National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 94 - AUGUST 1977

Disaggregate Travel Demand Models

An NCHRP staff digest of the essential findings from the interim report (Phase I) on NCHRP Project 8-13, conducted by Charles River Associates, Inc., Cambridge, Mass. The Principal Investigator is William B. Tye.*

THE PROBLEM AND ITS SOLUTION

The urban transportation planning process, as it has developed over the past two decades, is characterized by the creation of long-range systems plans based on simulations of regional travel patterns using models developed and calibrated with aggregate zonal data. Three of the basic criticisms that have been made of the regional simulation and planning process have been that the presently used aggregate models cannot be readily used for subregional and project planning; they are not responsive to the policy issues that planners are being asked to address; and they require expensive, large travel surveys for model calibration.

Research has been successful in meeting the objectives of Phase I by developing policy-sensitive travel demand forecasting models consistent with travel choice theory using data at the level of individual travelers. Such models are termed disaggregate models and were found to advance the existing state-of-the-art in explaining present travel behavior. They can be used by the practicing planner to predict likely changes in travel behavior in response to actions such as reduced transit fares, increased gasoline prices, increased driving times, and the introduction or new transportation modes.

The research confirmed other existing evidence that disaggregate models can be applied with greater ease than aggregate models to corridor and project planning within urban areas. Furthermore, confirmation was obtained on the need for fewer data to determine model coefficients. On the other hand, evidence to support model transferability from one urban area to another was inconclusive.

* In addition to loan copies of the interim report, a limited number of copies are available for purchase as noted at the end of this digest.

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

Experience in applying disaggregate models to metropolitan-wide forecasts has been limited. Most applications have involved mode-split only. New planning tools must be developed for aggregate forecasts. For example, application of disaggregate models may call for aggregation of disaggregate model output to describe the behavior of heterogeneous groups.

The research findings have shown practitioners should be aware of certain pitfalls in the application of aggregate and disaggregate models. The alternative choices for any given transportation decision can be different for different population segments. Another pitfall is the violation of an assumption inherent to the multinomial logit model (and most aggregate choice models) termed the "independence of irrelevant alternatives." These pitfalls point to the need of having qualified persons using disaggregate models. The disaggregate approach is not yet a formula or standardized approach, although standardized methodology to meet the needs of routine problems is the future goal. No single specification of a disaggregate model should be expected to apply to all situations.

Research is continuing and will eventually involve the structuring of models utilizing a new disaggregate data base being assembled by Charles River Associates, Inc., in Baltimore for the U.S. Department of Transportation.

FINDINGS

This study has developed new disaggregate demand models for work-trip mode choice and for shopping choices as follows: mode, destination, frequency, and time of day. Specific findings related to these models are as follows:

1. The most promising application areas for disaggregate models are forecasting the demand for new modes, analyzing the effects of transit fare changes and service improvements, determining the effects of alternative air quality controls and energy conservation policies, evaluating the impact of transit engineering improvements and toll policies on the use of roads, and evaluating other low-capital policy alternatives.

2. Disaggregate travel demand models offer considerable advantages over traditional models in applications discussed above because of reduced data costs, flexibility to meet different problem needs and response times, and potential for improved transferability of model estimation results from one geographic area to another.

3. The empirical results have reinforced several travel demand theories, including the greater importance of access travel time relative to in-vehicle travel time as a determinant of mode choice, the greater sensitivity of travel choice to changes in travel time than to changes in travel cost, and the relatively higher automobile preference (other conditions being equal) manifested by high-income travelers.

4. Disaggregate demand analysis shows that moderate changes in the travel environment are not likely to affect the travel decisions of most individuals.

5. Segmenting the travel market into market groups with similar tastes and socioeconomic attributes has potential to improve forecasting with the multinomial logit model, a common disaggregate demand model specification. The response of population segments having different incomes to changes in the travel environment differ significantly, and disaggregate approaches are a technique to account for those differences.

