Multidimensional Model System for Intercity Travel Choice Behavior

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In this paper, the relevant issues concerned with development of intercity travel demand models are examined, and a behavioral framework and model system for the set of complex and interrelated choices undertaken by travelers and potential travelers in the intercity travel market are developed. The desired properties of a data set for estimation of a disaggregate intercity travel demand model system are formulated, and existing intercity travel data sets are evaluated with respect to these properties. No existing data set satisfies all the requirements for estimation of a system of disaggregate intercity demand models. Nonetheless, it is useful to use the best available data to demonstrate the proposed behavioral framework and model structure. The 1977 National Travel Survey, supplemented with data on intercity level of service, is used to estimate models of intercity trip frequency and destination, mode, and air fare/service class choice. The estimation results support the proposed behavioral structure and the corresponding model structure. Deficiencies in the estimated models are attributed to the characteristics of the data set used in this study. Collection of data specifically for estimation of a system of disaggregate intercity travel models is needed to develop a model system that is behaviorally consistent and has a high degree of predictive accuracy.

Investment in intercity transportation services has received considerable attention in recent years. Examples in the United States include consideration of high-speed rail service in Southern California (*1*), in Florida (*2,3*), in Ohio (*4*), between Chicago and Milwaukee (*5*), and between Las Vegas and Los Angeles (*6*). Examples in Europe inclue the Channel Tunnel and expansion of the Très Grand Vitesse network in France. Accurate prediction of total intercity travel demand and its distribution among modes is an important component of the evaluation of these large capital investments.

Reviews of intercity passenger demand modeling studies undertaken during the last two decades (*7–9*) identify a number of important deficiencies in the models developed. Each of these reviews concludes that a new effort is needed to develop models that will provide accurate, policy-sensitive predictions of future intercity travel and that these models should be based on analysis of individual choice behavior.

Addressed in this paper are the methodological and practical issues associated with the development of a system of intercity travel demand models based on analysis of individual travel choices. Issues concerning the modeling approach, the theoretical basis of the model system, the model structure, and data needs are examined. The best available data are then used to estimate and evaluate the proposed approach.

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MODELING APPROACH

Previous modeling approaches can be grouped into two major classes. These are the aggregate and the disaggregate approaches. Models within each class have important similarities despite the many variations employed with respect to the modeling technique, the mathematical formulation, and the variables used.

Aggregate Approach

Early emphasis was on development of aggregate models, mostly in conjunction with the Northeast Corridor Transportation Project. Several different classes of aggregate models were developed. The aggregate models, which have been used most in intercity travel modeling, are sequential models. These models consist of two linked submodels that jointly predict intercity travel volume by mode. The first model predicts total intercity travel volume for the city pair as a function of the characteristics of each of the cities and composite measures of city pair level of service taking account of the attributes of all city pair travel modes. The second model predicts the share of total intercity travel volume assigned to each travel mode as a function of level of service by each of the available travel modes. An early sequential modeling aproach (*10*) has been used in a number of intercity corridor studies (*11*).

The variables used in the aggregate sequential models are averages or totals of the corresponding individual variables. The variables that have been used in different models include area descriptors such as population, employment, economic activity and cultural attraction indices, and intercity level of service measures such as travel time, travel cost, and frequency for each travel mode. The number of variables used in any one model is limited by the aggregate estimation approach because of sample size limitations and multicollinearity among area descriptors and among level of service variables.

Although no behavioral basis supported the development of these aggregate models, they were subjected to macroeconomic reasonableness criteria and provided useful insight into intercity travel behavior. The most important results of these studies are (a) the identification of city pair activity and attraction variables and city pair level-of-service variables as statistically related to travel volume, (b) the finding that segmentation by trip purpose (business and nonbusiness) and trip distance is important, (c) the recognition of the importance of trip generation and destination changes as well as corridor mode share changes, and (d) the recognition of the need to include travel service measures for all modes to obtain satisfactory forecasts of single mode volume.

