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Estimation of Demand for Transit Service Among the Transportation Disadvantaged

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Four techniques are presented for estimating demand for public transit or paratransit service among the transportation disadvantaged. These techniques are grouped in three basic categories: (a) graphic-analytic techniques, (b) mathematical formulation, and (c) regression techniques. The four techniques include estimating demand among the disadvantaged in New York City; determining the effects of barriers on demand in Massachusetts; using noncommitment response techniques to estimate demand if specific travel barriers are removed in Albany, New York; and using regression techniques to estimate demand in rural Pennsylvania. Each technique requires a description of the population to be served, an estimate of their current travel patterns, detailed descriptions of new transportation systems or system improvements, and some overall description of the service area.

If there is one characteristic that describes the United States, that characteristic is mobility. As federal, state, and local governments have become more aware that mobility is not experienced equally by everyone, they have generated laws to ensure that public transportation is made accessible to all, at least in the expenditure of public funds.

Section 16 of the Urban Mass Transportation Act of 1964 (as amended) specifies that "... special efforts shall be made in the planning and design of mass transportation facilities and services so that the availability to elderly and handicapped of mass transportation which they can effectively utilize will be assured." Of the two tasks—planning and design—planning is currently the most difficult. Planning implies the commitment to spend funds effectively, and that implies that the types of services required by the transportation-disadvantaged are available to some extent. But, because the available types of special services have been too diverse and have been funded by many disparate programs, no truly comprehensive set of data exists by use of which the future travel needs of this group can be projected or their travel behavior accurately described.

The difficulty planners face as they try to alleviate the travel problems faced by the transportation disadvantaged is that this group has so many labels: poor, the carless, the elderly, the young, the handicapped. Certainly, all of these labels are applicable. But we need to get a clearer focus on the term disadvantaged and to ask whether a more succinct definition is appropriate or necessary.

The current, overall social concept of the disadvantaged arose from the social programs of the 1960s. In particular, to be disadvantaged meant to have a quality of life that was below some presumed national level. This leads directly to the problem with which transportation planners have had to wrestle: Is there an assumed quality of transportation without which people become disadvantaged? Can this measure be translated into some measure of mobility, accessibility, or ability to pay or even some perceived level of opportunity?

The following example will show how difficult the problem of definition is. By all standards, poor, inner city minorities are on everyone's disadvantaged list. In terms of transportation, they spend a high percentage of their income on the journey to work; are most likely not to have an automobile; are subject to the whims of public transportation or dependent on rides with friends; and, finally, are finding that stores, doctors' offices, and other facilities that were once close by are no longer in their neighborhoods. What measure can be used to define the level of disadvantage at which this part of the population lives? To get the answer, the transportation planner must pose a series of questions that often tend to confuse rather than clarify the situation:

1. How different from the rest of the population is the group in question?
2. How much of the difference can be attributed to transportation?
3. How can transportation improve the quality of life of these people and, in improving the quality of life, is the objective to change the total number of trips, to improve the ability to shop for a wider variety of goods, to improve contacts in the community, to help save net income?
4. How much of a public investment should be made in transportation and how much in other areas (educa-

tion, housing, and health care) to have real impact on the quality of life of the disadvantaged?

There are, of course, real answers to this last question. Dial-a-ride for the elderly and commuter vans that provide transportation to work sites inaccessible by public transit are programs that have already been successful. Such programs suggest that the definition of the disadvantaged is currently ad hoc.

Situations that have required specific definitions of the groups to be served have often been described by the groups themselves. We know that transportation-disadvantaged groups exist only because of the effective lobbying of members of those groups. So far, the elderly and the handicapped have been the most effective lobbyists. But what about groups for which there are no advocates—such as those too young to drive, working mothers who do not have the family automobile, single-parent households, the rural poor? How are they included in the planning process? What would it cost to solve their problems? Some definition of the disadvantaged is clearly needed if planning capabilities are to be better than ad hoc.

CRITERIA USED TO DEFINE THE TRANSPORTATION DISADVANTAGED

Some of the more common criteria used in attempts to define the transportation disadvantaged are given below:

Criterion	Example
Socioeconomic data	Age, income, sex
Accessibility	Availability of an automobile, distance (in blocks) to a bus stop
Latent demand	Trips per person per day
Legislation	Requirements of the elderly and the handicapped

Each of these criteria has different dimensions, and each takes a different approach to the problem of definition. The difficulties that arise when these criteria are separately applied are analogous to those involved when equations that are not independent are used in a search for values among a set of variables.

Socioeconomic Data

Socioeconomic data are collected from sources such as U.S. or local censuses, origin-destination surveys, and real estate and employment records. Essentially, socioeconomic criteria used to define the disadvantaged state that the transportation disadvantaged can "most likely" be found in certain age groups or income groups. The term most likely is used because too often an entire group is called disadvantaged and costly or inefficient transportation solutions are imposed when in fact only a small number in that group will make use of the solution. In this connection, Falcocchio (1) cautions against using across-group comparisons and notes that it is better to examine levels of travel within a specified group than to compare travel needs of the rich with those of the poor.

The time-series nature of socioeconomic data is of great value to planners. Periodic censuses, travel updates, and updates of statistics on employment and the labor force are a few of the forms such data take. A planner can thus keep track of or spot potential groups for whom travel demand may increase but for whom current solutions are unavailable. The suburban elderly are such a group. As state requirements for getting a driver's license (such as eye tests and medical restrictions) become more stringent, many elderly who drive may find getting a license difficult. Those who are not poor and who live in suburban areas may find themselves suddenly isolated. Another group is working mothers. More women are choosing to enter the labor market. In households that own one automobile, new travel patterns are being established. Female heads of household encounter transportation difficulties different from those encountered by two-parent households in the same income category. It is important, therefore, that socioeconomic data be included in the definition of the transportation disadvantaged but only to help target potential disadvantaged populations.

Accessibility

Nothing creates a travel disadvantage in the United States as much as lack of access to an automobile. Recent studies have shown that the traditional socioeconomic variable—automobile ownership by household—is not sufficient to describe the nature of access to an automobile (2). A better descriptor is automobile availability (from any source) and the frequency of that availability. Many households without automobiles have limited access to or use of the automobiles of friends, neighbors, relatives, or car pools. Those most disadvantaged have the least access, and fewest of their travel needs are met by automobile.

Another misleading descriptor is distance to a bus stop. Most public transit serves the work trip and offers only spartan service during off-peak hours and to destinations outside the central business district. Dependence on the automobile or on specialized services becomes more critical outside urban areas, where public transit is almost nonexistent.

