transpor tation service to the facilitation of all public transportation options. The role of the RTA should be shifted from an entrepreneurial one of preserving the bus agency to a mission-oriented one of serving various public transportation needs. Until the RTA boards and executives recognize the difference between the entrepreneurial role of preserving specific transportation service and the public mission to solve a specific problem, it will be difficult to implement alternative solutions. To implement a mission-oriented approach, there is need to separate the rules, liability, funding, and guidelines that apply to the entrepreneurial operation of the traditional services and the promotion and procurement of alternative services. For example, if a transit authority finds it more cost effective to promote carpooling than to add additional buses into low-density suburbs, the carpool efforts should not extend the common-carrier liability standards. Section 13(c) labor protections, public hearings over route and fare changes, and non-competitive requirements to cover all carpools that develop.

Tax Issues

The IRS should resolve the tax issues and decide whether ridesharing is a business. The goal of ridesharing is to accomplish public goals through the cooperative effort of individuals (employers, employees, public officials, administrators, neighbors, friends, schoolmates, and other groups) who voluntarily decide to ride together. By making some vans tax-deductible and others highly taxed and by being unable to define when a vanpool is a business and thus which laws are applicable, the tax machinery is a strong force to artificially structure the form vanpools take.

Currently, transmissions are under way to subsidize employers to assume a large legal responsibility for their employees' transportation to work or to support transit authorities to do something they are ill-equipped to do, whereas individuals who can easily do it are discouraged by the uncertainty of liability and tax issues.

Federal tax law should recognize the following points:

1. Ridesharing is a cooperative area of activity and not subject to the traditional business or personal accounting and tax principles.
2. Employer efforts to promote ridesharing are a public service activity and should not necessarily be limited to employees only. For example, the investment tax credit should apply regardless of whether the pools include nonemployees, because this restriction encourages the destruction of pools involving neighbors or spouses who may work for nearby employers.
3. Individual pools are cooperative efforts and should have well-defined accounting and tax procedures without reference to whether or not the driver considers it to be a business.

Federal and state legislatures should explicitly recognize that it is in the national interest for government to permit individual citizens to cooperatively resolve their own transportation problems at their own expense and that these solutions should not be restricted to promote government-subsidized solutions, such as mass transit, the National Railroad Passenger Corporation (Amtrak), rail commuter services, subsidized intercity bus runs, or employment programs for drivers under the Comprehensive Employment and Training Act.

SUMMARY

Government seldom faces such a logical, inexpensive, and acceptable solution to a major national problem. Unfortunately, both state and federal government must make major legal and policy changes if the full potential of the ridesharing solution is to be realized. This paper has attempted to illustrate how government has unintentionally inhibited ridesharing by first making it illegal and then, after it was legalized, by applying archaic, inappropriate legal structures that did not recognize its cooperative, public service orientation. Seldom has government been faced with such a productive, low-cost situation requiring such a redirection in regulatory, tax, liability, insurance, and funding philosophy.

Demand Analysis for Ridesharing: State-of-the-Art Review

LIDIA P. KOSTYMIUK

The methods that are currently used to estimate demand for ridesharing for the work trip are reviewed. These techniques are categorized by the basic approach used, and models within each category are described, reviewed, and summarized. The first category consists of those techniques developed from the perspective of the formation of ridesharing units and includes the assessment of areawide ridesharing potential by estimation of possible matches and the identification of characteristics of the population that shares rides. The second category includes the techniques that view ridesharing as an individual household travel decision simulations. The third category includes those models concerned with estimating changes in ridership by various modes, including ridesharing, that result from the implementation of high-vehicle-occupancy treatments. These models consider demand and supply effects to obtain equilibrium traffic flows.

Ridesharing, the transportation of persons in a motor vehicle where such transportation is incidental to the purpose of the driver, did not generate much interest on the part of transportation analysts prior to 1973-1974. Until then, traditional transportation demand methodology developed in the 1950s and 1960s did not directly concern itself with ridesharing, and the sharing of rides entered into the planning process only through the automobile occupancy model. The objective of the automobile occupancy model was to convert person trips into vehicle trips for the purpose of planning highway facilities. Although the possibility of affecting vehicle occupancy by deliberate public policy did occur to planners in the 1960s, it ap-
peared at that time to be beyond the realm of practicality [1].

The energy crisis of 1974 and the subsequent concern with transportation system management (TSM) called for transportation-planning techniques, which included ridesharing specifically. Those responsible for contingency planning wanted to know how much of the urban travel could be diverted to ridesharing in times of emergency. Those responsible for TSM wanted to know the impacts of strategies to increase automobile occupancy. Employers and other agencies considering ridesharing programs wanted to know what results to expect from their promotional and organizational efforts. These needs led to the development of techniques for estimating demand for ridesharing and also generated basic research into the motivation for ridesharing behavior and its effects on the overall travel patterns. Thus, a growing body of knowledge is becoming available for ridesharing applications.