Despite these contributions of aggregate intercity analysis, there are a number of problems with this class of models. These include lack of behavioral basis, deficiencies of aggregate estimation methods (data aggregation leads to estimation bias and multicollinearity among variables), and unsuccessful functional form (the multiplicative form of the total demand model tends to magnify relatively small input errors into large prediction errors). These deficiencies lead to poor performance of the aggregate models, which in some cases overpredicted demand by as much as 50 percent (*9*).

Disaggregate Approach

Disaggregate models have been used extensively for both analyzing and forecasting urban passenger travel demand. The few attempts to apply the disaggregate modeling approach to the analysis of intercity travel demand have been limited by the characteristics of existing data sets (*12*). The most important advantage of disaggregate model estimation is that it overcomes estimation biases inherent in the use of aggregate estimation methods and incorporates a wide range of policy-sensitive variables. Thus, these models more accurately represent the behavioral response of travelers to changes in economic activities and to changes in fare and service characteristics.

The primary characteristic of disaggregate models is their use of data that describe each individual traveler or potential traveler, his or her characteristics and environment, and the attributes of service available to him or her. This approach provides improved estimation capabilities, as well as an increased ability to represent the terminal access and egress service characteristics for intercity trips.

The disaggregate models must be formulated consistently with an underlying behavioral structure; otherwise, the models will reflect only empirical relationships with limited usefulness. A proposed behavioral framework is discussed in the next section.

BEHAVIORAL FRAMEWORK

The development of a behavioral framework for intercity travel makes it possible to identify the proper structure of the models, identify the relevant variables to be used in the various models, develop policy-sensitive models, and prepare an appropriate data set. A framework, proposed earlier (*13*), describes an individual's intercity travel as derived from the individual's daily, weekly, and seasonal activity patterns, which are, in turn, based on the individual's demographic and life-style characteristics.

The individual's intercity travel and travel-related decision are classified into four decision categories: trip generation, destination choice, mode choice, and "at destination" decisions. Each of these categories includes several dimensions. Trip-generation decisions include the dimensions of trip frequency, purpose, time of the year, and party size. Destination choice includes the destination city, location within that city, and number of stops. Mode choice dimensions are mode selection for going and returning, carrier selection, and fare-type/service-class selection. The relevant decisions "at the destination" include the stay duration, lodging arrangement, and local transportation selection.

These decisions and dimensions are interrelated; models should be structured to reflect these links. Linkages among models make it possible to capture the effect of level-of-service changes on the total demand level (i.e., induced demand) by appropriate structure and specification of the model system.

Having established an appropriate model system, the calibration of the models requires a suitable data set. The attributes of a suitable data set are discussed in the following section.

INTERCITY TRAVEL DATA REQUIREMENTS

The information required to support disaggregate intercity travel demand modeling includes

- Individual survey data, such as demographic and location (residential and work) characteristics, intercity travel behavior of travelers over a defined period, and preference rankings or observed choices among a variety of real or artificial service alternatives;
- Urban area characteristics, such as size and activity measures for the origin area and potential destinations;
- Intercity travel volume information, including counts or other estimates of travel flows by mode and fare/service class; and
- Intercity travel service data including measures of service frequency or schedule delay, line haul and access/egress travel costs, line haul and access/egress travel times, and service quality.

None of the existing data sets includes all of the desired information. These data sets are in aggregate form with two exceptions: the 1977 National Personal Transportation Study (NPTS) (*14*) and the 1977 National Travel Survey (NTS) (*15*). These disaggregate data sets include trips of 75 mi and longer during a recall period of 14 days for the NPTS and 100 mi and 3 months for the NTS. There are three major deficiencies that limit the usefulness of these data sets:

- The lack of accurate information on the residence location of respondents makes it impossible to estimate access and egress time and cost for intercity trips.
- The absence of exact origin and destination city location in many cases limits the ability to develop representative destination choice models, as well as good mode choice models, because the level of service attributes cannot be determined accurately.
- The lack of information provided about the fare class used for common carrier trips limits both the ability to model fare class choice and the usefulness of the mode choice models, because travel cost and travel time restrictions cannot be defined.