Latent Demand

Latent demand is taken to mean the additional travel demand generated by a particular group when some transportation service is provided that is better than the service the group currently gets. An estimate of latent demand might start with trips per person per day apportioned among a variety of preferred activities. To say that there is a gap between some norm and some population group in the total number of daily vehicle trips serves no purpose. What is important is the activities for which these gaps are most pronounced—shopping trips, medical trips, or social outings. For example, some elderly may travel less than younger people do, but the majority of the difference may lie in social visits. A solution that provides more hospital trips may not overcome the disadvantage the elderly perceive. Estimates of latent demand also deal primarily with vehicle trips. A recent study (2) has shown that, when walking trips are considered, the gap (in trips per person per day) between those traditionally considered to be disadvantaged and the norm nearly disappears. (This refers to the mobile, or nonhandicapped, population). The disadvantaged suffer not in the number of daily trips but in the quality of those trips.

When latent demand is tied to the correct socioeconomic indicators, it can be a powerful guide in overcoming problems of definition. What must be considered is what activities people wish or need to frequent more often, in a better location, or at another time and what kind and quantity of transportation must be provided to meet that need.

Legislation

The Urban Mass Transportation Act of 1964 makes consideration of the elderly and the handicapped a necessity.

Demonstration programs have dealt with the urban and rural poor. Legislation of the U.S. Department of Health, Education and Welfare has dealt with the elderly, the sick, and young children. Important as such legislation is, it cannot deal with the more basic causes of immobility and, being geared to highly specialized aspects of travel, it cannot deal with the overall mobility of the individual. As federal and local funds become more difficult to get, it becomes more important to devise methods for using transportation dollars as broadly as possible. Thus, demand estimates—first for any service at all and then for well-defined types of service—become the critical data used to justify the allocation of resources.

PROBLEMS OF DEMAND ESTIMATION

This paper summarizes several current techniques used to estimate travel demand among the disadvantaged. The objective of each technique is to provide guidelines for specific transportation improvements for specific disadvantaged groups. At this point, the complexities of demand estimation that arise when specific groups of the disadvantaged, such as the handicapped, are studied become apparent.

In traditional journey-to-work demand analyses of a predominately nonhandicapped population, the variables that control demand—especially those related to comfort and convenience—might clarify actual mode choice, but they do not affect the traveler's choice as to whether or not to make the trip. On the other hand, the handicapped may not travel unless there can be certain guarantees of accessibility to a given mode. Such guarantees may include low height of stairs on vehicles, level boarding, door-to-door transportation, and provision for wheelchairs or packages. Demand models must take into account the range of special supply characteristics that would meet the needs of the population subgroup being studied. Then the important time and cost variables must be added to these supply variables. Only then can it be seen if current trip needs will be met or if new trips will be generated. In planning for the disadvantaged, there is an underlying feeling among those responsible for policy decisions that many travel needs are not being served and that much of the demand is the result of new trips (many of which are nonwalking trips) generated only when a particular set of supply characteristics meet a specific individual's needs.

One conclusion can be drawn immediately: There is a strong link between the activity an individual prefers and the attributes of available transportation. Modal attributes, of course, become the variable in demand models or demand estimates. Needs are determined by the user. In estimating demand, the planner must integrate these two factors to arrive at a number that represents an estimate of use for a particular service. Data given in Table 1 show the complexities involved in making such an estimate. For those without an automobile—one group of the disadvantaged—the table clearly indicates that there is no uniform choice of mode for getting to a wide number of activities (2).

Five guidelines should be followed in the preparation of a demand analysis of a disadvantaged group:

1. Identify the group to be studied as explicitly as possible.
2. Clarify or identify activities for which travel is to be provided.
3. If travel for all activities is needed by a certain group, identify those activities for which it is feasible to provide transportation.
4. Identify the modal characteristics or attributes to which the group in question would respond and the attributes that the group would not respond to or would reject.
5. Consider modes that correspond best to the attribute selected as most important by the group studied and base the demand analysis on those modes.

The discussion that follows integrates analyses of four approaches to estimating travel demand among the transportation-disadvantaged. These four methods were presented at the Fifty-sixth Annual Meeting of the Transportation Research Board. Although each is unique, all consider the basic rules outlined above in their analysis of potential ridership.

Table 1. Survey of modal preferences for various trip purposes.

	Preferred Mode			
	Those With Automobile		Those Without Automobile	
Trip Purpose	>50 Percent of Time	<50 Percent of Time	>50 Percent of Time	<50 Percent of Time
Shopping				
Clothes	Automobile	Bus	Bus	Automobile Walk
Groceries	Automobile	Walk	Walk	Automobile
Convenience	Automobile	Walk Bus	Walk	Bus
Medical	Automobile	Walk		Bus Walk Automobile
Bank	Automobile	Walk	Walk	Bus Automobile
Visit friends				
In neighborhood	Walk	Automobile	Walk	
Out of neighborhood	Automobile			Bus Automobile
Religious	Automobile	Walk	Walk	Automobile Bus
Bar or coffee shop	Automobile	Walk	Walk	Automobile Bus
Paid recreation	Automobile		Automobile	Bus Walk
Parks	Automobile		Walk	
Social group	Automobile	Walk		Automobile Walk Bus
Escort children	Automobile	Walk	Walk	Automobile
School	Automobile	Walk Bus		Walk Automobile

Note: Taxi does not appear among the preferred modes because it was used by less than 10 percent of the sampled group.

ANALYTIC TECHNIQUES

No single model or equation can solve the generic problem involved in the estimation of travel demand among the transportation-disadvantaged. Good or reliable data bases are often not available, and existing data are often incomplete, especially for nonwork travel. When funds are allocated for surveys for special groups such as the handicapped, identification of the whole population or a representative sample of the population becomes difficult. Because complex models often require either large samples or extensive surveys of small samples, relatively complex approaches must be taken.

The general techniques used in this discussion can be grouped in the following categories:

1. Graphic-analytic—Estimates are made from extrapolation or interpolation of existing data bases.
2. Mathematical formulation—Trip rates are plotted as functions of system characteristics. True demand rates are then abstracted from the rates indicated by surveys. This is a more complex graphic-analytic method.
3. Regression—Whereas linear regression on a single independent variable is considered in mathematical formulation, multivariable regression is used when

a number of influencing factors are believed to affect the level of demand. Regression is used to isolate those variables most important for specific trips, specific modes, or specific population groups.

Each of these approaches has unique data requirements. In some instances, such as the graphic-analytic technique, demand can be estimated from available data sets such as censuses and past surveys. In others, such as some mathematical formulation techniques, special surveys must be designed.

