TRANSPORTATION RESEARCH RECORD 660

Improving Transportation Services for the Elderly, the Handicapped, and the Disadvantaged

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Life-Styles and Transportation Patterns of the Elderly in Los Angeles

James B. Bunker, Robert D. Blanchard, and Martin Wachs, University of California, Los Angeles

The diversity of the elderly population in Los Angeles County is studied by using the concept of life-style. Life-style is defined by a set of socioeconomic, demographic, and behavioral characteristics. A methodology is presented that uses factorial ecology techniques; the data required are commonly available from census and administrative sources in metropolitan areas. Factor analysis is applied to census tracts to define dimensions of life-style that represent the major differentiating characteristics of elderly populations. Homogeneous life-style groups among the elderly are then identified by clustering tracts that show similar life-style dimensions. Finally, analysis of variance is used to identify differences in the travel characteristics of life-style groups. An investigation of the elderly population of Los Angeles County was conducted as a case study. Seven dimensions were defined that provided a basis for the identification of seven elderly life-style groups. Each group was found to be unique in terms of travel demands and socioeconomic composition. Life-style groups were also found to reside in specific areas of the county, a necessary condition for meeting their transportation needs.

Since 1970, considerable effort has been devoted to identifying the special transportation needs of the elderly. Federal, state, and local funds have been used for accessibility and mobility studies and for improvements in public transportation services for older Americans. Although significant advances have been made in these areas, senior citizens still seem to be viewed by transportation planners as a homogeneous group with common problems and needs. They are often stereotyped as central city residents who are relatively nonmobile, poor, and dependent on social security and public transportation. This is true of many of the elderly, but many studies have demonstrated that the elderly are actually a very diverse group. For example, census data for 1970 show that, although half of the elderly of Los Angeles County, California, resided on the most densely populated 5 percent of the land, the other half was scattered at much lower densities on the remaining 95 percent (1). Socioeconomic and demographic characteristics and travel demands of the elderly have also been shown to vary considerably with location in urban areas. These variations in travel behavior have important implications for the provision of transportation services for the elderly, but they have generally not been taken into account in transportation planning.

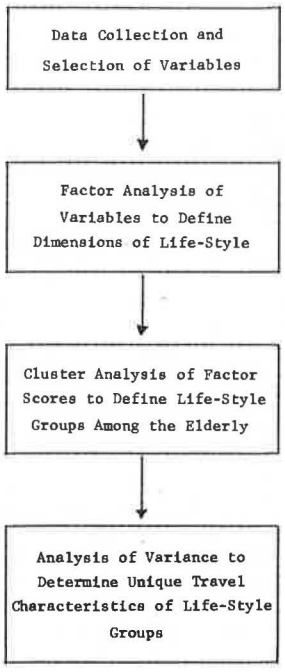
The concept of life-style is a potentially powerful tool for studying the residential location and travel patterns of the elderly (2). In this paper, life-style is taken to mean particular combinations of socioeconomic and demographic variables that represent the situations in which people live. Among these variables are income, family status, educational attainment, and residential density. In the elderly population, one life-style group of single persons may live alone in high-density, low-income, ethnically diverse areas characterized by relatively poor health. This life-style group would have very different travel needs and behavior than one consisting largely of husband and wife families who are in good health and live independently on moderate to high incomes in ethnically homogeneous areas. Because members of a life-style group are likely to live in close proximity to other members of the same group, it should be possible to distinguish between residential communities of the elderly on the basis of the life-styles of their residents.

This paper presents a methodology for using the concept of life-style in analysis and for identifying life-style groups among the elderly. The hypothesis that residential location and travel patterns differ significantly betwen life-style groups is also investigated. The methods are based on the factor analysis and cluster analysis techniques of factorial ecology and require age-specific data that describe the elderly population at a census-tract level. The methodology and the results of an application of the methods in a case study of the elderly population of Los Angeles County are described. Also discussed are the implications of the findings for the provision of transportation services for today's elderly population and for future generations of the elderly.

METHODOLOGY

The methodology consisted of four steps (Figure 1). First, socioeconomic and demographic variables describing the elderly population were obtained. These variables documented such attributes as automobile ownership, economic resources, social living arrangements, ethnicity, sex, physical living arrangements, educational attainment, and health (3). The primary data source was the 1970 files of the U.S. Bureau of the Census. Detailed age-specific data describing automobile ownership, income, household composition, and

Figure 1. Flow chart of research methodology.



employment were not available from regular census tabulations and were obtained as a special tabulation by the Bureau of the Census. Data describing the health of the elderly—including morbidity, mortality, and mental health care admission rates—were obtained at the census-tract level from the Los Angeles County Department of Health Services. All variables were expressed as relative frequencies. For example, the number of elderly females in a zone was expressed as the percentage of the elderly in the zone who were female.

The second step was to use principal components factor analysis to reduce the set of descriptive variables for the elderly population into a smaller number of life-style dimensions. The factors extracted through principal components analysis were rotated to varimax position, which resulted in a solution of "simple structure" in which each variable tended to associate, or load highly, with only one factor. This property of the solution made it possible to describe and interpret the factors more easily in terms of the variables with which they were most closely associated.

The number of factors retained and rotated was determined by examining the eigenvalues of the unrotated factors and the interpretability of the rotated factors. The procedure for accomplishing this involved the following steps. Initially, all factors with eigenvalues greater than 1.0 were rotated. These factors were then examined for their interpretability in the context of this study. If a factor could not be interpreted, the unrotated factor with the smallest eigenvalue was eliminated and the remaining factors were rotated and examined. These steps were repeated until it was determined that all rotated factors were interpretable. Factor scores that measured the positions of the zones with respect to the factor dimensions were then computed.

After the variable set was reduced to a smaller number of dimensions, cluster analysis was applied to identify homogeneous life-style groups. Zones with similar factor scores on the dimensions were clustered by using the K-means algorithm developed by MacQueen (5,6). The distance between a pair of zones was measured as the Euclidean distance in the factor space. That is, D_{xy}, the distance between zones x and y, was defined as follows:

$$D_{xy} = \sqrt{\sum_{i=1}^{p} (x_i - y_i)^2} \qquad (1)$$

where x_i and y_i are the factor scores corresponding to zones x and y respectively for the ith dimension and p is the number of factors defined in the principal components analysis.

The number of clusters in the final solution was determined by examining solutions with from 5 to 20 clusters and choosing the one in which the clusters were most easily identified and interpreted. Each cluster represented an area within the county in which the elderly residents tended to share common socioeconomic and demographic characteristics.

Finally, aggregate patterns of travel behavior of the life-style groups were identified, and analysis-of-variance (ANOVA) was applied to test for the presence of significant differences in those patterns among the groups. Data describing the travel patterns of the elderly were obtained from the 1967 Los Angeles Regional Transportation Study (LARTS), which consisted of an origin-destination survey of a 1 percent sample of the households in the Los Angeles area (7). The following travel variables were created from these data: possession of a driver's license (yes or no); vehicular travel on the survey day (yes or no); number of automobile driver trips on the survey day; number of automobile passenger trips; number of bus passenger trips; and number of trips for each of four purposes—personal business, leisure, work, and shopping.

One-way ANOVA was then applied to test for significant overall differences between group means for the travel variables. A value of the F-statistic of ANOVA was computed for each variable. The overall differences for each travel variable were considered to be significant if the value of F exceeded the value indicating statistical significance at the 0.01 level.