Thus, it is necessary to collect new data to develop fully behavioral intercity travel models. The design of a data collection plan is a complex process. Two important issues concerning data collection are reviewed in this section.

First, it will be necessary to collect data at both the home or work place and on board intercity travel modes. Home- or work-based data collection is needed to identify the frequency of intercity travel and the factors that influence that frequency. On-board data collection is necessary to obtain adequate representation of travel on infrequently used modes or travel classes.

Second, detailed level-of-service data are required for all travel modes and service classes including both line haul and access/egress service measures. These variables are especially important because they represent the policy measures that influence mode choice. The definition of intercity service variables is more complex than for urban travel because of the variety of modes and fare/service classes and the multiplicity of carriers for some modes. The required intercity data cannot be obtained from survey respondents for all of the travel service alternatives but must be provided from supplementary sources.

Despite the limitation on data availability, it is valuable to demonstrate and test the validity and usefulness of the proposed conceptual and model structure. The next sections describe the use of existing data to estimate intercity mode and fare/service class models.

Data Description

The 1977 NTS collected by the Bureau of the Census, supplemented with information from other sources, provides a resource to demonstrate and test the use of disaggregate techniques to develop behavioral intercity demand models. The NTS includes information on all trips of 100 mi or more during the 3-month period for randomly selected households in 34 metropolitan areas. Each record includes information about the trip made, the area of residence, the trip destination and characteristics of that destination, and characteristics of the trip such as purpose, timing, duration, and the means of transportation used. These data were supplemented by published level of service data for the available modes and fare classes including travel time, fare, and service frequency.

To control costs, the number of city pairs for which the level of service data were collected was limited to all city pairs with observed intercity trips with origins in one of the following seven cities: Atlanta, Baltimore, Boston, Buffalo, Chicago, Los Angeles, and Washington, D.C. The resultant data set contains intercity level-of-service information for 130 city pairs.

The data set developed is considered to be equivalent to a disaggregate data set for the purpose of developing a prototype model system. However, the level-of-service data describe city pair rather than true origin-to-destination data. Thus, it is not truly disaggregate. For this reason, the models estimated will be biased compared to a complete disaggregate model system. However, it is believed that this model system will be substantially better than any estimated exclusively with aggregate data. Thus, it is a step in the improvement of intercity travel demand models.

Model Structure and Formulation

An intercity disaggregate model is a system of interdependent submodels representing choice of trip frequency, trip destination, and travel mode and other related choices. This section describes the hierarchical structure and mathematical formulation of a specific proposed model.

Model Hierarchy

The choice structure depicted in Figure 1 describes a process in which the individual first decides whether to make an intercity trip and then how many trips to make during a given period. Next, for each intercity trip, the individual selects a destination. Then, the individual selects the transportation mode. Finally, the individual selects the fare/service class for modes with multiple classes.

Alternative model structures can be formulated to provide more detailed analysis of selected aspects of intercity travel. For example, the choice of intercity travel mode can be broken into a series of choices such as private automobile versus public carrier and a subsequent choice of a specific public carrier mode. Alternatively, the model can be simplified by, for example, combining trip frequency choice (zero or one trip in the study period) with destination choice in a single model.