The four cases studied here are

1. Estimating demand for the disadvantaged in large urban areas (graphic-analytic techniques),
2. Incorporating the effects of perceived barriers to travel on travel demand among the elderly and the handicapped in small urban areas (mathematical formulation method of noncommitment response),
3. Estimating demand in rural areas (regression techniques), and
4. Estimating demand by the handicapped based on specific improvements and data for larger urban areas (graphic-analytic techniques).

Graphic-Analytic Techniques

The studies of Falcocchio (1) and Teixeira and Stevens (3) present ways of determining responses to system improvements or new systems based on extrapolation from existing data sets. Falcocchio estimates latent demand for the elderly, the handicapped, the poor, and teenagers. In his method,

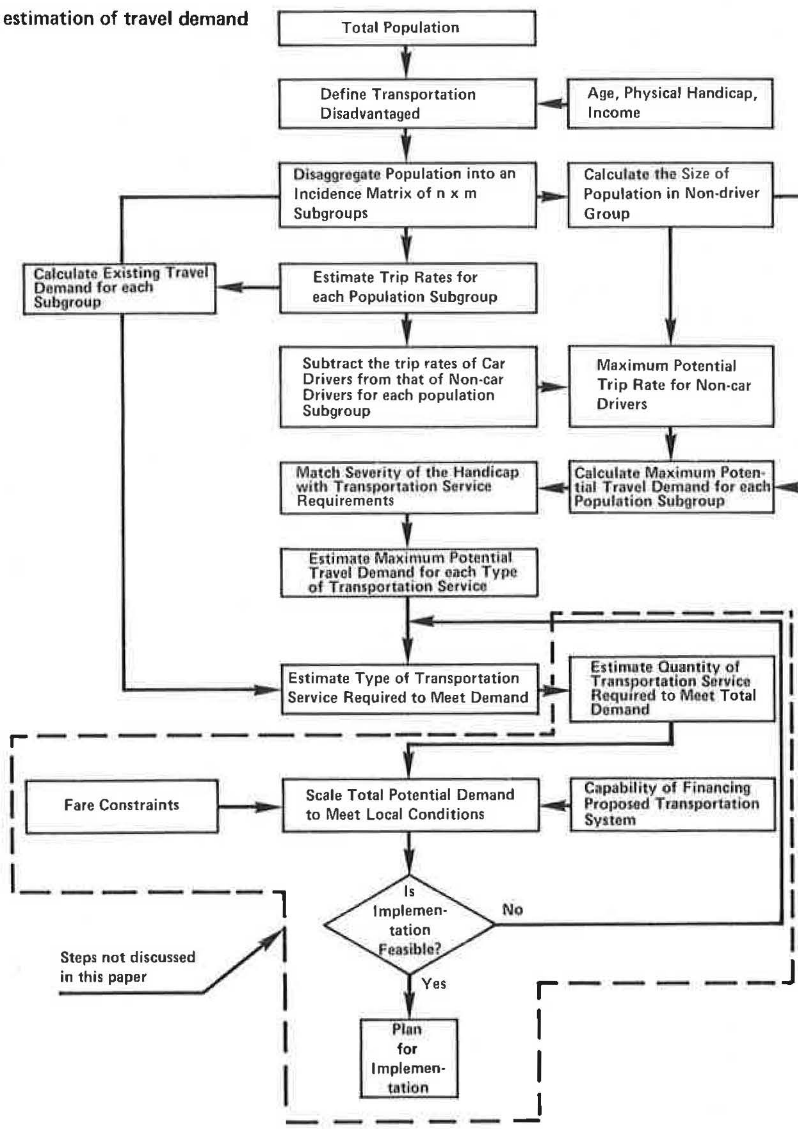
1. Estimates are made of the size of the sample who are disadvantaged within the general population.
2. The population is further divided into four classification groups: age, driver status, physical status (handicapped or not), and economic status.
3. Trip rates are estimated for each group.
4. Latent demand is estimated for each group in terms of trip rates.
5. Maximum potential demand is estimated.

This method is shown schematically in Figure 1.

The total travel demand of the disadvantaged (T) is then defined as

$$T = Te + Tp \tag{1}$$

Figure 1. Methodology for analysis and estimation of travel demand among the disadvantaged.



where

Te = existing travel and
Tp = potential travel (latent demand).

Te is estimated as follows:

$$Te = \sum_{i=1}^{6} \sum_{j=1}^{4} N_{ij} t_{ij} \qquad (2)$$

where

N_{ij} = number of people in each population subgroup and
t_{ij} = existing trip rate of each population subgroup.

Tp is defined as the maximum potential unrealized travel demand of those who are not automobile drivers. This is obtained from the product of the differentials between trip rates of automobile drivers and those of nondrivers and the number of nondrivers in each age status and each physical and economic status:

$$Tp = \sum_{i=1}^{6} \sum_{j=1}^{4} N_{ijNCD} (t_{ijCD} - t_{ijNCD}) \qquad (3)$$

where

N_{ijNCD} = number of nondrivers in age status i and physical and economic status j,
t_{ijCD} = trip rate of drivers in age status i and physical and economic status j, and
t_{ijNCD} = trip rate of nondrivers in age status i and physical and economic status j.

Estimates of trip rates for each of six age and driver groups and for each of four physical and economic groups, expressed as trips per day (excluding walking trips) are given in Table 2 (4, 5, 6, 7, 8). These data were derived for population subgroups in New York City. Not all of the trip rates could be estimated directly from the available sources; a number of them were therefore estimated by extrapolation. Although the accuracy of the travel demand estimates for the case study of New York City may not be sufficiently precise for purposes of system design, for the purposes of this discussion the estimates may be considered to approximate values that could be derived by more precise data collection.

The results of the application of Equation 2 are given in Table 3. Maximum latent travel demand in person trips per day (excluding walking trips) is given below for each population subgroup:

Population Subgroup	Person Trips per Day: Automobile	Nonautomobile	Maximum Potential Travel Demand
Teenage			
Handicapped, poor	–	0.3	0.5
Handicapped, nonpoor	1.1	0.6	0.5
Nonhandicapped, poor	0.7	0.6	0.1
Nonhandicapped, nonpoor	1.9	1.5	0.4
Elderly			
Handicapped, poor	0.6	0.3	0.3
Handicapped, nonpoor	2.7	0.8	1.9
Nonhandicapped, poor	0.5	0.3	0.2
Nonhandicapped, nonpoor	2.3	0.7	1.6
Middle			
Handicapped, poor	1.4	0.4	1.0
Handicapped, nonpoor	2.3	0.7	1.6
Nonhandicapped, poor	1.6	0.6	1.0
Nonhandicapped, nonpoor	2.4	1.7	0.7

Maximum latent demand in total trips (Equation 3) is calculated below (latent demand can be expressed as a percentage of existing travel for each age status and physical and economic status):