Ridesharing includes the arrangements of carpooling, vanpooling, and buspooling. The obvious difference among these is the type of vehicle used. Carpools use private automobiles and although privately owned vehicles are used in some vanpools and buspools, such vehicles are usually supplied by employers, third-party providers, or transit companies. The number of persons in each arrangement is obviously a function of the capacity of the vehicle. In all cases the routes followed by the vehicles are tailored to the convenience of the rider group and can be modified to reflect rider needs. Collection and distribution arrangements also vary; a common collection point is popular for large groups. Payment arrangements range from no monetary exchange in shared driving arrangements to payments by pool members to the driver and, in some employer-organized vanpools, through payroll deduction. Since most of the ridesharing promotional efforts have concentrated to encourage the solo driver to change to ridesharing during the work trip, most research on ridesharing behavior and forecasting techniques has also been concerned with the work trip.

Ridesharing, and therefore demand estimation for ridesharing, can be considered from several approaches. One approach is consideration of the group who will travel together in a common vehicle. Of interest here is the process of formation of the group as well as the conditions for its existence as a unit. Another way of viewing ridesharing is in the context of household travel decisionmaking and under what circumstances ridesharing is an option for households. Still another way to look at ridesharing is from its influences on the movement of traffic in an urban area, especially on the capacity and level of service of traffic corridors.

Although this categorization of approaches is not unique, most ridesharing demand estimation methods can be broadly classified under one of these three approaches. This paper reviews the methods currently used to estimate demand for ridesharing. The techniques are categorized by the basic approach used, and the models within each category are described and reviewed.

Ridesharing Unit Formation

The first approach is based on the ridesharing unit formation process and stems from the concern of identifying and matching people into such units. A set of conditions necessary for the formation of a ridesharing unit requires that

1. The origins and destinations of the trips of the potential pool members be spaced in such a way that the travel between them is acceptable to all the potential pool members,
2. The time interval in which the trip occurs be acceptable to all potential members of the pool,
3. The potential ridersharees be aware of each other,
4. There be sufficient incentive (economic, social, etc.) to travel together, and
5. The group be adequately compatible so that the ridesharing arrangement will be maintained over a period of time.

Consideration of ridesharing group formation leads to the issues of the target population, the matching process, and the characteristics of the resulting ridesharing units. The types of ridesharing estimation techniques that come from the consideration of the formation process are the ridesharing-potential models and the technique of identifying characteristics of users and potential users and applying these in an expansion process to the population under consideration.

Models of Ridesharing Potential

The objective of these models is to estimate the ridesharing potential of an area. There are two categories of these models—the maximum-potential models and the economic-incentive-potential models. The objective of the maximum-potential model is to give a practical upper limit of the ridesharing potential of an area. Results from such a model would be used to plan for emergencies and crises such as energy shortages or transit strikes in large cities and can also be used as a reference for evaluation of ridesharing programs. The economic-incentive-potential models, on the other hand, give estimates that could be used for planning long-term ridesharing programs.

An early maximum-potential model was developed by Kendall [2] and was used to estimate the carpooling potential of the eastern Massachusetts metropolitan area.

The model matched origins and destinations in zones with origins and destinations of which had been established a priori. An assumed maximum allowable time interval in terms of inconvenience to commuters was also set a priori. Thus, all workers with common origins and destinations who depart the zones within the same time interval were candidates for carpooling. The need for the car during the day as well as the concept that a portion of the population does not travel to work during the peak periods were included as adjustment factors in the model. There was no consideration of economic incentives, user preferences, or the compatibility of the ridesharees.

By using trip tables developed from a 1963 home interview survey and matching time intervals of 30 min and average origin and destination sectors of 1 mile each, the ridesharing potential was estimated to be approximately 60 percent of the morning commuter trips.

Another type of maximum-potential estimation was carried out by Lee and Glover [3] using 1976 Michigan driver data. It was assumed that the maximum potential for ridesharing was reached when the automobile occupancy for all trips more than 10 min long commencing between 6:00-9:00 a.m. and 3:00-7:00 p.m. was at least three persons. Considering only trips in the Standard Metropolitan Statistical Areas in Michigan, they calculated that this level of ridesharing would result in an annual 10 percent reduction in gasoline consumption. Although Lee and Glover did not estimate ridesharing potential directly, Cheslow, in a comparison of the two potential models [3], reports that when their analysis is
Identification Method (SAIM), which can be used to calculate the areawide demand for ridesharing. Aggregate origin-destination data are used in a simple algorithm that compares the travel costs and travel times of each of the trips by carpool or vanpool with travel costs and travel times of driving alone. The objective of SAIM is to identify those trip patterns that would be best served by each of these modal alternatives. The output of SAIM gives maps of the service areas for each mode, summary tables of regional information on number of users, trip lengths, etc., and zone-by-zone listings for both origin and destination of total trips and number of trips that can be considered to potentially use the mode considered.