The travel choices in the hierarchy are interrelated. Linkages among models are used to represent relationships among travel choices. First, each travel choice in the hierarchy is made conditional on all higher-level choices. For example, the choice of travel mode is made conditional on the selection of a specific destination city. This conditioning provides the basis for characterizing the service attributes of the mode alternatives under consideration. Second, the higher-level choice is influenced by the expected choices at lower levels

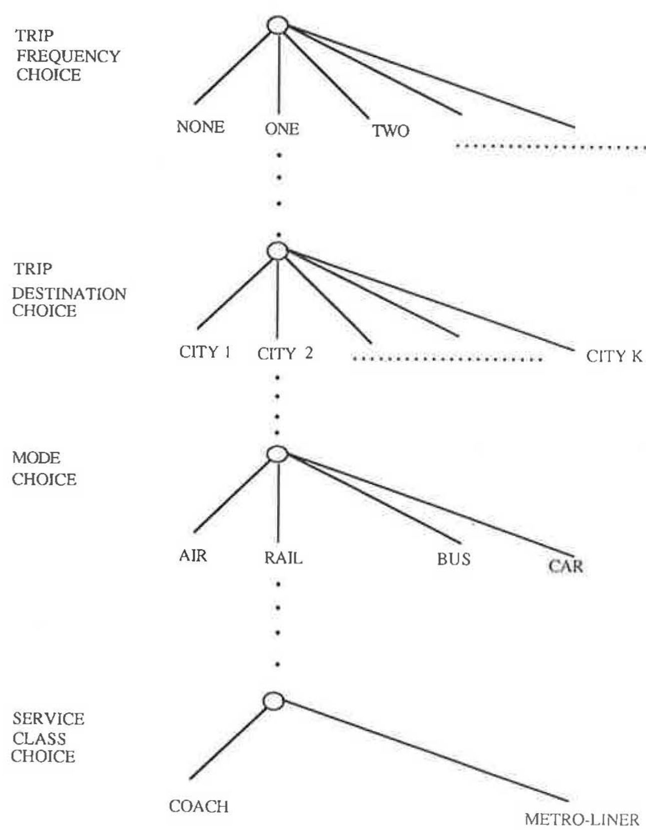

FIGURE 1 Proposed intercity disaggregate model system.

in the hierarchy. For example, the destination choice should reflect the travel service options to the destination city. However, because the mode that will be chosen is not known when the destination choice is made, the expected modal service is represented by a composite measure of the characteristics of all modes to each destination. A variety of composite measures can be formulated for this purpose (*16*). For example, the service characteristics of each mode could be weighted by the probability of being chosen. The composite service measure used in this analysis is based on specific properties of the nested logit model used in this study (*17,18*). This model is described next.

The intercity travel choice models reported in this paper are the choice of trip frequency, destination, mode, and, for air travel, fare/service class. The trip frequency is represented by a linear regression model that predicts the expected trip frequency for each traveler or potential traveler. The other choices are represented by logit models that predict the probability that each alternative in the choice set will be selected by the traveler. The logit model relates the probability of choosing an alternative, $Pr(i)$, positively to the observed utility of that alternative, V_i, and negatively to the utility of each other alternative, V_j (*19*).

The observed utility for each alternative is a function of the characteristics of the individual and the attributes of the alternative. The range of variables included can be extensive. For example, in a mode choice model, individual characteristics may include income, sex, and household automobile availability, and alternative attributes may include travel time, travel cost, and frequency of service offered by each mode. Generally, the utility function is formulated as a linear function of variables, but this is not required.

The multinomial logit model is capable of representing the choice process of an individual who is making a choice among several alternatives independent of any other choice. However, the choice process included in this study is multidimensional. That is, the individual is making choices from several choice sets (e.g., trip frequency, destination, mode, and fare class). These decisions are interrelated as discussed earlier. This interrelated choice structure can be represented by the nested multinomial logit model (*17*), which is a structured series of submodels with each submodel corresponding to one stage in the hierarchical choice process.

The formulation of the nested multinomial logit model includes a multinomial logit model at each level in the choice hierarchy. The models differ from independent multinomial logit models in two ways. First, each lower-level model is conditional on the results of the higher-level choice. Thus, the fare class choice model applies only if the air mode is chosen in the mode choice model. Second, the higher-level model includes a composite variable that represents the combined attributes of all the alternatives in the lower-level choice. Thus, the mode choice model includes a variable that represents the different fare classes for the air mode. The mathematical form of these models and the interrelationships between them are described by McFadden (*17*), Sobel (*18*), and Ben-Akiva and Lerman (*19*).