Population Subgroup	Demand Rate		Nondrivers		Estimated Maximum Potential Travel Demand (trips/d)
Teenage					
Handicapped, poor	0.5	x	5 526	=	2 763
Handicapped, nonpoor	0.5	x	20 448	=	10 224
Nonhandicapped, poor	0.1	x	167 687	=	1 677
Nonhandicapped, nonpoor	0.4	x	670 511	=	268 204
Total					282 868
Elderly					
Handicapped, poor	0.3	x	126 002	=	37 800
Handicapped, nonpoor	1.9	x	169 108	=	321 305
Nonhandicapped, poor	0.2	x	234 004	=	46 801
Nonhandicapped, nonpoor	1.6	x	314 058	=	502 493
Total					908 399
Middle					
Handicapped, poor	1.0	x	47 764	=	47 764
Handicapped, nonpoor	1.6	x	55 738	=	89 181
Nonhandicapped, poor	1.0	x	771 644	=	771 644
Nonhandicapped, nonpoor	0.7	x	2 401 775	=	1 681 243
Total					2 589 832

Table 2. Trip rate for population subgroups in New York City (per person per day).

Age Group	Driver Group	Physical and Economic Group[a]: Handicapped, Poor	Handicapped, Nonpoor	Nonhandicapped, Poor	Nonhandicapped, Nonpoor
Teenage	With automobile	–	1.1	0.7	1.9
	Without automobile	0.4	0.6	0.6	1.5
Elderly	With automobile	0.6	2.7	0.5	2.3
	Without automobile	0.3	0.8	0.3	0.7
Middle	With automobile	1.4	2.3	1.6	2.4
	Without automobile	0.4	0.7	0.6	1.7

[a] Excludes walking trips.

Table 3. Estimate of current daily trips for population subgroups in New York City.

Age Group	Driver Group	Physical and Economic Group: Handicapped, Poor	Handicapped, Nonpoor	Nonhandicapped, Poor	Nonhandicapped, Nonpoor	Total
Teenage	With automobile	0	87	332	7 050	7 469
	Without automobile	2 211	12 267	100 612	1 005 766	1 120 856
Elderly	With automobile	3 979	80 575	6 158	127 470	218 182
	Without automobile	37 801	135 286	70 201	219 840	463 128
Middle	With automobile	7 406	54 837	137 181	2 470 397	2 669 821
	Without automobile	19 106	39 017	462 986	4 083 018	4 604 127
Total		70 503	322 069	777 470	7 913 541	9 083 583

Although the nonhandicapped nonpoor in the middle age group are not considered to be disadvantaged, improvements in transportation service designed to meet the needs of those who are disadvantaged will also increase the travel demand of this group.

Falcocchio's analysis shows that the potential travel demand of those who are disadvantaged because of physical or economic circumstances falls between 105 and 135 percent of their existing travel. The incidence of latent demand is highest, however, for those in the middle age group who are handicapped and poor and is lowest for poor, nonhandicapped teenagers.

As a group, the elderly have the highest percentage increase in travel demand (133 percent)—about three times the average increase (42 percent). Teenagers would travel 25 percent more than they do now, and those in the middle group would make about 33 percent more trips than they do now. Those who are not handicapped, poor, or elderly tend to show the lowest increase in travel (26 percent for both teenagers and those in the middle age group).

The Handicapped

Teixeira and Stevens cite data for transportation systems on which improvements have been made to predict travel by the handicapped on transportation systems on which improvements are to be made. Their approach uses the following steps:

1. Determine the size of the handicapped population and especially that portion of the population for whom specific improvements to the transportation system would be relevant.
2. From the existing data, determine the rate of use of a specific improvement in trips per day (for example, the number of people who use the elevator on the BART system).
3. Use modal-split analysis to determine how many handicapped would use the system if the improvement were made.

The handicapped face a number of barriers in attempting to use conventional public transportation. Steps and escalators are the greatest obstacle on public bus and rapid transit systems. The handicapped also experience problems in getting to the nearest bus or subway stop. Alternative transit designs for the handicapped would include (a) fixed-route bus systems equipped with wheelchair lifts; (b) subway systems that have elevators and use light rail vehicles equipped with wheelchair lifts; and (c) specialized systems that provide door-to-door service. Procedures for estimating travel demand could then be developed to accommodate these improvements.

A method for calculating travel demand for the Massachusetts Bay Transportation Authority (MBTA) in Boston involved the use of actual operating data obtained from the Bay Area Rapid Transit (BART) system in San Francisco. Since the opening of BART in 1973, use of the system's elevators has been surveyed annually. The BART data provide estimates of the overall potential use of elevators in rapid transit systems and the number of handicapped persons who are using those elevators. The 1975 rate of elevator use, expressed as the ratio of elevator trips to total station boardings, was 0.001 28. For every 1000 passenger trips made on BART, about 1.28 passenger trips are made by a person who uses the elevators. This figure has been increasing slowly over the years but is believed to be lower than the true figure by some unknown amount.

The 1975 BART data showed that only about 16 percent of those using the elevators were in wheelchairs. The other 84 percent of elevator users constituted a microcosm of the general public: the elderly; people with bicycles; children; people with packages, luggage, or baby strollers; and overflow crowds. Using these figures and applying them to the 1975 counts would yield a rate of elevator use for wheelchair-bound individuals of 0.0002 trips/d/total passengers.

The BART trip rates can be used to estimate total trips by the handicapped and trips by the wheelchair-bound for both an accessible rapid transit system and an accessible fixed-route bus system. In making these estimates, the planner must know the number of daily boardings on both systems. In addition, he or she must assume that the wheelchair-bound will use an accessible fixed-route bus system and that they will be the only people to use lifts on buses. This assumption makes it possible to apply the BART trip rates to the total demand on any accessible, fixed transit facilities.

Such an analysis for the MBTA system is given in Table 4. By using the appropriate BART trip rates and the data given in Table 4 on use of the total MBTA system by the general population, planners can determine both total transit trips by the handicapped (items 6 through 9) and the number of trips by the wheelchair-bound (items 10 through 13) on a totally accessible system. A variation on this theme would be to determine the number of trips that would be made if there were no accessible bus system (items 14 through 16). The data show that an inaccessible bus system would reduce the travel demand of the handicapped by only approximately 17 percent.

Mode-Split Application

The mode-split technique is an extension of mode-split models that apply to the general population. Use of this method requires collecting data on mode split for the general population, the frequency of trips by the handicapped, and the number of handicapped who are likely

Table 4. Application of BART trip rates to use of modes by the handicapped on the MBTA system.