RESULTS OF FACTOR ANALYSIS

Fifty-one variables describing life-style were created from the available data (Table 1). The application of principal components analysis resulted in a seven-factor solution in which each factor was logically interpretable. The seven factors accounted for 57.0 percent of the variance in the original data matrix. The factor-loading matrix for the seven-factor solution is given in Table 2. The percentage of variance explained by each rotated factor is tallied under the corresponding column of factor loadings. By examining the factor-loading matrix, it was possible to label and interpret each life-style dimension as follows:

1. Proximity to services—The first dimension was strongly associated with variables describing social living arrangements, economic resources, and automobile ownership and appeared to be an index of the need to reside in close proximity to services, including public transportation. Many elderly residents of zones with positive factor scores probably had a significant need for such services. They tended to live alone, in densely populated areas of the county, on low incomes, and in older apartment structures. The rate of automobile ownership among the residents was also relatively low.

2. Financial security—Several variables that reflected wealth, occupational status, and income were correlated with this dimension of life-style. In portions of the county with positive factor scores, the elderly tended to live in expensive housing and apartments on moderate to high incomes; apartment living was a common physical living arrangement. A large proportion of the elderly residents owned automobiles and had college educations, and those who worked generally had white-collar jobs.

3. Isolation—Like the first two dimensions, the third dimension was closely associated with income variables. Descriptors of employment status, automobile ownership, and sex of the elderly population were also correlated with this factor. It is likely that many of the senior residents of the zones with positive scores were socially isolated and nonmobile. They were characterized by low automobile-ownership rates, employment levels, and incomes. A relatively high proportion of the households received social security or railroad retirement benefits as their principal source of income. Elderly females far outnumbered males of retirement age, which suggests that a relatively high percentage of the elderly females were widows.

4. Long-term residence—The fourth factor was almost exclusively related to physical living arrangements and included variables descriptive of the age of housing and the year of occupancy. Zones with positive scores were among the most stable residential areas in the county. Many elderly residents moved into their homes before 1950, and a large proportion occupied single-family dwellings. Despite the social and economic pressures that often force those in retirement to move to apartments or smaller homes, many of the

elderly had remained in residences they had occupied since they were much younger.

5. Race and occupation—The fifth life-style dimension reflected the ethnic composition of the elderly population and the occupations of those who worked. Elderly blacks and persons with service-related occupations tended to live in zones with positive factor scores. Although a small proportion of the elderly population was white, these elderly whites constituted a relatively large proportion of the total white population of the zones. The value of homes in these areas was relatively low—evidence of the fact that service employment is associated with low income.

6. Spanish American ethnicity—This dimension was also associated with variables descriptive of ethnicity and occupational status and was strongly related to measures of educational attainment. Positive scores identified areas in which both the Anglo and Spanish American cultures were represented. Elderly persons of Spanish American background who had low levels of formal education and blue-collar occupations were concentrated in these areas. Home values, rents, and the level of automobile ownership were relatively low, and a significant proportion of the elderly families were classified as living in poverty.

7. Poor health—The seventh dimension was an index of the health-related status of the elderly and was closely related to mortality and morbidity rates. Variables describing the proportion of the elderly population who had participated in World War I and the proportion who lived in homes for the aged and dependent were also correlated with this dimension, and these variables appeared to be indirectly related to health status. Zones with positive scores showed high morbidity and mortality rates, relatively high proportions of married elderly, and significant numbers of the elderly living in homes for the aged.

RESULTS OF CLUSTER ANALYSIS

The seven life-style dimensions represented the major sources of variation in the original set of 51 variables, and each dimension represented an important characteristic on the basis of which the elderly populations of the zones in Los Angeles County could be distinguished from one another. Cluster analysis was then applied to the matrix of factor scores in order to identify homogeneous life-style groups among the elderly. After solutions with from 5 to 20 clusters were examined, the 7-cluster solution was chosen because of the high degree of geographic contiguity among the zones within the clusters and because the areas represented by the clusters could be easily identified and described.

The seven life-style groups were given the following descriptive titles: (a) central city dwellers, (b) the financially secure, (c) the institutionalized, (d) new sub-

Table 1. Glossary of census and administrative variables.

Variable	Definition
AUTOF0	Percentage of elderly husband-wife and other families with no automobiles available
AUTOF2	Percentage of elderly husband-wife and other families with two or more automobiles available
AUTOP0	Percentage of elderly primary-individual families with no automobiles available
AUTOP2	Percentage of elderly primary-individual families with two or more automobiles available
BENFIT	Percentage of elderly persons receiving social security or railroad retirement payments
B1949	Percentage of elderly-occupied units built in 1949 or earlier
B6064	Percentage of elderly-occupied units built from 1960 to 1964
B6570	Percentage of elderly-occupied units built from 1965 to 1970
CNEGRO	Percentage of the elderly who are black
CSPAN	Percentage of the elderly who are Spanish American
CWHITE	Percentage of the elderly who are white
DENPOP	Density of elderly population
EDLT5	Percentage of the elderly with less than 5 years of education
ED912	Percentage of the elderly with 9 to 12 years of education
EDCOLL	Percentage of the elderly with 1 or more years of college education
EMPL52	Percentage of the elderly employed 50 to 52 weeks in 1969
FAMILY	Percentage of the elderly residing in homes for the aged or other dependent situations
FEMALE	Percentage of the elderly who are female
HUSWFE	Percentage of elderly households classified as husband-wife households
ILT3K	Percentage of elderly-occupied units with a household income of less than $3000/year
I7K15K	Percentage of elderly-occupied units with a household income of from $7000 to $15 000/year
IGT15K	Percentage of elderly-occupied units with a household income of $15 000 or more/year
MARRY	Percentage of the elderly who are married
MENTAL	Annual visitation rate among the elderly at county mental health facilities
MOBLE	Percentage of the elderly occupying mobile homes or trailer units
MORBID	Annual morbidity rate of communicable diseases among the elderly reported at county health facilities
MORTAL	Annual mortality rate among the elderly per 100 persons
NEGROC	Percentage of the black population who are elderly
NOTEMP	Percentage of the elderly not employed in 1969
01949	Percentage of elderly-occupied units occupied by head before 1949
06064	Percentage of elderly-occupied units occupied by head from 1960 to 1964
06570	Percentage of elderly-occupied units occupied by head from 1965 to 1970
OCCBC	Percentage of members of the elderly labor force classified as blue-collar workers
OCCSER	Percentage of members of the elderly labor force classified as service workers
OCCWC	Percentage of members of the elderly labor force classified as white-collar workers
OWNOCC	Percentage of elderly-occupied units that are owner occupied
POOR	Percentage of the elderly classified as being below the poverty level
POP	Percentage of the total population who are elderly
PRMIND	Percentage of elderly households classified as primary-individual households
RELATV	Percentage of families with elderly family members in residence (other than the head of household or spouse)
RTLT60	Percentage of housing units occupied by elderly renters that rent for less than $60
RT6099	Percentage of housing units occupied by elderly renters that rent for from $60 to $99
RGT150	Percentage of housing units occupied by elderly renters that rent for $150 or more
SPANC	Percentage of the Spanish American population who are elderly
UNITS1	Percentage of housing units occupied by elderly renters in one-unit structures
UNITS3	Percentage of housing units occupied by elderly renters in structures of three or more units
VLLT15	Percentage of housing units valued at $15 000 or less that are occupied by elderly owners
VL1520	Percentage of housing units valued at $15 000 to $19 000 that are occupied by elderly owners
VLGT25	Percentage of housing units valued at $25 000 or more that are occupied by elderly owners
WHITEC	Percentage of the white population who are elderly
WWIVET	Percentage of elderly persons classified as World War I veterans

urbanites, (e) the black community, (f) the Spanish American community, and (g) early suburbanites. The travel-variable means and the ANOVA results are given in Table 3. Because the cluster of zones in which the institutionalized resided consisted of only 14 zones and because only 23 persons in the LARTS sample resided in this area, travel data for the institutionalized group were not listed in Table 3 and were not incorporated in the ANOVA.