MODEL ESTIMATION RESULTS

The estimation results for intercity trip frequency, trip destination, travel mode, and fare/service class models are described in this section. The estimation of these models proceeds sequentially from the lowest- to highest-level model. The estimation results are reported and discussed in this estimation sequence.

Fare/Service Class Choice Model

The fare/service class choice model is estimated for the air mode only because the data do not provide information about a range of service classes for the other modes. Even for the air mode, the actual class chosen is not reported. However, the NTS data included information about the actual intercity travel cost. This cost was compared to fares by fare/service class to identify the chosen fare/service class.

Available fare/service classes were combined to obtain three alternatives: first, coach, and discount classes. A total of 235 trips were assigned to a fare class. This sample is too small to estimate separate fare class choice models for business and nonbusiness trips, so a single model is estimated with trip purpose included as a variable influencing choice of fare/service class.

The level of service variables included in the model are fare and daily number of departures (frequency) for each service class (not all flights included all service categories). Travel time is excluded because it is invariant over fare/service classes. The traveler's household income and trip purpose are included to account for expected differences in mode choice behavior among these groups.

The estimation results (Table 1) show that both fare and departure frequency significantly influence fare/service class choice. As expected, lower fares and increased frequency for any class increase the utility of that class.

Traveler's household income also significantly affects fare/service class choice. An increase in income leads to higher utility for first class and lower utility for discount class relative to coach class. This effect is highly significant between first class and coach class and less significant but strong between discount class and coach class.

Trip purpose is very significant in the choice between discount and coach class with business travelers being much less likely than nonbusiness travelers to take discount class. However, trip purpose has little effect on the choice between coach and first class. The probable reason for the low utility of

TABLE 1 THE FARE/SERVICE CLASS CHOICE MODEL

Variables	Parameter Estimate	(t-Statistic)
Alternative specific constants		
Discount class	−0.311	(0.6)
First class	−0.889	(1.2)
Level of service		
Fare cost ($)	−0.010	(2.7)
Daily departures	0.055	(4.1)
Income ($10,000)		
Discount class	−0.263	(1.3)
First class	0.350	(2.1)
Business trip		
Discount class	−1.605	(3.7)
First class	−0.160	(0.3)
Statistical Information		
Likelihood ratio index (ρ^2)	0.333	
Number of cases	235	

discount class to business travelers is the inability of business travelers to meet the restrictions associated with discount travel such as advanced reservation and minimum stay duration.

These estimation results demonstrate the feasibility of estimating a fare/service class choice model for intercity air travel. Good estimation results are obtained even with the small sample available for this purpose.

Mode Choice Models

The intercity travel modes considered in this study are car, air, rail, and bus. The intercity trips used in the mode choice analysis are round trips from home to one or more destinations and return home. Separate models are estimated for business and nonbusiness travel to account for the differences in these choice contexts.

All individuals in the sample were assumed to have all four modes available for each trip. All three common carrier modes were available for trips between all 130 city pairs included in the analysis. The data set did not include information about the car ownership of the household, and it was assumed that a car was available for all trips.

The variables considered for inclusion in this model and the rationale for their inclusion are as follows:

- Level of service variables (travel time, travel cost, and number of daily departures) represent the basic service characteristics for the alternatives.
- Composite utility of air fare/service classes reflects the combined attributes (cost and daily departures) of the three air fare/service classes (inclusion of this variable tests the effect of air fare/service class choice on mode choice). Composite utility of air classes is a monotonically increasing function of the utility of each fare/service class.
- Distance between city pairs reflects the empirically observed change in mode shares from bus, car, and rail to air as distance increases.
- Household income reflects a generally observed shift to higher-cost/higher-service alternatives with increasing income.