The potential models with economic incentives differ from the maximum-potential models in that they are intended for more than just contingency planning and are designed to explore ridesharing potential under different conditions that affect the cost and travel time of the work trip. The SAIM model is intended as a complete planning tool for ridesharing. Examining this model for the general necessary conditions for formation of a ridesharing unit shows that the model addresses the spatial requirements, i.e., the adequate clustering of trip origins and destinations that are adequately clustered, so that the cost of pooling, considering the users' value of time, is less than the cost of driving alone.

The compatibility of the poolers is not addressed. The model is, however, useful for identifying areas of ridesharing potential where ridesharing matching and promotional programs could be attempted.

Identification of Ridesharers

The existence and knowledge of a set of characteristics of ridesharers and potential ridesharing programs would be extremely useful in identifying incentives for ridesharing and in organizing and coordinating ridesharing programs. The knowledge of the distribution of the characteristics of potential ridesharers and the levels of incentives at which they respond could be an estimation technique in itself or could be used for market-segment identification for other estimation procedures.

Attempts to identify a simple set of sociodemographic characteristics of ridesharers have generally been unsuccessful. Income does not appear to be a discriminating factor. Table 1 shows some of the results of sociodemographic comparison of ridesharers and solo drivers from several studies. No clear-cut differences in sociodemographic characteristics are immediately obvious. There is agreement in the literature that any existing relationships between demographic and work-trip ridesharing behavior are very weak.

Attempts to identify a simple set of sociodemographic characteristics of ridesharers and solo drivers have been found to be significant in a number of studies. There is general agreement (8, 9, 11, 16, 17) that those who rideshare to work tend to have longer commuting times and distances than the rest of the population. This is supported by an investigation of the relationship of travel costs and sociodemographic factors carried out at the New York State Department of Transportation (NYSDOT) (18) in which it was found that the best discriminator between ridesharers and solo drivers was the distance to work and travel time. Household size and licensed drivers per household were the only demo-

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Table 1. Sociodemographic characteristics of ridesharers.

<table>
<thead>
<tr>
<th>Source</th>
<th>Year Data Collected</th>
<th>Place</th>
<th>Sample</th>
<th>Age</th>
<th>Income</th>
<th>Auto-mobile Availability</th>
<th>Workers per Household</th>
<th>Marital Status</th>
<th>Occupation</th>
<th>Household Size</th>
<th>Licensed Drivers per Household</th>
<th>Salary Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voorhees (16)</td>
<td>1972</td>
<td>Los Angeles, CA</td>
<td>1896 free way drivers</td>
<td>Younger</td>
<td>Slightly lower</td>
<td>Low</td>
<td>Male</td>
<td>Female</td>
<td>Professional</td>
<td>Manage-rial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kendall (2)</td>
<td>1973-1974</td>
<td>United States</td>
<td>2084 automobile commuters</td>
<td>Lower</td>
<td>Lower</td>
<td>Low</td>
<td>Male</td>
<td>Female</td>
<td>Professional</td>
<td>Manage-rial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heaton (8)</td>
<td>1974</td>
<td>Boston, MA</td>
<td>1293 participants</td>
<td>Higher</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
<td>Male</td>
<td>Professional</td>
<td>Manage-rial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davis [12]</td>
<td>1975</td>
<td>Knoxville, TN</td>
<td>Commuters</td>
<td>Yes</td>
<td>Yes</td>
<td>Male</td>
<td>Yes</td>
<td>Married</td>
<td>Yes</td>
<td>Large</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pless, Mitchell, and Co. and Market Facts (17)</td>
<td>1977</td>
<td>Chicago, IL, Pittsburgh, PA, Sacramento, CA</td>
<td>100 in each of 3 concentric rings in each city</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Horenwitz and Sheth (9)</td>
<td>1977</td>
<td>Washington, DC</td>
<td>822 commuters to 43 large firms</td>
<td>Older</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
</tr>
<tr>
<td>Margolin and Misch (11)</td>
<td>1977</td>
<td>Los Angeles, CA</td>
<td>899 central-business-district commuters</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Dobson and Tucker (14)</td>
<td>1977</td>
<td>Los Angeles, CA</td>
<td>899 central-business-district commuters</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Bruno, Kosci, and Ugozli (19)</td>
<td>1979</td>
<td>Albany, NY</td>
<td>901 commuters</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambridge Systematics, Inc. (12)</td>
<td>1980</td>
<td>Minneapolis,</td>
<td>Choice-based sample of 200 commuters to 2 sites</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
<td>Male</td>
<td>No difference</td>
<td>Married</td>
<td>No difference</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*One site in this study showed a higher percentage of female commuters carpooling than male commuters.*

Graphic variables that entered interactively into the discrimination, but only in a minor way. It is interesting to note that in a recent similar investigation of nonwork ridesharing (19), these same demographic characteristics were a much stronger discriminator between ridesharers and nonridesharers than they were for the work trip.