The ANOVA results showed that there were statistically significant differences between the life-style groups for eight of the nine travel variables. The groups were not found to be significantly different from one another in terms of the number of trips made for the work purpose. Table 3 shows that the range of mean values for this variable varied only slightly—from a low value of 0.13 trips/person for the Spanish American community and central city life-style groups to a high value of 0.23 trips/person for the new suburbanite and the financially secure life-style groups. The lack of variation could be attributed to the fact that very few trips were made for the work purpose, which leaves little room for variation. But it may also be explained by the fact that the distribution of employment rates was relatively uniform across life-style groups.

Three elements of the data base were used in the description of life-style groups:

1. Detailed census data were aggregated to the cluster level to provide socioeconomic and demographic profiles of the life-style groups.
2. The nine travel variables defined previously were computed for each group to describe characteristics of travel behavior.
3. Maps of the clusters were produced so that the residential locations of life-style groups could be identified.

Central City Dwellers

The first life-style group represented about 26 percent of the county's elderly population and included many

Table 2. Factor-loading matrix.

	Factor						
Variable	Proximity to Service	Financial Security	Isolation	Long-Term Residence	Race and Occupation	Spanish American Ethnicity	Poor Health
PRMIND	0.827						
HUSWFE	-0.822						
OWNOCC	-0.812						
POP	0.757						
DENPOP	0.738						
WHITEC	0.653				0.315		
B1949	0.547			0.629			
UNITS3	0.527	0.373					
AUTOF0	0.524					0.322	
ILT3K	0.512	-0.526	0.330				
I7K15K	-0.512	0.427					
AUTOP0	0.509		0.390				
FAMILY	-0.467						0.421
POOR	0.437	-0.369				0.397	
AUTOF2	-0.362	0.307	-0.546				
SPANC	0.357						
06570	0.357			-0.660			
RT6099	0.349	-0.533					
UNITS1	-0.336						
RELATV	0.321	0.307					0.474
01949				0.794			
VLGT25		0.820					
OCCWC		0.739			-0.307	-0.384	
EDCOLL		0.719					
RGT150		0.679					
VL1520		-0.628					
OCCBC		-0.607				0.344	
VLLT15		-0.486			0.376	0.342	
IGT15K		0.434	-0.723				
EMPL52		0.425					
OCCSER		-0.381			0.699		
NOTEMP			0.689				
ED912						-0.627	
EDLT5						0.749	
FEMALE			0.705			-0.349	
AUTOP2			-0.667				
BENFIT			0.592				
B6570				-0.605			
B6064				-0.661			
06064				-0.417			
CNEGRO					0.891		
CWHITE					-0.865		
NEGROC							
CSPAN						0.783	
RTLT60						0.428	
WWIVET							0.749
MORTAL							0.695
MARRY							0.634
MORBID							0.418
MOBLE							
MENTAL							
Percentage variance explained	13.34	11.60	7.45	6.54	6.37	6.82	4.89

Note: Only factor loadings greater than 0.3 in absolute value are listed.

persons who resided in and near its major urban centers (Figure 2). The mean value for the zones for the dimension of proximity to services was especially high, indicating that this life-style group was unique in terms of home- and automobile-ownership rates, the percentage of single-person households, the average income, and the age of the structures occupied. Although nearly 50 percent of the residences in the county occupied by elderly households were owned, only about 26 percent of central city dwellers owned homes. Almost 47 percent of elderly households had moved into their residences since 1965, a percentage considerably higher than the county average of about 36 percent. But most of the structures were quite old; more than 69 percent were built before 1950.

Almost 47 percent of the households were composed of single persons compared with the country average of 34 percent. In addition, because about 71 percent of the persons living alone did not own an automobile, an especially high dependence on friends and relatives who drive and on public transportation could be expected in this area. The low level of automobile ownership was probably related to the inability of many residents to afford automobiles. Incomes of less than $3000/year were reported by almost half of the households. Although it is commonly believed that central city areas are the location of the least mobile elderly subpopulation, the LARTS data showed that this is not the case. The average number of trips reported by members of this life-style group was below the average for the county's elderly population, but it was much higher than rates for the Spanish American and black community life-style groups. This group had the highest rate of bus travel and relatively high rates of automobile driver and automobile passenger trip making. Central city dwellers nonetheless tended to make fewer vehicle trips than the average elderly person in the county.

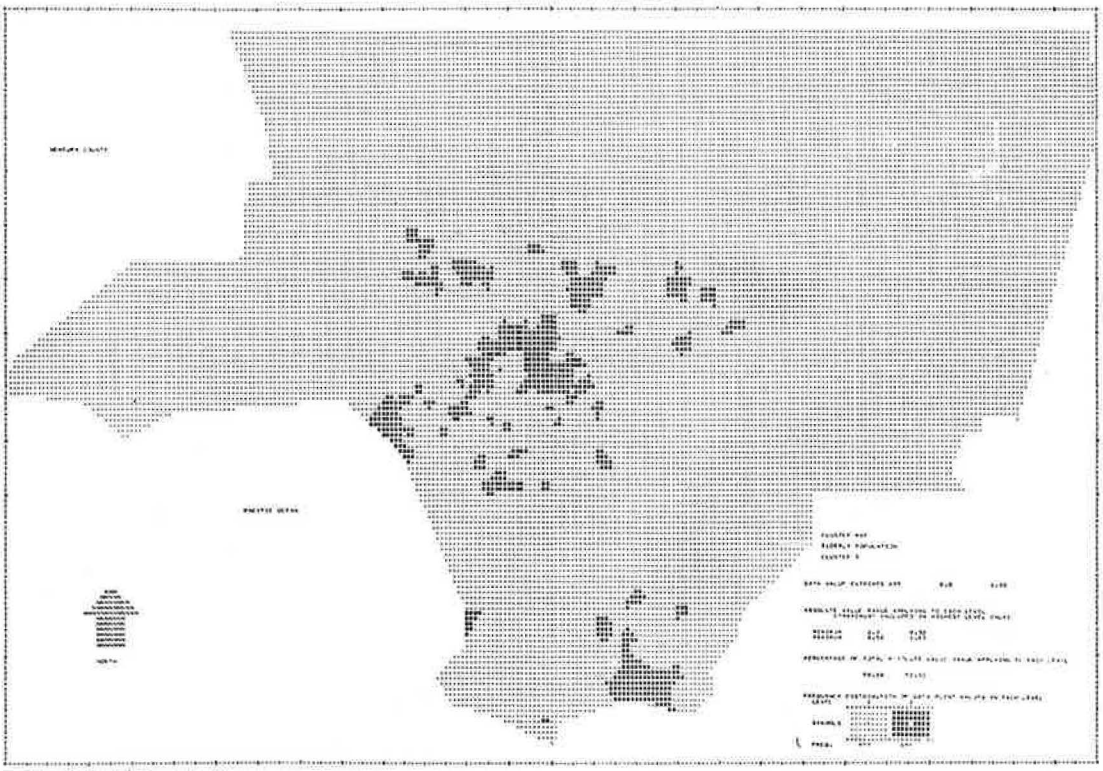
The average number of trips reported by the mem-

Table 3. Travel-variable means and results of analysis of variance.