Collinearity problems between travel time and travel cost make it difficult to obtain significant estimates for both variables in these models. Estimation of models with only travel cost or travel time obtained significant estimates for these variables. Also, the estimation results for models with cost indicated that travel time for high-income travelers (more than $20,000 per year in 1977) is valued much more highly than travel time for lower-income travelers. The problem of collinearity is resolved by constraining the ratios between travel time and travel cost parameters based on judgmentally selected values of time of $60 and $20/hr for high- and low-income business travelers, respectively, and $45 and $15/hr for high- and low-income nonbusiness travelers.

The estimation results are reported in Table 2 for both business and nonbusiness mode choice. The overall statistical fit is good for both models. The cost and time variables (estimated jointly) are highly significant. The bus/rail frequency variable has the correct sign and is marginally significant in the nonbusiness model. This variable could not be estimated satisfactorily in the business model because of the small number of business travelers who chose bus or rail in this data set.

The fare class composite utility variable has the correct sign, indicating that an improvement in service characteristics of any fare/service class will lead to an increase in air mode utility. This parameter is significant in the nonbusiness model

TABLE 2 MODE CHOICE MODEL FOR BUSINESS AND NONBUSINESS TRIPS PARAMETER ESTIMATE (*t*-STATISTIC)

Variables	Business Trips		Nonbusiness Trips	
Alternative constants				
Car	−0.883	(1.5)	1.687	(4.0)
Bus	−1.703	(2.2)	0.386	(0.6)
Rail	−2.227	(2.8)	0.136	(0.2)
Level of service				
Cost ($)	−0.00460	(3.0)[a]	−0.00256	(3.8)[a]
Travel time (minutes) (high income)	−0.00460	(3.0)[a]	−0.00193	(3.8)[a]
Travel time (minutes) (low income)	−0.00153	(3.0)[a]	−0.00064	(3.8)[a]
Bus/rail frequency			0.0399	(1.9)
Composite air class utility	0.324	(1.5)	0.456	(4.0)
Income ($10,000)				
Car	−0.0865	(0.4)	0.046	(0.3)
Bus and rail	0.354	(1.3)	−0.4910	(2.4)
Distance less than 250 mi				
Car	2.263	(4.3)	1.703	(3.8)
Bus and rail	1.994	(2.9)	0.857	(1.5)
Distance greater than 500 mi				
Car			1.796	(3.5)
Bus and rail			−0.816	(1.3)
Statistical Measures				
Likelihood ratio index (ρ^2)				
Equal shares base	0.623		0.465	
Number of cases	251		356	

[a]Cost and time parameters estimated jointly with value of time equal to $60 and $20/hr for high- and low-income business travelers, respectively, and $45 and $15/hr for high- and low-income nonbusiness travelers, respectively.

but not significant in the business trip model. It is likely that this variable would be significant in both models if the model were estimated with a larger sample. The inclusion of this variable is important because it provides a linkage with the fare/service class model.

The income variables are excluded from the business models because of poor estimation results. The effect of income in this model is through the use of income-segmented travel time parameters. The income variables in the nonbusiness model indicate little influence of income on car versus air choice but a strong negative effect on the use of bus and rail.

The distance variables indicate that the likelihood of choosing surface modes (car, bus, or rail) relative to air decreases substantially with increasing distances.

These results demonstrate the feasibility of estimating nested multinomial logit mode choice models with existing data and including the composite utility from the lower-level air mode fare/service class model.

The differences between the business and nonbusiness models reflect reasonable differences in the travel behavior for business and nonbusiness travel.

Destination Choice Models

Destination choice models for business and nonbusiness travel are estimated for a reduced set of destinations to place some limit on the requirements for gathering intercity travel service data. The data set used in this process consists of trips originating at one of seven locations, with the destination choice set including the chosen destination and four additional destinations selected randomly from the set of nonchosen destinations for which level of service data were collected. This sampling approach will produce consistent estimators for logit choice models under a wide variety of conditions (*17*).