Another factor considered to be related to ridesharing behavior is the individual's employment characteristics. A widespread method of estimating ridesharing potential at an employment site is to multiply the number of employees in firms over a certain size by a factor transferred from a ridesharing program at a similar site.

Subrier and Wagner (20) report that a literature review of vanpooling contained estimates of the vanpool modal share that ranged from 25 to 50 percent of those eligible to vanpool and that, within individual companies, vanpool shares of about 10 percent of all employees are common. Carpooling shares are often estimated to be about 30 percent.

The problem with this transfer procedure is that the ridesharing programs, especially vanpool programs, differ greatly from one area to another. Thus, care must be taken when using this method for predicting demand.

In attempts to yet differences between ridesharers and solo drivers, several studies have sought to identify attitudinal and perceptual differences between the two groups with respect to ridesharing. Horowitz and Sheth (9), in a psychosocial analysis of ridesharers, identified the primary difference between the ridesharers and solo drivers as their perception of the time convenience, reliability, comfort, and saving of travel time. The Margolin and Misch investigation into the profiles of carpooling perceptions (11) of the two groups shows that the greatest differences were time-related (risk of being late, arriving home when expected, travel and wait time), comfort (crowding), and convenience (difficulty of making arrangements and space for packages).

In Heaton's study (8), the features of carpooling that carpoolers reported as being most appealing were cost savings, alleviation of congestion and pollution, and relief from driving. The features least liked by the carpoolers were reduced independence and mobility. Difficulties of adhering to schedules, other people's driving habits, inconvenience, responsibility to others, and increased travel time were of secondary importance. Reasons given by nonpoolers for not pooling were the need for a car at work, irregular working hours, and reduced mobility and independence.

A semantic differential analysis of attitudes of poolers and nonpoolers (16) showed that poolers liked to drive with others, whereas solo drivers did not; poolers perceived a real cost savings whereas nonpoolers felt that the amount of savings was not worthwhile. Another difference was in reliance on others. Poolers were not averse to relying on others or having others depend on them, whereas nonpoolers disliked both options. It was concluded that the reasons given for not pooling are in fact excuses and that the real reasons involved personal independence, privacy, and freedom from others.

Social interaction emerged as the primary consideration in decisions to share rides in the Margolin and Misch study of ridesharing behavior (11). Disturbing the computer matching was expressed by insistence on meeting people before arranging a carpool. Carpooling with strangers was ruled out by 39 percent of their sample. Women more than men and white- and blue-collar workers more than members of the managerial-executive-professional group were concerned about ridesharing with strangers. This finding is also reported by Levin and Gray (21), who
in an analysis of interpersonal factors found that acquaintance was an important factor in carpooling and that the desirability of carpooling for an individual decreased with the number of nonacquaintances in the pool increased.

Status, a sensitive issue in our culture, also emerged as a consideration in the social interaction (11). It was found that, in general, people are wary of carpooling with others somewhat different from themselves, even carpooling for nonwork-related behavior, i.e., talking, eating, and smoking. Since there are no established rules of etiquette or codes of behavior for ridesharing, rules of ridesharing (even rulemaking itself) were a source of anxiety. Margolin and Wisch point out that smoking was an especially "hot" issue and that, although it was a legitimate issue in itself, it seemed to become a surrogate for other sources of dissatisfaction.

To date, the search for a set of identifying characteristics of ridesharers and potential ridesharers has not yielded a simple set. The only common characteristic of ridesharers across the studies reviewed is a long distance to work. However, there is evidence from these studies that the set of characteristics that defines ridesharer profiles consists of interactions of demographic, locational, and employment characteristics. Furthermore, it is reasonable to suspect that these interactions vary across different segments of the population as well as with the incentives offered for ridesharing.

No study to date has systematically explored the carpool or vanpool as a unit of behavior and examined the similarities and differences of the characteristics of the individual members of pools.

**DISAGGREGATE TRAVEL CHOICE**

The second category of ridesharing estimation techniques is based on the disaggregate approach, which considers the choice to rideshare in the context of household activity and travel behavior. Included in this are model sequences based on the assumptions of utility-maximization methods based on simulations of household activity and travel behavior.