Travel Variable	Life-Style Group							
	Central City Dwellers	Financially Secure	New Suburbanites	Black Community	Spanish American Community	Early Suburbanites	County	F-Statistic
Percent with drivers' licenses	34.55	58.64	48.14	32.89	23.43	45.61	42.49	39.24[a]
Percent reporting vehicle travel	40.82	55.95	47.84	33.68	31.35	47.11	44.79	19.19[a]
Automobile driver trips	0.66	1.38	1.04	0.56	0.40	1.02	0.91	23.86[a]
Automobile passenger trips	0.35	0.52	0.43	0.21	0.23	0.49	0.42	8.58[a]
Public bus passenger trips	0.21	0.09	0.04	0.16	0.19	0.05	0.11	26.06[a]
Personal business trips	0.59	0.92	0.62	0.53	0.44	0.70	0.66	12.05[a]
Leisure trips	0.23	0.43	0.30	0.13	0.09	0.29	0.27	11.99[a]
Work trips	0.13	0.23	0.23	0.16	0.13	0.19	0.18	2.36
Shopping trips	0.31	0.46	0.39	0.16	0.21	0.43	0.36	13.03[a]
Total trips	1.26	2.04	1.54	0.98	0.87	1.61	1.47	
Sample size	1528	736	706	387	308	2080	5768[b]	

[a] Statistically significant at the 0.01 level.
[b] Includes 23 persons who resided in the institutionalized life-style area

Figure 2. Life-style area of central city dwellers.



bers of this group on the survey day was 1.26/person, or about 85 percent of the county average. Forty percent reported at least 1 trip, only 4 percentage points lower than the county figure, and 7 and 9 percentage points higher than for the black and Spanish American communities respectively. The rate of driving was much lower than the countywide rate, which reflected the low level of automobile ownership among the residents. However, the average number of automobile passenger trips was 0.35, only slightly lower than the county average of 0.42. Bus ridership was nearly double the county average of 0.11 trips/person/d. Trip-making rates for the four trip purposes were all fractionally lower than the county rates.

The Financially Secure

Figure 3 shows the second life-style area, that in which the most affluent portion of the elderly population is located. On the average, members of the financially secure life-style group earned high incomes, lived in expensive homes and apartments, and were high school or college educated. They appeared to be unburdened by the economic constraints that often accompany retirement and that tend to limit travel and the ability to engage in activities. About 14 percent of the county's elderly were members of this group. The life-style dimension most strongly represented in this cluster was financial security; the mean value of the long-term residence dimension was also relatively high. Many of the residents therefore lived on high incomes, had lived in their homes for a long period of time, and had grown old with their neighborhoods and communities. About 60 percent of the housing units occupied by members of this group were owned, and more than 70 percent of the homes were valued at over $25 000. Among those who rented, about 40 percent paid ≥ $150/month. This percentage was substantially higher than the county figure of 12 percent. About 25 percent of the elderly had lived in their homes for 20 years or more, and approximately the same proportion had moved into their residences since 1965.

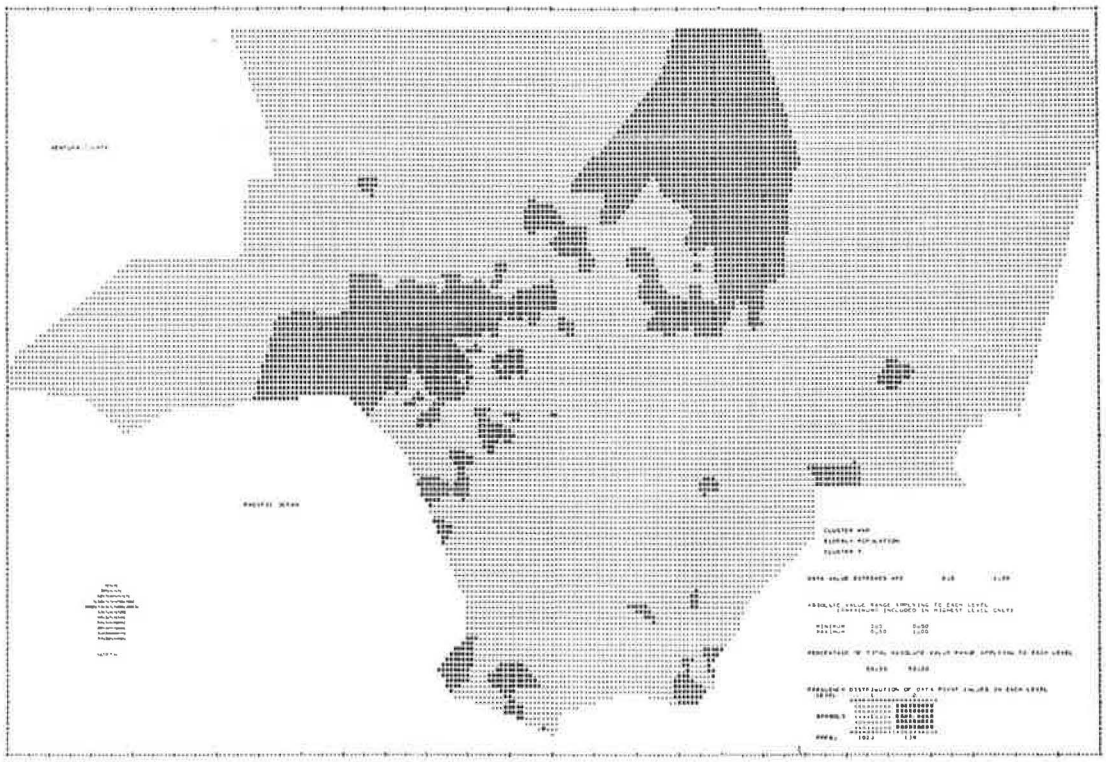
Education and employment levels were also quite high. More than 32 percent of the group were college educated compared with a countywide figure for the elderly of about 17 percent. Forty-five percent of the residents continued to work past retirement age in some capacity, primarily in white-collar occupations.

The average number of trips reported by members of this life-style group was 2.04 trips/person, over one-third higher than the countywide rate and the highest among the life-style groups. The proportion of licensed drivers—59 percent—and the proportion that reported at least one vehicular trip—56 percent—were much larger than the corresponding proportions for the elderly of the county. The average number of work trips was relatively high, and the frequencies of travel for the other trip purposes were much greater than in any other life-style area. The daily number of personal business trips was 0.92 trip/person—approximately as high as the average rates of trip making for the Spanish American and black community groups for all trip purposes and significantly higher than the county average of 0.66 trips/person. Automobile passenger trips were also made more frequently in this area than in any other life-style area.