Item	User and System Category	Type of Trips on Total System by Mode	Daily Ridership
1	General population	Total rapid transit (unlinked)[a]	379 200
2		Rapid transit only	38 400
3		Bus and rapid transit (linked)	340 800
4		Bus only	100 800
5		Total bus	441 600
6	Handicapped on totally accessible system	Rapid transit only (item 2 × 0.001 28 trips/d)	50
7		Bus and rapid transit (item 3 × 0.001 28 trips/d)	435
8		Bus only (item 4 × 0.0002)	20
9		Total rapid transit	505
10	Wheelchair-bound on totally accessible system	Rapid transit only (item 2 × 0.0002 trips/d)	8
11		Bus and rapid transit (item 3 × 0.0002 trips/d)	68
12		Bus only (item 8)	20
13		Total rapid transit	96
14	Handicapped by all modes on wheelchair-accessible rapid transit system only	Rapid transit only (item 6)	50
15		Bus and rapid transit (item 7 to item 11)	367
16		Total rapid transit	417

[a]Trips for which the bus is not used.

users of the modes being considered. Data obtained by use of these techniques are summarized below:

	Total Trips by Handicapped	
Mode	Per Day	Per Year
Subway	1435	431 000
Bus	1990	597 000
Commuter rail	115	34 500

By using the BART trip-rate technique, a total handicapped ridership of 505 passenger trips/d or 170 000 passenger trips/year can be shown to occur on a fully accessible MBTA system equipped with elevators and bus lifts. This figure is considerably lower than the 1 028 000 passenger trips/year predicted by using the mode-split technique. The difference is easily accounted for by the fact that putting elevators and lifts in transit systems simply does not allow the handicapped to achieve a share of the modal split equal to that achieved by the general public. Thus, the prediction of 1 028 000 trips/year is untenable or perhaps represents an upper bound that will be approached but will never be reached.

Mathematical Formulation

In a number of studies (11, 12, 13), the New York State Department of Transportation has applied a technique of demand estimation that is based on (a) past observation, (b) surveys in which people are asked about their demand for new modes, and (c) analytic techniques that combine these two approaches. At the heart of the technique is what is known as the "noncommitment" method, in which a translation is made between what people say they will do if certain transportation changes are made and what they actually do when the changes are instituted.

The technique is applied here to the estimation of travel demand among the elderly and the handicapped in the event that specified barriers to the use of specific modes are removed. Use of the technique requires data on the perceptions of the design population with regard to well-defined barriers such as steps on buses and the degree to which these barriers impede travel. Other (survey) data that give personal estimates of travel as a function of the defined barriers and observational data (when it is possible to obtain them) that give current levels of travel as a function of well-defined barriers are also used.

Demand is then estimated by

1. Developing a quantitative barrier score (B_i) for each person as a function of the individual's assessment of possible transportation barriers he or she faces,
2. Determining trips the person says he or she would make if the barrier were removed (noncommitment trips),
3. Developing a mathematical relation for travel demand (T) as a function of overall barrier levels, and
4. Converting the noncommitment response to actual estimates of transit use.

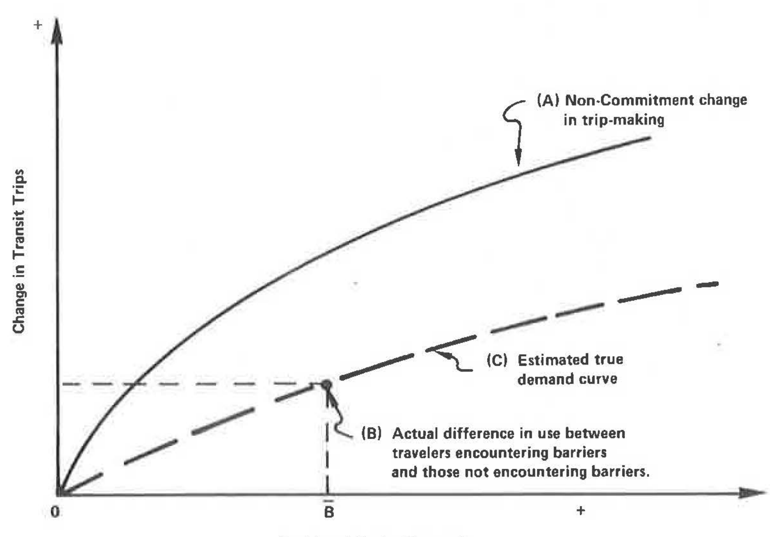
The noncommitment method is then used to estimate how much more the elderly or the handicapped would use transit if certain barriers to their use of it were removed. This technique extends basic models of transit demand among the elderly and the handicapped developed for the Albany, New York, area (13).

If barriers such as high boarding steps on buses prevent some elderly and handicapped persons from using transit service, it is logical to expect that ridership will increase if these barriers are removed. This general relation is shown in Figure 2. Curve A in the figure is a curve of noncommitment: It shows how much people say they would increase their use of the service if the barrier problem were reduced by a given amount. It must therefore be adjusted downward to account for overresponse. The adjustment procedure can be described as follows:

1. A point (B) that shows an actual relation between the perceived barrier problem and transit trips is established to compare trip rates and problems with barriers for actual elderly or handicapped transit riders. This observed point would be expected to fall well below the noncommitment line.
2. The noncommitment line may be factored down proportionately so that it passes through the observed point. The adjusted curve (C) provides a reasonable approximation of the true relation between a reduction in the barrier problem and a change in transit trips.

Respondents were asked to indicate whether each barrier they mentioned presented a moderate problem (score = 1) or a severe problem (score = 2). From these data, a "barrier score" was developed for each respondent (an additive model was assumed):

Figure 2. Relation between removal of barriers and use of transit.



$$B_i = \sum_{j=1}^{\text{all barriers}} b_{ij} \quad (4)$$

where

B_i = barrier score for person i ($B \geq 0$) and
b_{ij} = score assigned to barrier j by person i (0 if the barrier was not mentioned, 1 if the barrier was a moderate problem, and 2 if the barrier was a severe problem).

Each respondent was also asked to indicate how many transit (regular bus or dial-a-bus) trips he or she would make if the barriers he or she mentioned were removed. This item constitutes the raw noncommitment use of transit. The noncommitment change in transit use can be calculated from these data by subtracting the present rate of use:

$$\Delta T_{NC,i} = T_{NC,i} - T_i \quad (5)$$

where

$\Delta T_{NC,i}$ = noncommitment change in transit use for person i (trips/week),
$T_{NC,i}$ = noncommitment use for person i (trips/week), and
T_i = current reported transit use for person i (trips/week).