**Methods Based on Utility Maximization**

The methodology that has had widespread influence on the estimation of ridesharing impacts was developed by Cambridge Systematics, Inc. (CSI) in a series of projects for the Federal Energy Administration and the U.S. Department of Transportation (22-25). It links together several models of household transportation choices to predict automobile ownership, work-trip mode choice, and nonwork travel (frequency, destination, and mode). Aggregated, it provides information for estimating changes in demand for travel under various TSM strategies as well as in energy use.

It has been adapted to be compatible with the Urban Mass Transportation Administration (UMTA) Urban Transportation Planning System, a set of computer programs in widespread use by metropolitan planning organizations for highway and transit network supply and equilibrium analysis, and has also been adapted for manual sketch planning (26).

The model sequence for a single household includes automobile ownership models for households with at least one worker and with no workers and work mode-choice models with a possible choice among three modes—driving alone, sharing a ride, and using transit. Since some of the level-of-service variables in this model depend on the number of people in the shared-ride arrangement, a separate submodel determines the size of carpool the person would be in if he or she shared a ride to work.

The household nonwork travel is modeled by trip-generation and joint-destination and mode-choice (automobile and transit) models for social and recreational trips and other nonwork-based trips.

The structure of the mode-choice model is logit with a linear additive utility function with level-of-service, locational, and socioeconomic variables.

Since carpools of various sizes cannot be treated as separate alternatives without violating a basic assumption of the logit model, a carpool-size submodel precedes the mode-choice model in the model sequence. Thus, the model predicts the size of a carpool that the individual would join, assuming that the individual would choose to rideshare, and the level-of-service variables based on carpool size are generated for the individual's ridesharing alternatives. The carpool-size submodel is structured with a linear specification and was calibrated by standard linear-regression techniques. The CSI set of models treats the vanpooling option by introducing it as a new mode only in circumstances where it was available to a worker (by having that information in a data set) or in situations about employer sizes in destination zones) and if the work journey was over some minimum trip length.

The household results are aggregated to give areawide estimates by using a random-sample enumeration method. The joint distribution of independent variables is represented by an appropriately weighted subsample of households from the original home interview survey. The choice probabilities are forecast for each sample household and expanded to the entire population. Advantages of this method are that no assumptions on the distribution of the independent variables are required and impacts of policies aimed at particular identifiable groups can be estimated by using larger appropriately weighted samples from such groups. Furthermore, as more knowledge is gained about the identification of market segments of carpoolers, it could readily be applied in this aggregation procedure.

Another model for ridesharing based on utility theory developed by Peat, Marwick, Mitchell, and Company (PMM) and Market Facts, Inc. (27), used a trade-off approach in assessing the multiattribute utility functions of a set of individuals for various modes to work. Trade-off analysis is a type of contingent measurement technique that attempts to answer the question of which combinations of circumstances are preferred to other circumstances by a set of subjects. A set of attributes, preselected by the researchers to represent what the researchers perceived to be relevant to the choice, were the mode used (e.g., driving alone in a car; driving with passengers in a car, being driven by another in a car, riding public transportation); travel costs (including gasoline and tolls or transit fare, as appropriate); parking cost; extra time (e.g., the time spent walking, waiting for others or for public transportation pickup, or dropping off on time); riding time (e.g., the line-haul time); the number of people in the vehicle; the ease of finding transportation during the day for personal business; and the supply of gasoline available for consumption.

A special survey instrument was then designed to provide basic data for the trade-off model and to supply the parameters and base condition values necessary for simulating various carpool strategies. The survey also elicited information on trip characteristics and socioeconomic and attitudinal data. The subjects to which this survey was administered were from three urban areas (Chicago, Pittsburgh, and Sacramento), stratified by employment characteristics of the individual members of pools.
The model yields a utility function for each subject that can be evaluated for each alternative for various levels of the attributes as determined by carpooling incentives. The aggregate model split was estimated from the proportionality of the calculated utilities for the modes of each individual. Since each subject was taken to represent a group of people similar with respect to sociodemographic and locational characteristics, the proportionality was used to estimate the aggregate shares.

This demand-estimation procedure uses a very powerful tool from the field of decision theory and has made progress in the development of the type of demand model that is policy-sensitive and can handle modes such as ridesharing. The study concludes with observations on methodology with the recognition that it did not incorporate the "soft" variables such as comfort and convenience and reliability. Nor did it include any social-interaction variables that are being identified by recent work (11) as being important.

Microsimulation

A microsimulation model sequence that uses the logit specification was developed by Bonsall (28) for the prediction of ridesharing. This computer model generates a set of commuters and simulates their decision process with respect to ridesharing. The sample of commuters is generated by a process designed to replicate the socioeconomic and locational characteristics of the population under consideration; it maintains the intercharacteristic probabilities revealed in a household survey and within a control total derived from published census material. The model allows for applications for up to seven types of ridesharing schemes, which range from carpooling to giving or receiving rides in the morning or in the evening or both. A filtering process is used to establish a feasible set of alternatives for each actor.