6. The application of disaggregate demand models to explain choice of mode for work trips has proven highly successful. Several different functional forms have been estimated during this project using disaggregate data from both Pittsburgh and the twin cities of Minneapolis/St. Paul. The results have been encouraging in terms of expanding the set of explanatory factors, such as autos per worker and autos per licensed driver. These have been shown to influence mode choice behavior and help to explain more of the data variation. Estimation results for the Pittsburgh data are summarized in Eq.1, a multinomial logit model:

$$\ln \frac{P(\text{auto})}{P(\text{transit})} = -5.72 + 1.38\ \text{HINC} + 4.07\ \text{APERW} - 0.117\ \text{OVTT}$$

$$-0.0348\ \text{INVTT} - 9.06\ \text{C/INC} \qquad (1)$$

where

P(auto)	=	probability of choosing auto;
P(transit)	=	probability of choosing transit;
HINC	=	1 if household income exceeds $7,000/year (1967); 0 otherwise (alternative specific variable entered in the auto utility function);
APERW	=	autos per worker (alternative specific variable entered in the auto utility function);
OVTT	=	difference (auto minus transit) in out-of-vehicle travel time (in minutes);
INVTT	=	difference (auto minus transit) in in-vehicle travel time (in minutes);
C/INC	=	difference (auto minus transit) in cost in dollars divided by income code (see Table 1 for appropriate code).

7. Disaggregate demand models can be used to model discretionary shopping trips. These models can explain the effects of policy changes on the full dimension of shopping trip choices; i.e. mode, destination, frequency, and time of day. A new specification of a disaggregate model of shopping travel featuring additional expenditure variables and a revised functional form has been successfully estimated using a multinomial logit model. Estimation results for mode choice, destination choice, and frequency choice are summarized in Eqs. 2, 3, and 4, respectively. However, continued conceptual development is required to explain the complex situation of travel tours made up of linked trips.

$$\ln \frac{P(\text{auto})}{P(\text{transit})} = -6.63 + 2.16\ \text{HINC} + 2.03\ \text{APERDR}$$

$$-0.34\ \text{OVTT} - 0.04\ \text{INVTT} - 13.50\ \text{C/INC} \qquad (2)$$

where

HINC	=	1 if household income exceeds $7,000/year (1967); 0 otherwise;
APERDR	=	autos per licensed driver; and all other variables are as previously described.

TABLE 1

INCOME CODES USED IN MODELS ESTIMATED

WITH THE PITTSBURGH DATA BASE

Work Trips, Equation 1		Shopping Trips, Equation 2	
Code	Household Income Range**	Code*	Household Income Range**
1	< $3,000	1.5	< $3,000
2	$3,000 - $4,999	4.0	$3,000 - $4,999
3	$5,000 - $6,999	6.0	$5,000 - $6,999
4	$7,000 - $9,999	8.0	$7,000 - $8,999
5	$10,000 - $14,999	9.5	$9,000 - $9,999
6	$15,000 - $19,999	12.5	$10,000 - $14,999
7	$20,000 - $24,999	17.5	$15,000 - $19,999
8	$25,000 - $29,999	22.5	$20,000 - $24,999
9	$30,000 or more	27.5	$25,000 - $29,999
		35.0	$30,000 or more

* The midpoint of the corresponding income range.

** 1967 dollars

$$\ln \frac{P\ (\text{dest } j)}{P\ (\text{dest } j)} = 1.06\ (\tilde{p}_i - \tilde{p}_j) + 0.54\ (\text{EMP}_i - \text{EMP}_j) \qquad (3)$$

where

P(dest i) = probability of choosing destination i;
P(dest j) = probability of choosing destination j;
EMP_i = fraction of regional retail employment at destination i; and
$\tilde{P}_i$ = inclusive price of travel to destination i.

$$\tilde{p}_i = \ln \sum_{m=1}^{M} e^{V_{mi}}$$

V_{mi} = utility function associated with travel to destination i by mode m (see explanation beginning page C151 of the interim report)

M = total number of modes

$$\ln \frac{P(\text{freq.} = 1)}{P(\text{freq.} = 0)} = 0.14\ \tilde{p}_f + 0.071\ \text{INC} + 0.77\ \text{DMW} \qquad (4)$$

where

$\tilde{p}_f$ = inclusive price of travel for frequency = 1
INC = household income code (see Table 1)
DMW = number of licensed drivers minus number of workers in the household

8. Two basic types of variables - level of service attributes of transportation choices and individual or household level socioeconomic characteristics - should be included in disaggregate travel demand models. Empirical research on this project has corroborated previous findings that travelers place different emphasis on the individual components of level of service (walk-access time, wait time, vehicle time, transfer time, and out-of-pocket costs). The precise specifications of explanatory variables should be tailored to the transportation problem being analyzed. For example, travel time variability, a measure of the reliability of service, may prove to be a significant factor in choosing a dial-a-ride mode but less important in choosing between the automobile and conventional transit.