The Institutionalized

The third life-style area was unique in that it consisted of only fourteen zones (Figure 4). A large positive mean value in the dimension of poor health indicated that this area was the location of elderly who frequently experienced health problems and visited county medical facilties. An examination of census data on a zone-by-zone basis revealed that this life-style group included less than 1 percent of the county's elderly population

Figure 3. Life-style area of the financially secure.



and that a large proportion resided in health care centers such as hospitals, convalescent homes, or other group quarters for the aged. Because the LARTS sampling rate was low, the institutionalized group was not considered in the analysis of travel data. The sample size of 23 was considered to be too small to give an accurate description of the travel patterns of the group members.

New Suburbanites

The new suburbanites lived in the most recently populated areas of the county and represented 12 percent of the county's elderly population (Figure 5). They had suf-

Figure 4. Life-style area of the institutionalized.

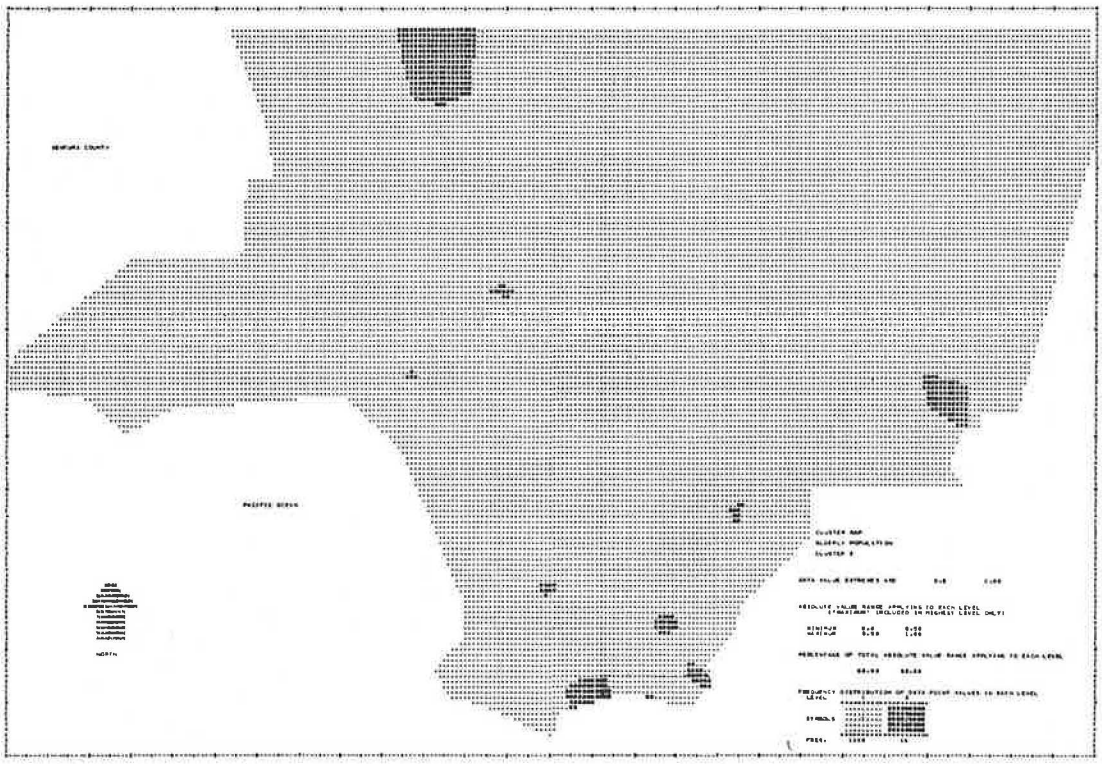
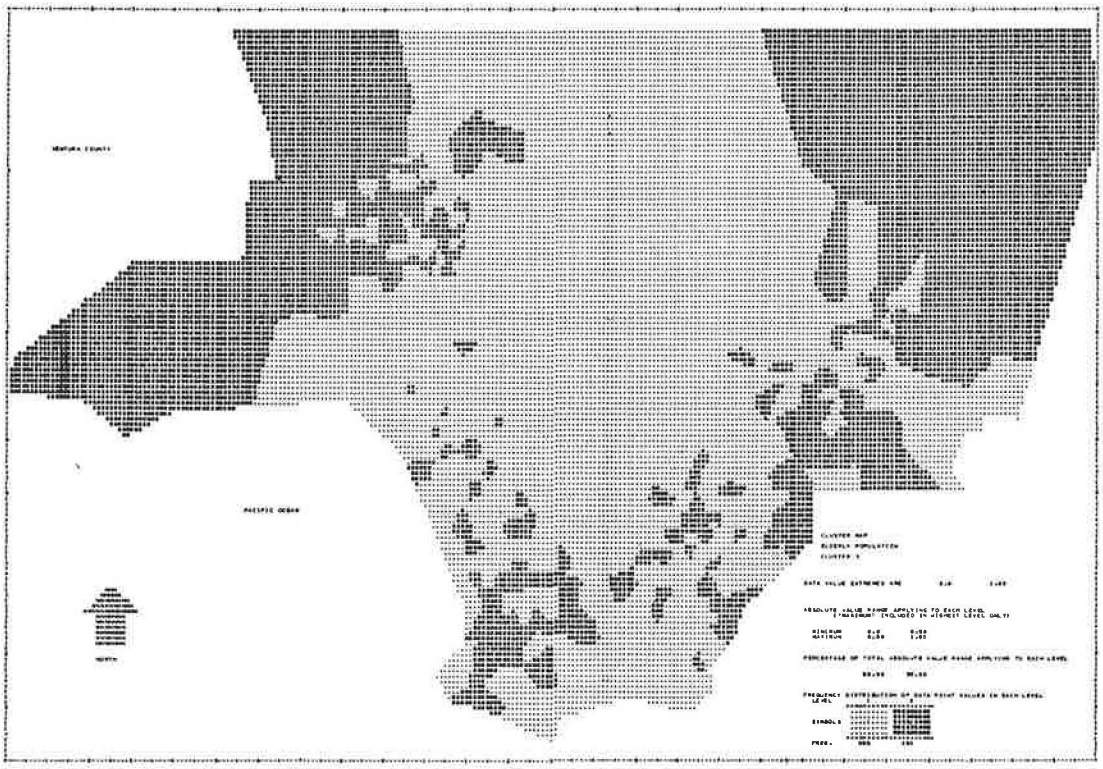


Figure 5. Life-style area of new suburbanites.



ficient economic resources to maintain homes in low-density areas, and many probably had little need for the public services available in more urbanized areas. A negative mean score on the dimension of long-term residence indicated that many of the members of this group had recently moved into new homes. About 48 percent of the elderly households had moved into their residences in 1965 or later compared with a countywide figure of <37 percent. Family living was the most common social living arrangement: Approximately 90 percent of the elderly lived with spouses or relatives. As would be expected in suburban areas, the level of home ownership was high. About 6 out of 10 units occupied by members of this subgroup were privately owned. Those who rented tended to choose large apartment complexes. About 24 percent of the units occupied by the elderly were located in structures with three or more units, a percentage slightly higher than the countywide figure of 17 percent. The average number of trips per elderly person was 1.54, only slightly higher than the countywide average of 1.47 trips/elderly person. The rate of automobile driver trip making was 1.04 trips/person, slightly higher than the county rate of 0.91; the average number of public bus passenger trips was only 0.04 trip/person. This was the lowest rate for the six life-style groups. Nearly 50 percent of the elderly had a driver's license, a proportion only fractionally higher than the proportion for the county's elderly population. For all other travel variables, the mean values for the new suburbanites were similar to the mean values for the elderly population of the county.