A series of binary logit models is calibrated and used to calculate the probability that each commuter will join a carpooling arrangement. This is converted to a likelihood of submitting an application, checked against a threshold of interest, and determines whether the commuter submits an application. A model simulates the processing of applications and matches ridesharing interests, times, and locations.

The model further simulates the decision of each person; it considers a list of potential traveling companions supplied by the organizers. The expected utility to a given person of a given arrangement is assumed to be a function of the personal characteristics of that person, of personal characteristics of the proposed partners in the arrangement, and of the operational consequences of the arrangement such as delays and diversions. The parameters are calibrated on a series of regression equations by using data from a field survey.

The model user defines the scale and location of the ridesharing scheme to be tested by defining a target population in terms of their residential location, work location, or some combination of the two. The user also specifies a threshold of interest, which may be taken to represent the intensity of an advertising campaign conducted among the target population.

The model maximizes this utility for each individual. For any arrangement that has positive net expected utilities, the one with the maximum net expected utility to the applicant is selected, and a match is designated as successful. Since the decision to match was based on expected utility, which in reality may be revised, the next submodel simulates the survival of the match.

The last feature of the model is the output of system performance indicators. These include the summary statistics, information on work-journey public transit patronage lost, and information on private vehicle use changes in automobile occupancy.

TRAFFIC-EQUILIBRIUM MODELS

Another perspective from which ridesharing has been considered is that of traffic flow equilibrium. En-
encouragement of ridesharing by high-occupancy-vehicle (HOV) strategies such as priority ramps and exclusions lanes on urban radial expressways combines the conventional logit demand model with a simple traffic-flow model. The demand model includes level-of-service variables such as transfers, in-vehicle and out-of-vehicle waiting and walking times, and travel cost and socioeconomic variables such as income, age, number of children, and length of residence in the neighborhood. The modes considered are car (with one or two occupants), carpool (three or more occupants), bus with walk access, and bus with car access. The travel speeds are obtained by a deterministic queuing model of traffic flow and the demand-and-supply models are iterated to equilibrium. The planning model for transportation corridors also uses a large number of modal logit models for demand and socioeconomic variables. In this case, data for a representative sample of households in the study area are used to calculate modal choices for driving alone, ridesharing local bus, and express bus and/or rapid transit with various access modes. The choices with various access modes are carefully defined to avoid possible violations of assumptions of the logit model. The change in the level of service for both the access and line-haul portions of the trip is determined by supply-side relationships and a simultaneous solution to the demand-and-supply equations determines the equilibrium modal volumes.

The JHK/Shirley Highway model is based on the assumption that current carpools will choose the fastest path and that modal shifts will occur as the relative travel times between carpools and other modes change for any origin-destination combination. Modes considered are bus, single-occupant automobile, two-occupant automobile, three-occupant automobile, and carpool, which is defined as an automobile with four or more occupants. Diversion curves developed from empirical findings about modal shifts from the Shirley Highway demonstration project are used in this approach. The method consists of defining an origin-destination zonal system and a coarse network for the corridor of interest, identifying minimum time paths for every origin-destination pair, and obtaining average times and speeds for each link for the base and forecast period. The modal shares for each zonal pair before implementation of the HOV strategy are also required. The diversion factors from the Shirley Highway modal shifts are used to obtain changes to carpool modal shares. This method has its own interpretations. Its main merit is that it uses information from an actual observation of shifts to ridesharing.

Computerized traffic-flow models such as FREQ and TRANSYT have also been used to assess the impacts of HOV Strategies. These models, which have undergone several rounds of refinement at the University of California at Berkeley, can be used to assess demand shifts and travel-flow characteristics resulting from implementation of HOV strategies on expressways and arterial streets at the micro level. The modal shifts between automobiles and ridesharing and automobiles and bus are obtained by using demand relationships from a previously calibrated logit model, and the differences in travel time by various modes are calculated by a detailed supply-side algorithm. The demand shifts, however, are sensitive only to in-vehicle travel time. No access time changes are considered.