The data used in this example were collected in a telephone survey of households in Albany, New York, and in Schenectady and Rensselaer counties and part of Saratoga County in New York State. A systematic sampling procedure was used to obtain a random sample of 110 households with nonhandicapped, elderly members and 29 households with handicapped members. Demographic characteristics of the sample compared well with census data. Detailed documentation of the sample is given by Hartgen, Howe, and Pasko (13).

The travel data collected were essentially limited to the nonwork travel patterns of persons who were not at work on the day of the survey. In addition to demographics, trip frequency, and other choice data, the respondents were asked to identify problems they encountered in using bus service. They were not provided with a list of problems to choose from. Many respondents could not identify specific problems—probably because they were unfamiliar with the bus system. But several problems were mentioned frequently by both the elderly and the handicapped; these problems and the percentage of the respondents who mentioned them are given below:

Problem	Percentage of Respondents Mentioning Problem: Nonhandicapped Elderly	Percentage of Respondents Mentioning Problem: Handicapped
Climbing steps	17.0	59.3
Bad weather	14.2	33.3
No handrails	9.4	40.7
Crossing uneven ground	8.5	40.7
Street crossings and curbs	8.5	40.7
Seats not right	6.6	37.0
Not enough time to sit down	7.3	18.5
Distance to the vehicle	6.6	29.6
Length of travel time	6.4	11.1

The following analysis was performed for data on the nonhandicapped elderly from the Albany study for dial-a-bus only (110 respondents were sampled). First, the sample was divided into current transit users ($T_i > 0$) and current nonusers of transit ($T = 0$). (Twenty individuals in the sample reported using transit.) The data for transit users were then organized by barrier score (equation 4). The sample of elderly who currently use the system were divided into those who perceived no barriers or only slight barrier problems (score of 0 to 2) and those who perceived severe barrier problems (score of 3 or more). Current use of the bus system by elderly users is given below:

Ranking of Barrier Problem	Number of Persons in Group	Average Transit Trips per Week	Average Ranking of Barrier Problem
0 to 2	16	4.62	0.37
≥3	4	4.25	4.25

(The occurrence of the 4.25 figure in both of the last two columns is coincidental.) The average rate of trips per week was then plotted against the average perceived level of the barrier problem.

Because there are only two points to be plotted, a linear relation is predetermined. This line is shown in Figure 3. The equation for the line is

$$T = a - kB \quad (6)$$

where

T = actual transit trips,
B = perceived level of barrier problem, and
a and k = estimated parameters.

From the data analysis, the equation becomes

$$T = 4.63 - 0.09B \quad (7)$$

Equation 7 indicates that, as the perceived level of the barrier problem increases by one unit, the trip rate will decline by 0.09 unit. The noncommitment line, however, will be based on the ranking of the barrier removed (B_R). To reflect the sign of the coefficient,

$$T = 4.63 + 0.09(B_R) \quad (8)$$

This means that weekly travel will increase by 0.09 for each unit change in the barrier score. The relation shown in Equation 8 is plotted in Figure 3.

The noncommitment trip rate for dial-a-bus is determined by responses of elderly transit users to questions about how much they would use dial-a-bus service if barriers to its use were removed. In this case, the respondents are divided between those who perceive no barriers (ranking of 0) and those who perceive barriers (ranking of 1 or more):

Ranking of Barrier Problem	Number of Persons in Group	Average Noncommitment Trip Rate per Week	Average Ranking of Barrier Problem
0	11	5.0	0
≥1	9	6.6	2.55

Line B in Figure 3 plots the ranking of barriers removed versus noncommitment trips per week per user. The equation for the total noncommitment demand curve is determined to be

$$T_{NC} + 5.0 + 0.64B_R \quad (9)$$

where

T_{NC} = noncommitment trip rate and
B_R = ranking of barrier removed.

As expected, T_{NC} increases with increasing B_R. It is clear from Figure 3 that noncommitment trip rates (line B) increase much faster than actual trip rates (line A). It is possible to obtain the change in dial-a-bus transit use described as noncommitment change for various levels of barrier reduction by comparing the noncommitment trip rate (equation of line B in Figure 3) with the actual trip rate (equation of line A). Graphically, this would be the difference between lines A and B in Figure 3. The resulting noncommitment change in trip rates with change in the level of barrier reduction is shown in the figure as line C. The equation for this line is

$$T_{NC} + 0.27 + 0.55(B_R) \qquad (10)$$

where T_{NC} = change in the rate of transit trips.

The actual change in trip rates for a given B_R is substantially less. One point for actual change may be estimated from the line for the actual trip rate (line A in Figure 3). The difference between the trip rates of the two plotted levels of B_R provides this point. A change in B_R from 4.25 to 0.37 results in an actual increase in trip rate from 4.25 to 4.62. An actual decrease in B_R of 3.87 results then in a 0.37 increase in the rate of transit trips (point D in Figure 3).

The T_{NC} line in Figure 3 (line C) is then shifted proportionately downward so that it passes the actual observed data point (D). The equation that gives the change in transit use as a function of barrier removal (line E) is then estimated to be

$$T_B = 0.037 + 0.087(B_R) \qquad (11)$$

where T_B = change in transit use caused by a given barrier reduction, in trips per week. This equation represents the estimated actual change in the use of dial-a-bus service by elderly users if barriers of a B_R ranking were removed.

The results of the analyses described here can be fit to a more detailed analysis of demand for a given mode as a function of the removal or reduction of specific barriers. [A step-by-step analysis of this type for the elderly and the handicapped is given elsewhere by Knighton and Hartgen (13).] The analysis makes use in the following way of the data developed:

1. A base (mode-split) equation for transit use of the type transit trips per person per week = f (socioeconomic factors, automobile and transit availability, existing barriers) is used.
2. A quality improvement effect is added (the effect if an improved mode, such as dial-a-bus, is substituted for an old mode); that is, an increment of trips per person per week, independent of the barrier factor, is needed.
3. The effect of barrier removal is added (travel that will occur if specific barriers are removed, as calculated above).

One conclusion of the Albany analysis is that even an ambitious program of barrier removal will not greatly affect the rate of transit use. It is possible that even the effect shown in these examples is somewhat overstated because the effect of barrier reduction has been assumed to be additive. This assumption is reasonable when only a few barriers are considered, but many perceived barriers are interrelated—e.g., no shelter and bad weather, crowding and time to sit down. The model thus probably overstates the effect when several barriers are reduced simultaneously.

Regression Equations

The use of regression equations is perhaps most familiar to those estimating demand in cases in which data are available on a wide range of factors that influence both choice of mode and frequency of travel. Regression equations are, of course, based on data that describe the current population, and it is then inferred that future projections are affected by the same factors.