The variables considered for the destination choice models are the city characteristics (e.g., population and recreation/cultural indices), the distance between the origin city and the destination, and the composite utility variable from the mode choice models. Further, in order to take some account of the variation in geographic destination attractiveness other than that included in the city characteristics, a set of alternative specific constants was formulated by grouping cities by geographic area.

Models were estimated for both business and nonbusiness trips because of the expectation that different city characteristics would be important for business and nonbusiness travel. Both models include the geographic destination constants, variables describing city characteristics, distance, and the composite mode utility variable from the respective mode choice model.

The destination models for business and nonbusiness trips (Table 3) show that the accessibility of the destination, represented by both the distance to the destination city and the composite mode utility variable, significantly affects destination choice. As expected, the higher the accessibility, the higher the probability that a destination will be selected. These two variables are collinear, which may explain the difference in estimation significance of the individual variables between the two models.

The attractiveness of the destination is reflected by population size and indices of museum (cultural) and other recreational resources. The larger the destination standard metropolitan statistical area, the higher the probability that this destination will be selected for business travel and the lower the probability for nonbusiness travel, all other things being equal. Taken together, the estimation results for these three variables support the conclusion that city size is an important determinant of destination choice for business travel, and other attraction indices are important for nonbusiness travel.

The geographic constants are positive and mostly significant for all areas relative to New York for business travel and

TABLE 3 DESTINATION CHOICE MODELS FOR BUSINESS AND NONBUSINESS TRIPS PARAMETER ESTIMATES (*t*-STATISTICS)

Variable	Business Trips		Nonbusiness Trips	
Regional Constants[a]				
Washington	2.040	(3.7)	−0.726	(1.4)
Northeast	1.046	(1.6)	−0.866	(1.7)
California	2.006	(3.3)	0.605	(1.4)
Southeast	2.835	(3.7)	0.081	(0.1)
Carolina & Virginia	2.867	(3.8)	−0.633	(1.1)
Midwest	1.145	(2.0)	−0.728	(1.6)
Ohio	1.936	(2.8)	−0.710	(1.3)
Texas, Arizona, Oklahoma	2.167	(2.7)	0.451	(0.7)
Denver and Omaha	2.128	(3.0)	−0.865	(1.4)
Florida	1.745	(2.0)	1.295	(2.2)
Pennsylvania	1.288	(2.0)	0.339	(0.7)
Las Vegas	2.800	(2.5)	−0.103	(0.1)
Northwest	1.776	(1.6)	1.062	(1.9)
Other Variables				
Distance (1,000 mi)	−0.988	(3.9)	−0.0717	(0.3)
Log of destination population in thousands	0.770	(2.5)	−0.2729	(1.3)
Museum index at destination	0.000143	(1.3)	0.000187	(2.3)
Recreation index at destination	0.000491	(0.9)	0.000660	(1.9)
Log sum of business mode choice	0.4233	(1.8)	0.5655	(5.4)
Statistical Measures				
Likelihood ratio index	0.256		0.313	
Number of cases	253		355	

[a]New York City is base alternative.

generally nonsignificant for nonbusiness travel with the exception of Florida and Las Vegas.

The most important result of these models with respect to the model structure put forth in this study is that the parameters for composite utility for the intercity travel modes are consistent with the proposed hierarchical structure.

Trip Generation Models

The trip generation models differ from the other models in two important ways. First, a linear regression approach is used because the formulation of a choice model for frequency choice is somewhat cumbersome. Second, the composite variable that would represent the service characteristics to destinations by the available modes is excluded because the sampling structure of the data will introduce bias in the estimation of the parameter for this variable.

Thus, the estimated trip generation models do not include any level of service measure but do include variables describing the household. These are household income, size, and structure and the age, occupation, and employment type for the head of household. Constants were tested to identify differences among origin (residence) cities. These constants, which represent the average effect of all the factors that influence the amount of intercity travel but which are not included in the model, were not significant. This suggests that the average rate of intercity trip making is not significantly affected by the variations in service among the residence cities (Atlanta, Baltimore, Boston, Buffalo, Chicago, Los Angeles, and Washington, D.C.) considered in this study.