Use of aggregate before-and-after data coupled with the simultaneous consideration of demand and supply is the important feature of a technique developed by Charles River Associates (CRA) 39 to predict travel-volume changes on urban corridors resulting from implementing HOV priority strategies. This method, intended to be used as a first-cut estimate, does not need origin-destination data or the socioeconomic characteristics of the area. Supply relationships between travel time and travel volume were obtained from speed-volume relationships for various facilities from the Highway Capacity Manual. Traffic volumes were measured in 12 corridors before and after implementation of HOV treatments to assess the sensitivity of travelers to levels of service for various modes and to estimate elasticities and cross-elasticities for various modes. The basic underlying assumption in models of this third category is that commuters respond to changes in transportation level of service. There is no concern for the matching of commuters into workable ridesharing units. With the exception of the JHK/Shirley Highway model and the CRA models, the demand model specification is a multinominal logit with level-of-service and, in most cases, socioeconomic variables, and the main difference among the models is in the treatment of the supply side and equilibrium. The treatment of demand in the traffic-flow models is extremely simple and demand is assumed to be sensitive only to changes in the in-vehicle travel time. The JHK/Shirley Highway model and the CRA model use information from observed modal shifts to ridesharing after the implementation of HOV strategies.

SUMMARY

The knowledge about ridesharing has increased significantly since 1973-1974 and the national recognition of its possible benefits. Estimation techniques have also progressed from near nonexistence to the wide variety described in this report. The following tables present an overview and summary of those techniques. The estimation techniques vary not only by the purpose for which they are intended, but also by their degree of readiness for application. Some are offered as complete planning tools;
Table 2. Summary of ridesharing estimation methodologies.

<table>
<thead>
<tr>
<th>Model</th>
<th>Ridesharing Application</th>
<th>Basic Approach</th>
<th>Model Type</th>
<th>Ref.</th>
<th>Past Application</th>
<th>Data Required</th>
<th>Computational Requirement</th>
<th>Merits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum potential</td>
<td>Contiguity planning</td>
<td>Formation of ridesharing unit</td>
<td>Kendall</td>
<td></td>
<td>Tested with data from Boston, MA</td>
<td>O-D trip tables for automobile home-based work trips</td>
<td>Computer required</td>
<td>Benchmark for evaluation of ridesharing programs</td>
<td>Does not consider user preferences, compatibility of group, enroute matching or off-peak travel</td>
</tr>
<tr>
<td>Service-area identification</td>
<td>Identifies areas of ridesharing potential</td>
<td>Formation of ridesharing unit</td>
<td>Matching origins, destinations, and time</td>
<td></td>
<td>Tested with data from Chicago, IL</td>
<td>O-D information</td>
<td>Computer required</td>
<td>Test for ridesharing plans</td>
<td>Does not consider user preferences or compatibility of group, separately</td>
</tr>
<tr>
<td>CSI</td>
<td>Areawide ridesharing demand; demand at employment sites; modal shifts from HOV strategies</td>
<td>Household decision, equilibrium</td>
<td>CSI</td>
<td></td>
<td>Tested with data from Washington, San Francisco, Minneapolis</td>
<td>Socioeconomic, transportation LOS information, need for base modal shares for manual method</td>
<td>Manual re-calibration requires computer</td>
<td>Determines the effect of ridesharing on traffic flow</td>
<td>Does not consider user preferences or compatibility of group, separately</td>
</tr>
<tr>
<td>JHK/Shirley Highway carpool modal shift</td>
<td>Estimates modal shifts from HOV treatments</td>
<td>Traffic equilibrium</td>
<td>JHK</td>
<td></td>
<td>Applied to data from Shirley Highway and Metro K line and I-66 corridor in northern Virginia</td>
<td>Specification of transportation analysis zones, routes, and number of work trips for all O-D pairs, travel times, and speeds</td>
<td>Manual</td>
<td>Based on observed modal shifts to carpools</td>
<td>No further interaction with supply</td>
</tr>
<tr>
<td>PMM and Market Facts trade-off</td>
<td>Estimates area-wide ridesharing demand</td>
<td>Household decision</td>
<td>Trade-off</td>
<td></td>
<td>Applied to data from Chicago, Pittsburgh, and Sacramento</td>
<td>Conjunct measurement data about modes used, time, cost, automobile occupancy, socioeconomic data, existing modal shares</td>
<td>Computer required</td>
<td>Gives much information about commuter preferences from socioeconomic groups and location in city</td>
<td>Does not consider comfort, convenience, reliability, long, tedious method</td>
</tr>
<tr>
<td>Economic simulation for priority lane on urban expressway</td>
<td>Estimates modal shifts from HOV treatments</td>
<td>Traffic equilibrium</td>
<td>Small</td>
<td></td>
<td>No application in actual environment</td>
<td>Socioeconomic, transportation LOS information at household level</td>
<td>Computer required</td>
<td>Workable equilibrium procedure</td>
<td>Experienced analyst required; does not consider user preferences</td>
</tr>
<tr>
<td>University of California, Berkeley, traffic simulation</td>
<td>Estimates modal shifts from HOV treatments</td>
<td>Traffic equilibrium</td>
<td>Cilliers, May, and Cooper</td>
<td></td>
<td>Case studies on Santa Monica Freeway and Wilshire Boulevard</td>
<td>Detailed network information, travel time by modes, signals</td>
<td>Computer required</td>
<td>Gives micro-effects on traffic corridors</td>
<td>Demand sensitive only to changes in in-vehicle travel time</td>
</tr>
<tr>
<td>CRA-HOV travel-volume change</td>
<td>Estimates travel-volume changes from HOV treatments for sketch planning</td>
<td>Traffic equilibrium</td>
<td>CRA</td>
<td></td>
<td>Visually being tested</td>
<td>Existing modal volumes and LOS characteristics</td>
<td>Manual</td>
<td>Does not need socioeconomic data, calibrated on observed changes in travel volumes</td>
<td>Provides only first-cut estimates</td>
</tr>
<tr>
<td>Car-sharing micro-simulation</td>
<td>Areawide demand; demand at employment site</td>
<td>Household decision</td>
<td>Bossall</td>
<td></td>
<td>Applied to data from Leeds, England</td>
<td>Household travel survey, socioeconomic, LOS data, census data</td>
<td>Computer required</td>
<td>Considers compatibility of group</td>
<td>Extensive data requirements</td>
</tr>
<tr>
<td>Planning for transportation corridors</td>
<td>Estimates modal shifts from HOV treatments</td>
<td>Traffic equilibrium</td>
<td>Tal-Vale</td>
<td></td>
<td>Prediction of HOV lane in I-80 corridor, San Francisco</td>
<td>Socioeconomic, transportation LOS information at household level, free-flow speeds, bottleneck capacities</td>
<td>Computer required</td>
<td>Workable equilibrium procedure; access and lane-based mode choices considered separately</td>
<td>Modal share of representative household holds may not represent actual mode shares in corridor</td>
</tr>
</tbody>
</table>