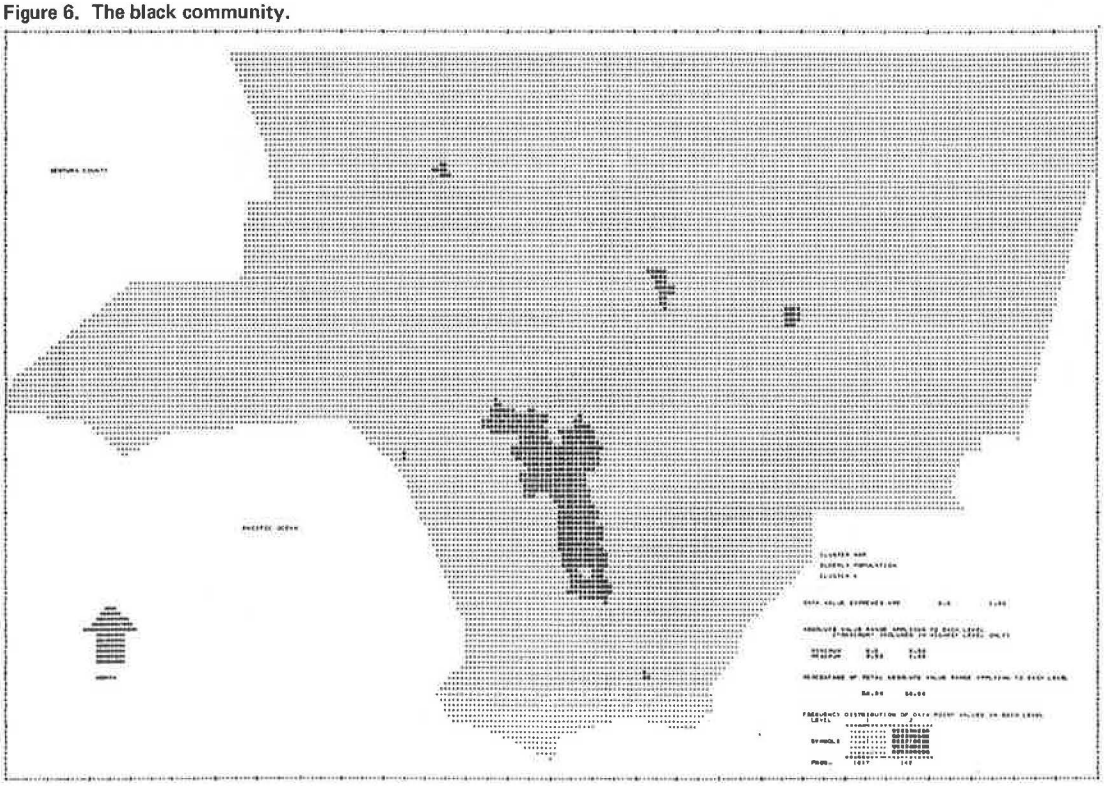
The Black Community

Figure 6 shows the fifth life-style area—the principal location of the elderly black population. The race and occupation dimension was strongly represented in the zones within the area. Of the 42 579 members of this life-style group, about two-thirds were black. Although this life-style group constituted only 7 percent of the elderly population in the county, it accounted for more than three-quarters of the elderly black population. The proportion of residents who were white was only about 29 percent, the lowest percentage among the seven elderly life-style groups. Of those who worked, a high proportion were employed in service occupations, and there was some blue-collar employment.

The negative centroid mean value for the financial security dimension indicated that the average member of the group lived on an extremely low income. Over half of the elderly households reported incomes of $3000 or less; about 42 percent of the elderly households in the county were classified in this income bracket. Because income is directly related to the ability to own and operate an automobile, transit dependency is probably quite common among the life-style group members. Although the level of home ownership was relatively high, the average home had a low market value. Less than 10 percent of the units owned by elderly persons were valued at over $25 000, and 40 percent were valued at less than $15 000. The rents paid by the elderly residents were also low; less than 1 percent of the units had monthly rents greater than $150. The percentage for the county's elderly population was more than 11 percent.

The average number of daily trips reported by group members was only 0.98 trip/person, which is about two-thirds of the countywide average. A low rate of automobile driving accounted for much of this difference; the group mean of 0.56 trip/person was significantly lower than the countywide rate for the elderly—0.91 trip/person. Only 33 percent possessed a driver's license, and about two-thirds did not report a trip on the day of the survey. The average number of automobile passenger trips was especially low—only 0.21 trip/d—which suggests that the opportunities for ride sharing in this area were scarce. Although frequencies of travel for personal business and work purposes were

Figure 6. The black community.



nearly as high as they were countywide, leisure and shopping trip rates were only about half as high.

The Spanish American Community

The life-style area designated the Spanish American community is shown in Figure 7. More than half of this life-style group had Spanish surnames; more than 30 percent of the elderly population in the county who had Spanish surnames were residents of this life-style area. Low education levels were common among the elderly residents; 40 percent of the group had had less than 6 years of formal education. Efforts to improve transportation services in this area should therefore involve the dissemination of bilingual information and the use of media that do not require English language reading skills.

The negative mean centroid value on the race and occupation dimension indicated that in this group the proportion of blacks and the percentage in service occupations were low. Employment in blue-collar occupations was common, and the number of elderly employed in blue-collar jobs was more than twice the number of service workers.

Housing in this life-style area was relatively old, as indicated by the positive centroid value on the dimension of long-term residence. About 82 percent of the group lived in structures built before 1950, and about one in every three elderly households moved into their home before 1950.

The elderly members of the Spanish American community reported, on the average, fewer vehicle trips than did the elderly residents of any other life-style area. A low rate of automobile travel and a relatively high rate of bus travel were prominent in their travel patterns. The average number of leisure trips was also small, reflecting both the overall low rate of trip making and the possibility that many elderly of Spanish American background were not able to engage in activities outside the home because of language or educational barriers. Although this group included only about 5 percent of the elderly population of the county, the rate of transit use was high. This life-style group is thus a prime target for the provision of public transportation services. Only 23 percent of the group had a driver's license compared with 42 percent for the elderly countywide. The rate of automobile driver trip making was less than half the county rate. Trip-making rates for the automobile passenger mode and for the four trip purposes were also low although the average number of work trips was nearly as high as the average for the county's elderly population. Bus passenger trips accounted for nearly 22 percent of the reported trips, and the rate of 0.19 bus passenger trip/person was almost twice the county rate.

Early Suburbanites

The life-style group designated early suburbanites lived in the areas of Los Angeles that were on the urban fringe in the 1940s and 1950s but have more recently become the densely populated areas between major urban centers (Figure 8). The average member of the group lived in a densely populated area in a moderately valued structure that he or she owned. The level of home ownership was higher in this life-style group than in any of the other six groups; more than 63 percent of the elderly households owned homes. Most houses were in the $15 000 to $20 000 range; only a small proportion were valued at more than $25 000. The minority who did not own homes paid relatively low rents. Less than

Figure 7. The Spanish American community.