Several measures of socioeconomic status have entered significantly in the disaggregate demand models estimated during this project (e.g., income, household size, sex, age). Addition of an expanded range of socioeconomic variables is highly dependent on the ability of the analyst to predict these variables for a forecasting problem.

9. To the extent that travel choice differs between different trip purposes, separate demand models should be developed and applied in urban transportation policy analysis. Theoretical considerations suggest that traditional trip purpose stratifications employed in disaggregate demand model analysis of home-based work, home-based other, and non home-based trips may not be adequate. Non home-based trips do not represent a unique trip purpose, but rather a collection of different trip purposes (e.g., social, shopping, personal business). Similarly, home-based other trips

encompass several different trip purposes. Demand analysis on trip purpose classified in this manner may mask significant behavioral differences associated with trip types classified by other means. Even within a single trip purpose category (e.g., shopping), behavior may differ depending on the nature of the goods being purchased. Currently available data do not permit a rigorous empirical test of differences in travel behavior by trip purpose.

10. Although empirical research to provide statistically reliable demand models using currently available data has been highly encouraging, significant improvements to state-of-the-art modeling can be achieved with the collection of additional data. Recommendations to guide future disaggregate data collection efforts have been prepared as part of this project. In summary, the recommendations stressed the importance of improving the quality of the level of service data, improving the techniques employed to determine feasible choices for specific population segments, improving the definition of trip purpose categories and mode alternatives, and improving sampling procedures to ensure a diversity of travel choice data. Identifying the relevant choices (e.g., the choices of mode and destinations actually available to a traveler is important in both model estimation and application. In model estimation, an incorrect specification of the relevant choices in the estimation sample could yield biased coefficients. This problem is particularly evident in destination choice modeling.

11. An extensive analysis of the independence of irrelevant alternatives (IIA) property of some disaggregate models, specifically the multinomial logit model of travel demand, has been conducted. The IIA property states that if (for example) two modes are available and a new mode is introduced, the ratio of the probabilities of choosing the two old modes will be unchanged regardless of the probability of choice for the new mode. The conclusions are:

(a) The independence of irrelevant alternatives property is not an inherent drawback to disaggregate demand modeling and is not presently an impediment to implementation of disaggregate demand models.

(b) The IIA assumption may be reasonable or unreasonable, depending on the circumstances of the particular application. Therefore, diagnostic tests to determine whether the assumption is valid in a particular application have been designed as part of this study.

(c) When the IIA assumption is unreasonable, the multinomial logit model cannot be applied without error. The error may be large or small, depending on the circumstances.

(d) If the IIA Assumption is invalid, corrective measures to take the dependence into account have been identified as part of this study.

APPLICATIONS

Benefits of disaggregate models occurr through (a) their use in evaluating public policy alternatives, (b) their economy in data collection costs, (c) their flexibility to be tailored to the geographical area of concern, and (d) their flexibility to meet decision-maker's needs. The report gives hypothetical examples to illustrate how disaggregate models can be used to forecast the effects on travel of changes in the price of gasoline, of a reduction in off-peak transit fare, of an increase in driving time to the downtown, and of change to the transportation modes available to individuals (such as a new mode). The report also reviews the results of an actual case study in Los Angeles where disaggregate models have been applied.

The two-volume report is available for purchase at a cost of $6.00. Postage is additional if first-class mailing is desired. Copies may be ordered from:

Program Director
National Cooperative Highway Research Program
National Research Council
2101 Constitution Avenue
Washington, D.C. 20418

TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 42970

000015M001
JAMES W HILL

IDAHO TRANS DEPT DIV OF HWYS
P O BOX 7129
BOISE ID 83707