Note: LOS = level of service, O-D = origin-destination.
tion to a new situation and also include the household-interaction simulation games.

RESEARCH NEEDS

Estimation techniques for ridesharing still present a challenge to transportation analysts for several reasons. Ridesharing is not strictly a private mode of transportation nor is it public. Travelers' decisions to rideshare are more complex than decisions to use either public transport or private automobile in that coordination with other travelers is required. Depending on the nature of the ridesharing program, some or all of this coordination becomes the responsibility of the travelers themselves; this increases the relative effort necessary to use this mode. Innovative ridesharing arrangements and promotional efforts are introduced regularly and predicting demand for these new situations compounds the problem for the analyst.

The following two proposed studies are seen to have an immediate impact on the improvement of ridesharing estimation techniques. The first is a multivariate analysis of ridesharing at employment sites. Since many ridesharing estimates are made by transferring a known modal share from one place to another, it would be extremely useful to provide a good set of factors for such transfer. These could be obtained from a multivariate analysis of a data set from a national sample of employment sites that contains the following information about each site: type of industry, number of employees, incentives for ridesharing, incentives for driving alone, degree of ridesharing assistance, number of ridesharing units by type (carpool, vanpool, buspool), and pool composition (intracompany, intercompany, with household members, with neighbors). The second study would be to simply field test a set of estimation techniques at several sites so that an assessment of accuracy, strength, and limitations could be made.

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REFERENCES

Activity Flexibilities of Rural Households: Implications for Ridesharing

CHRISTIAN F. DAVIS

The research described in this paper deals with activity patterns and their relationship to travel needs in a rural area in eastern Connecticut during a typical weekday. It was part of a larger effort to determine the potential for dynamic ridesharing in a low-density area. Various types of activity flexibilities are examined based on the results of a home interview survey of 601 households in the 330-square-mile Windham Planning Region. Activity flexibility in time was found to be very great except for work or school. With the exception of these two, it was found that 75 percent of all activities were judged to be not fixed in starting time. In fact, 37 percent of all activities could have occurred on a completely different day. Demands on the responsiveness of a ridesharing program should not be excessive since most activities are known well in advance. In the case of the sample households, only 5 percent of the recorded activities occurred with no advance notice and 75 percent were known 24 h in advance. The results indicate that an effective program to encourage ridesharing should recognize that activities occur with great regularity and hence can be scheduled far in advance or are quite flexible in time and can thus be rescheduled to be compatible with ridesharing.

There would appear to be little doubt that ridesharing is an effective strategy for conserving energy, increasing mobility, or achieving some favorable combination of the two. For the most part, previous studies have focused on satisfying existing travel patterns that in turn are partly the result of habits gained during a period of cheap energy. The possibility of taking advantage of the underlying flexibility of the activities that give rise to the travel patterns has received little attention. It is suggested here that, within limits, not only can the transportation system adapt to travel patterns, but travel patterns can be adapted to the transportation system and that this adaptation can take place within the constraints established by our pattern of daily activities.