A detailed set of regression models has been developed for the prediction of travel demand for rural public transit systems (11). The following procedure is established for determining what type of analysis should be done:

1. Decide the type of service to be studied—fixed-route or demand-activated.
2. Determine the area of analysis—macro for systemwide estimates or micro for small geographic areas (these may be cited in sequence).

Figure 3. Method of determining travel demand in relation to removal of barriers.

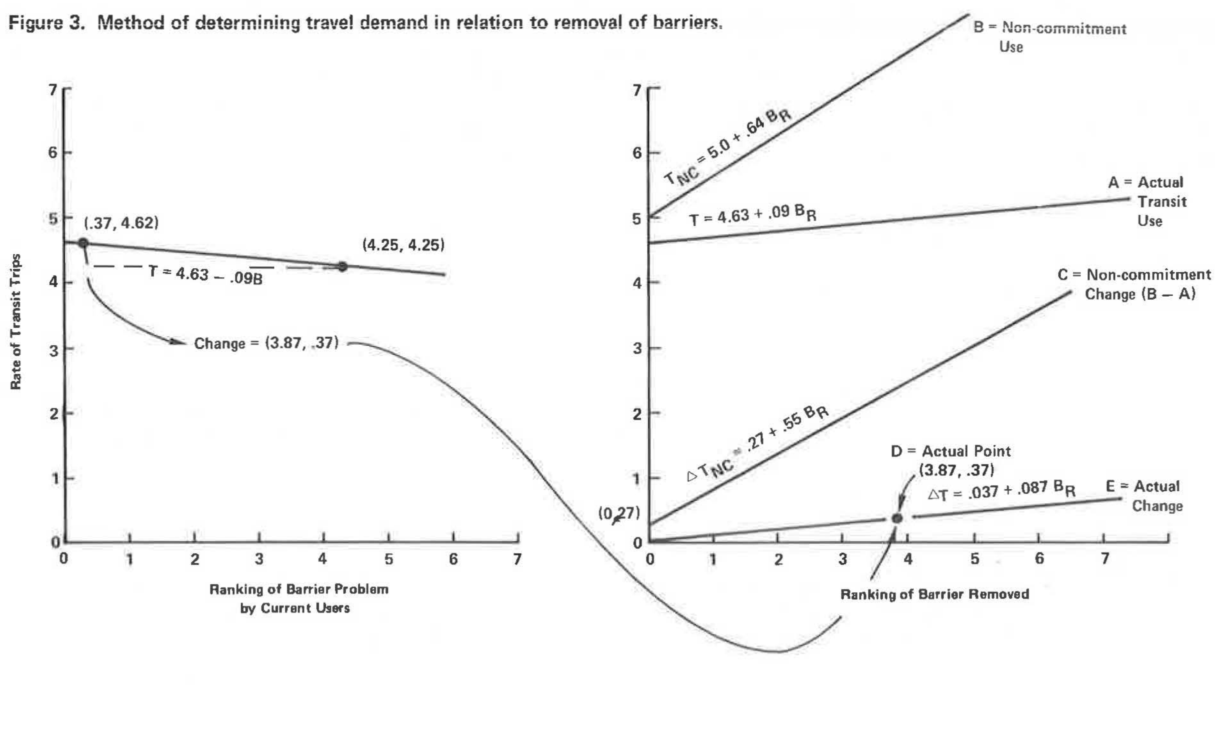
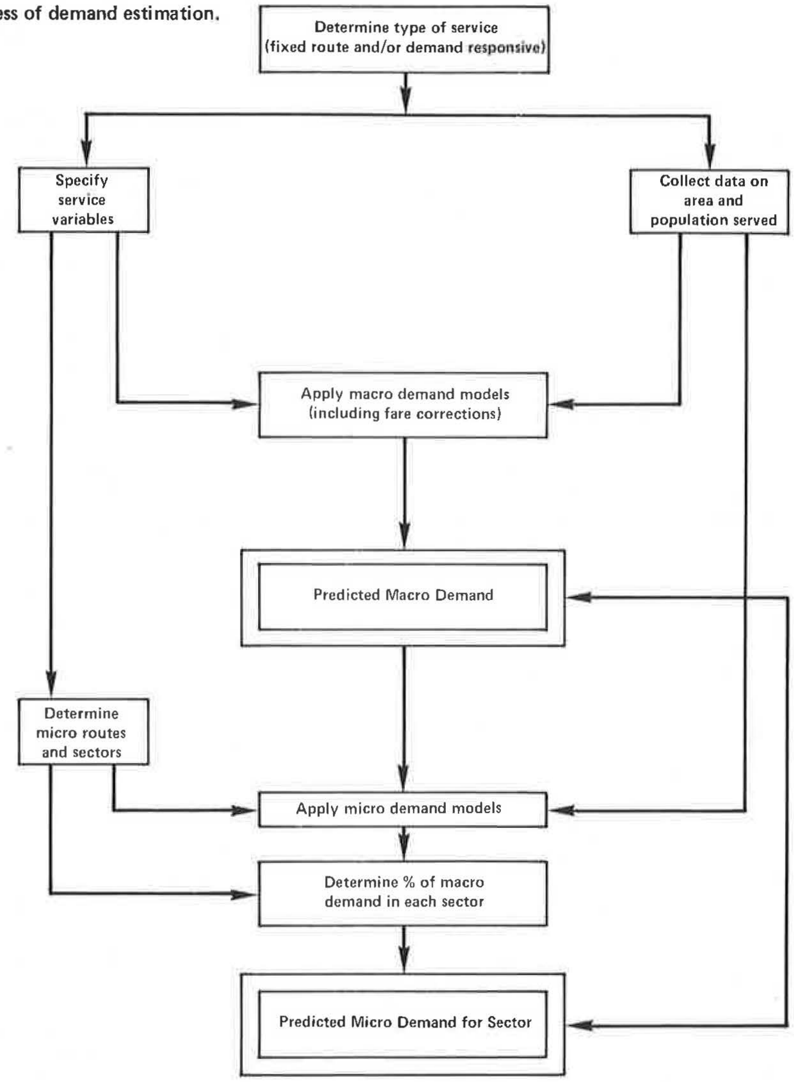


Figure 4. Flow diagram of the process of demand estimation.



3. Choose the data for estimating equations.
4. Evaluate parameters of the model in the following form: trips $= a_0 + a_1 x_1 + a_2 x_2 + \ldots$, where a_0 are estimated parameters and x are significant regression variables.

This sequence is shown in Figure 4.

