, 1969.

28. Abo-Baker. Determinants of Consumer Demand for Transportation: A Study in Statistical Methodology. Ph.D. Dissertation, University of Illinois, 1968.