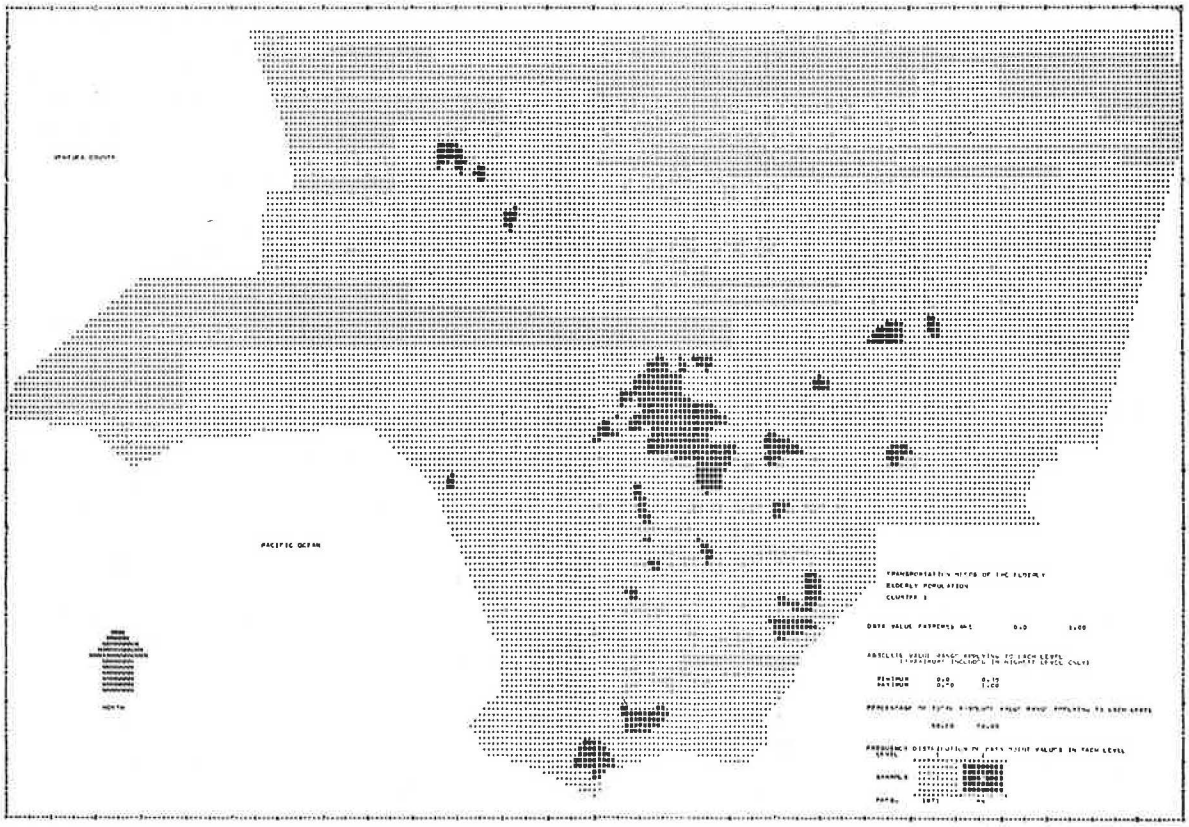
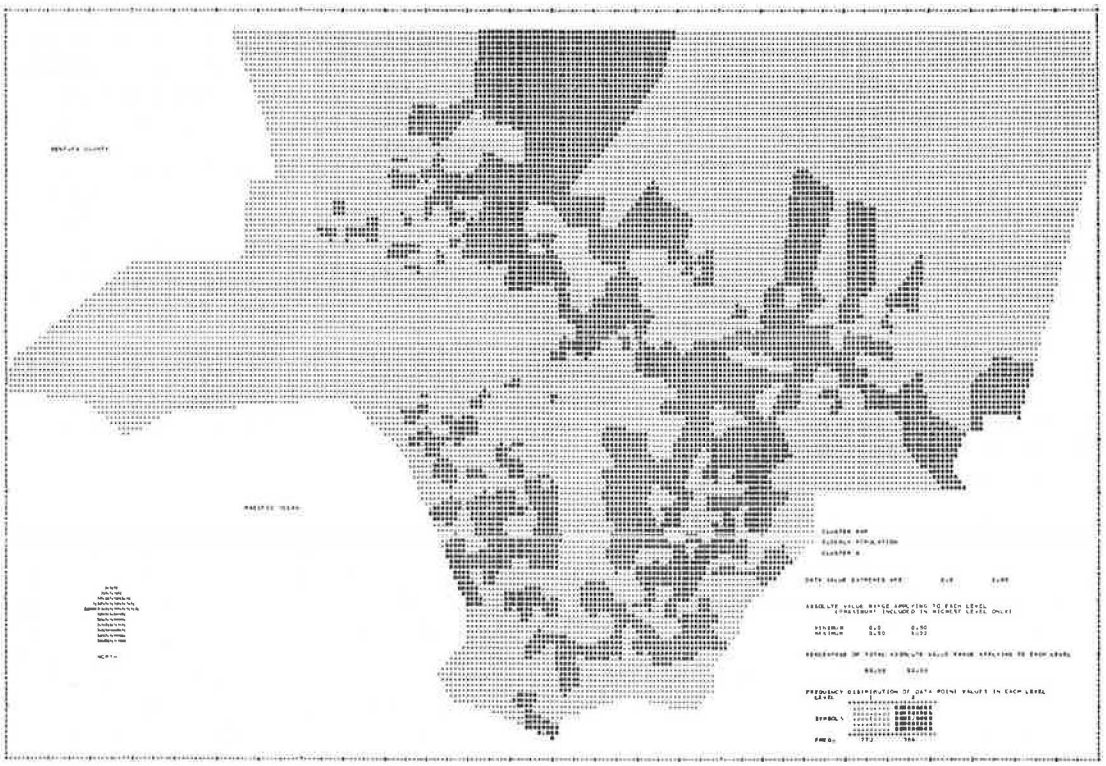


Figure 8. Life-style area of early suburbanites.



5 percent of the rented units had monthly rental rates greater than $150 compared with 12 percent for the county as a whole.

The large size of the group indicated that the residents were a relatively diverse mix. Nearly 35 percent of the elderly population of the county lived in this life-style area, but only about 8 percent of the total population in the area was elderly.

The high level of automobile availability and the low level of dependence on public transportation that are usually associated with suburban living were reflected in the travel patterns of these early suburbanites. Trips were made more frequently by the automobile driver and passenger modes and less frequently by bus in this life-style area than in the county as a whole. The average number of daily trips for this group was 1.61 trips/person, somewhat higher than the county average of 1.47 trips/person. Relatively high rates of trip making for personal business and shopping purposes were also found. The proportion of licensed drivers and the proportion that reported one or more vehicle trips were slightly higher than corresponding countywide figures for the elderly.