For the example discussed here, that of rural transit, the following data are needed on the area served (because the regression models were developed in U.S. customary units, no equivalent SI units are given):

1. Population of the service area (usually county)—the number of persons to be served by the system;
2. Population with a high probability of transit use—the number of persons who will most likely use the system, defined in most cases as the poor plus the elderly who are not poor (unless service is restricted to some particular group, such as the poor alone);
3. Restricted population (if applicable)—the number of persons who are allowed to use the system (if there are no restrictions, the population of the service area is used as the restricted population);
4. Other transportation systems in the area—if a fixed-route system is planned, the number of bus miles provided by all other fixed-route and demand-responsive systems and, if a demand-responsive system is planned, whether or not any other public transit is available;
5. Distribution of trips—by type of destination [if there is reason to believe that the distribution of trips by destination will vary significantly from that given by Burkhardt and Lago (14), their values may be substituted]; and
6. Land use data—the location of activities and land uses that will act as major trip generators for rural systems, given in sufficient detail so that activities that function as probable trip destinations by sector or route can be located.

The kind of service the system will provide must be established before demand is estimated. System specifications can be changed several times in an analysis. Specified system characteristics should include

1. Bus miles—the total number of vehicle miles traveled by all vehicles in the system during an average month,
2. Frequency of service (for fixed-route systems only)—the number of times per day or per month that service is provided on a particular route,
3. Reservation time (for demand-responsive systems only)—the average amount of time between a call for service and pickup by the vehicle,
4. Trip distance—the round-trip distances for routes or sectors for the micro models, and
5. Fares—the average out-of-pocket cost per passenger for one-way trips.

Examples

Examples of the development of regression equations for fixed-route systems are given below.

Macro (Systemwide) Estimates

To determine how many persons would be served on a fixed-route system, the following model, based on Pennsylvania data, was used:

$$\log RTPASS/M = -0.353 + 0.407 \log BMILES + 0.533 \log FREQ + 0.611 \log RESTRPOP - 0.123 \log COMPBMS \quad (12)$$

where

RTPASS/M = number of round-trip passengers per month on the system;
BMILES = total vehicle miles per month for all vehicles on the system;
FREQ = average round-trip service frequency per month along fixed routes of the system (determined by dividing total bus miles per month by total round-trip route mileage);
RESTRPOP = number of persons (in hundreds) who live in townships and boroughs along the routes and can use the system (if there are no restrictions on use of the system, this number is the same as the total population); and
COMPBMS = sum of the monthly bus miles of all other fixed-route and demand-responsive systems operating in the service area (which may or may not coincide with the county).

Round-trip route mileage is defined as the sum of the actual physical length of all routes regardless of the number of times certain portions of the street or road may be duplicated by other routes. One-way route mileage is defined as half the round-trip route mileage. The persons who live along the routes comprise the population in townships and boroughs traversed by the routes. Double counting of this population should be avoided in cases where two or more routes operate in the same borough or township. Taxi service is not included in the sum of bus miles for the COMPBMS variable (bus miles of competing systems) because the limited taxi information available was found to be insignificant.

Micro (Route) Estimates

The following equation should be used in estimating by route how many persons would be served on a fixed-route system:

$$\log(OWPASS/DAY) = 6.344 + 0.697 \log FREQ - 2.547 \log D + \log PoP_o + \log PoP_d \quad (13)$$

where

OWPASS/DAY = number of boarding or one-way passengers per day on the specific route being examined (one-way passengers are approximately twice the number of round-trip passengers);
FREQ = number of round trips on the route per day;
D = round-trip distance between the farthest origin point served and the main destination (miles);
PoP_o = population (in hundreds of thousands of people) of the townships, boroughs, and cities traversed by the route on the given day minus the population of the largest city or township (which is defined as the destination population); and
PoP_d = population (in hundreds of thousands of people) of the largest city or borough traversed by the route on the given day.

The micro route model has been developed on a daily basis because the frequencies and even the length of routes may be different on weekdays, weekends, and holidays. Equation 13 may be used to determine transit use on weekdays and weekends by separately introducing weekday and weekend service attributes into the equation.

One-way passengers per month may be derived by multiplying the daily figures in Equation 2 by the number of weekdays and the number of Saturdays and Sundays that service is provided. The systems examined operated, on the average, 21.5 d/month. Round-trip passengers can be found by dividing the number of one-way passengers by 2.

In the overall analysis of a variety of rural travel systems, several crucial variables that account for most of the variation in the estimates of demand were identified:

1. Bus miles of service per month—The more service is provided, the more people will ride the system. But the increase is not proportional, which means that bus miles will increase faster than the number of riders. At some point, the cost of adding bus miles will be greater than the benefit that results from more passengers using the system. Bus miles of service must not be increased beyond that point.

2. Availability of service—For fixed-route systems, availability of service can be expressed as service frequency (the number of times per day or per week a particular route is served); for demand-responsive systems, it is the reservation time (the number of hours or days between the request for service and the pickup). Again, the increase in patronage is less than proportional to the increase in service.

3. Population served—As the population served by the transit system increases, the number of riders will increase but at a slower rate than the population. This means, for example, that, if the population served increased by 100 percent, the number of riders would increase by less than 100 percent. Indications are that, as major increases in density occur, the relation is less valid.

4. Other public transportation systems—As the service provided by other transportation systems increases, the number of riders attracted to a system decreases. But the decrease in patronage is less than the increase in competition.

5. Trip distance—As the trip distance increases, the number of passengers will decrease. On demand-responsive systems, the decrease in passengers will occur at a greater rate than the increase in distance, which means that increases in distance will have more of a negative impact on fixed-route than on demand-responsive services.

6. Fares—As the cost of the trip increases, the number of riders will decrease; the percentage decrease in riders will be smaller than the percentage increase in fares.

Use of the Equations

In the development of regression equations to be used in determining transit demand for a variety of systems, estimates of the number of persons served often show substantial variation. The number of trips actually made when a system is operational may differ slightly from the number of trips predicted by the models. It is important to remember that the demand equations provide estimates, not iron-clad guarantees.

The greatest benefit of the demand equations is that they provide a "ballpark" estimate of how many people might use a transit system under specific area and system conditions. In using such equations, it is possible to experiment with different levels of service to find the most appropriate system configuration for a given area.

SUMMARY

The variety of techniques presented here for estimating the travel demand of the transportation disadvantaged are not comparative techniques. That is, one method is not inherently better than another method. Rather, the techniques show that demand estimates for special transportation services for particular groups must still be done on an ad hoc basis. Each technique requires the following elements: (a) a description of the population to be served, (b) an estimate of their current travel patterns, (c) a detailed description of new transportation systems or system improvements, and (d) some description of the service area.

Estimates of travel demand are ballpark figures, but they are helpful in the decision-making process when resources are to be committed to making changes in the system.

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