The estimation results for business and nonbusiness trip generation (Table 4) identify household income as having a strong positive and almost equal effect on both business and nonbusiness travel. Other variables tend to be more important for either business or nonbusiness travel.

Business trip making, undertaken to serve the needs of the firm, is affected by occupation (professionals, managers, and sales people travel more than others) and type of organization (government employees and self-employed persons travel less than others).

Nonbusiness trip making, undertaken to serve the needs of the household and its members, is affected by individual and household characteristics. Interestingly, the occupation of the household head is a significant determinant of trip making, with households headed by professionals and managers making more nonbusiness trips than others.

The estimation results for the trip generation model show that intercity trip frequency is heavily influenced by the characteristics of the individual and the household. However, a large fraction of the variation in intercity trip frequency is not explained by these models. It is supposed that level of service differences are responsible for some of this variation.

Summary of Model Estimation Results

Overall, the model estimation results are consistent with the choice behavioral conceptualization proposed and the corresponding model structure. The hierarchical choice structure is supported by the estimation results for the composite variables in both the mode and destination choice models.

TABLE 4 TRIP GENERATION MODEL FOR INTERCITY TRIPS

Variable	Business Travel	Non-Business Travel
	Parameter Estimate (t-statistic)	Parameter Estimate (t-statistic)
Household Income ($000)	0.054 (7.2)	0.067 (7.4)
Household Structure		
Non-married, no children		1.280 (3.7)
Non-married, children		0.426 (1.3)
Married, no children		0.653 (2.1)
Household Size Measures		
Number of Persons		0.590 (7.0)
Number of Children (5 to 18 years)		-0.351 (4.3)
Number of Babies (less than 5 years)		-0.743 (5.1)
Age of Household Head	-0.008 (1.6)	-0.024 (4.1)
Occupation of Household Head		
Professional	1.536 (6.2)	1.057 (4.0)
Manager	2.446 (8.7)	1.240 (4.0)
Salesman	2.518 (6.3)	
Employment Type of Household Head		
Self Employed	-0.530 (1.4)	
Government Employed	-0.714 (3.0)	
Constant	-0.079 (0.3)	0.868 (1.7)
Goodness of Fit Measures		
R^2	.130	.144
F	42.4	33.4
Sample Size	1998	1998

The importance of cost, travel time, and frequency of service in fare class and mode choice is supported by the significance of the corresponding parameters. The importance of specific demographic variables is also supported by the estimation results. Income influences class choice, mode choice for nonbusiness trips, and trip frequency. Other demographic characteristics affect overall trip making in reasonable ways. Finally, trip characteristics have an important impact on travel choices. Most important among these is trip purpose.

These estimation results are obtained despite the use of data that do not include precise origin and destination locations and thus exclude access travel times and costs, rely on travel service data obtained from published schedules rather than actual performance, and are based on a relatively small sample. It is concluded that implementation of this analysis approach with a true disaggregate sample is likely to produce results that are substantially better than those reported here.

SUMMARY AND CONCLUSION

Some of the issues associated with developing a behaviorally based disaggregate modeling approach for intercity travel are presented in this paper, and a hierarchical conceptual model for intercity travel choices is proposed. This approach can represent more accurately the decision-making process of the behavioral unit, which is the individual and his or her household.

A disaggregate type data base was developed from the 1977 NTS and used to estimate a hierarchically structured model of trip generation, destination choice, mode choice, and air fare/service class choice.

Overall, the estimation results support the conceptual structure and the corresponding model structure described in this paper. We conclude that the conceptual structure and the derived models reasonably represent the intercity travel demand relationships. Nonetheless, there are a number of deficiencies in the estimation results that can be attributed to the limitation of the data set used in this study. It appears that collection of data specifically for estimation of a system of disaggregate intercity travel models is likely to provide a basis for development of a model system that is behaviorally consistent and has a high degree of predictive accuracy.

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