SUMMARY AND CONCLUSION

Although this research was based on a detailed case study of the 1970 travel behavior and residential location patterns of the elderly of Los Angeles County, many of the general findings are probably applicable to other metropolitan areas. The major results can be summarized as follows:

1. Through the application of factor analysis and cluster analysis, it was possible to isolate among the elderly population a number of life-style groups that were unique and homogeneous with respect to socioeconomic, demographic, and travel characteristics. The members of these groups tended to reside in close proximity to one another in specific locations within the county.
2. Major differences were found between the elderly residents of low-density suburban areas and those who lived in high-density, central city locations. Many city residents conformed to the stereotype of the elderly—living alone in apartments, earning low incomes, traveling infrequently, and not owning automobiles. However, about one-quarter of the elderly population of the county was characterized by high incomes, suburban residential locations, and relatively high trip-making rates. The majority of these persons probably have little or no need for many public services.
3. Differences in the frequency of trip making among the elderly were associated with variations in modal choice and mixes of trip purpose. The most mobile elderly traveled by automobile and made a significant percentage of their trips for leisure purposes. Those who traveled less frequently often made trips as bus or automobile passengers and tended to make a large proportion of their trips for purposes of necessity such as work and shopping.
4. Little variation was found in the work-trip rate. The rate of employment appeared to be relatively low and uniform across the life-style groups identified in this study.
5. Ethnicity was a particularly important attribute in explaining variations in travel demand. Elderly residents of the most ethnically mixed areas of the county averaged less than 1 trip/d/person, a significantly lower rate than that for the average elderly resident of the county and lower than the rate for central city residents.

The finding that elderly life-style groups tend to reside in specific locations and have unique travel patterns has important implications for the provision of

transportation services to the elderly. It should not be assumed that a single transportation service or a uniform mix of services will adequately serve the members of all life-style groups. Rather, the results of this study would suggest that there are a number of transportation markets among the elderly population. Although the operation of barrier-free buses and the implementation of fare-reduction programs will increase the accessibility of elderly persons who are relatively poor and live in densely populated areas, these same services will probably not be as effective in improving the mobility of suburban residents. Because many elderly suburbanites live great distances from transit stops and because the level of transit service is low, a relatively inexpensive door-to-door service may be more effective in serving the needs of the elderly in the suburbs. The results of additional studies, including attitudinal and behavioral surveys, should make it possible for transit operators to study more closely the travel needs of the elderly and determine the appropriate locations for the operation of transit and paratransit services.

The possibility of implementing a variety of transit services according to the specific needs of elderly life-style groups becomes especially important when one considers the travel demands of future generations of elderly persons. A recent study completed in Los Angeles County (3) showed that since 1940 there has been a strong and consistent trend toward suburbanization of the elderly population. If present trends continue, in coming decades the elderly can be expected to be more decentralized within urban areas and characterized by life-styles even more diverse than those of the elderly population of today. The transportation needs of the elderly will not be adequately served in the future if it is assumed that the elderly will be a homogeneous group with common transportation requirements.

ACKNOWLEDGMENT

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Evaluation of Pennsylvania's Free Transit Program for Senior Citizens

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The findings of an evaluation of Pennsylvania's Free Transit Program for Senior Citizens are reported. Impacts on both senior citizen users and participating transit operators are analyzed. Personal interviews were conducted with over 2100 elderly persons and 5 participating transit operators. Telephone interviews were conducted with an additional 154 older persons, and 36 transit operators returned written questionnaires. Based on these surveys it was concluded that the program has benefited senior citizens by enhancing their mobility. Individual trip making has increased by an average of 8.2 rides/month. In addition, new riders—generally those with lower incomes—were attracted to transit. Users reported significant cash savings, beyond the fare savings, as a result of being able to travel to lower priced stores. Transit operators generally felt positive about the program despite a dissatisfaction with the compensation received and the method of determining it. Operators enjoy an improved image in the community as a result of their participation while experiencing no major program-related cost increases.

On July 1, 1973, Pennsylvania initiated the first statewide Free Transit Program for Senior Citizens in the United States. The program, funded through the state lottery, involves 72 private and public local transit agencies that serve over 95 percent of all local transit ridership in the state. During 1973 and 1974, approximately 49 million rides were taken by senior citizens under the program at a cost to the state lottery fund of $10.8 mil-

lion. In succeeding years the program's cost and senior citizen ridership have increased. The reimbursement for 60 million free rides during the 1975/1976 fiscal year was approximately $12.8 million.

DESCRIPTION OF THE PROGRAM

The Pennsylvania program provides free transit to all persons aged 65 and older on any participating transit system during off-peak hours on weekdays and all day on weekends and holidays. Regular transit fare must be paid during peak hours—the weekday periods from 6:00 to 9:00 a.m. and from 3:30 to 6:30 p.m. Eligibility is determined when a medicare card or a senior citizen identification card (furnished by the local transit agency) is presented to the transit vehicle operator or cashier at the time the fare would normally be paid. The program is restricted to local public bus, trolley, and subway-elevated systems that operate regular schedules over fixed routes. Travel by intercity carrier, school bus, charter or excursion bus, limousine, and taxi is not covered. Participating transit properties are compensated for the estimated transit losses incurred but are not compensated directly for the additional rides generated as a result of the program.

STUDY DESIGN

In January 1975, the Pennsylvania Bureau of Mass Transit Systems, with support from the Urban Mass Transportation Administration, undertook a study to evaluate the impact of the Pennsylvania program on transit riders and operators. Elderly transit riders were interviewed on board transit vehicles during peak and off-peak hours. Each interview averaged 8 to 10 min and was conducted by a professionally trained interviewer. A total of 2136 interviews were completed in the cities of Pittsburgh, Erie, Lancaster, Lebanon, and Clearfield. The sample was statistically selected to ensure randomness and reliability, and the cities were chosen to reflect geographic distribution, size, and system stability.

In addition, 154 telephone interviews were completed in Pottsville, a city whose transit operator was originally involved in the program but later discontinued participation. Finally, a mail-survey questionnaire was sent to all transit operators in the program; this was supplemented by in-depth interviews in the cities where on-board surveys were conducted. Of the 72 participating operators, a total of 36 responded.

The underlying rationale of a free-fare program is to improve the ability of elderly citizens to participate in community life by removing the financial burden of riding public transportation. It is well known that the elderly are generally poorer and more often without access to an automobile than other groups. Free transit, therefore, has intrinsic appeal as a means for assisting the elderly to achieve greater mobility. But the supplier of these services considers the effects of such actions in terms of overall operations and systems management. For these reasons, this study addressed two areas of major program impact: (a) the effects of the program on senior citizens and (b) the perceptions and experiences of transit operators in the program. Potential benefits of program ideas for the nonriding elderly were not within the scope of the study.

SURVEY OF SENIOR CITIZEN TRANSIT RIDERS

The on-board survey yielded information about the free transit program's impact on senior citizens who now ride transit. An analysis of these data led to the findings summarized below, which cover personal and transit-related characteristics, trip characteristics, trip frequency, and personal attitudes and opinions about the program.

Ridership

The effects of the program on ridership were identified for the following categories of riders:

1. Senior citizen riders who used transit before the program and were making new trips;
2. Senior citizen riders who used transit before the program and were not making any more trips than they did before;
3. New senior citizen riders attracted to transit because of the program; and
4. New senior citizen riders attracted to transit for reasons other than the free-fare program.

Of all elderly riders interviewed, 85.5 percent had used transit before the free-fare program and 14.5 percent were new. Nearly one-third of the previous riders reported making more trips than before, and more than half of the new riders began to use transit because of the free fare. More detailed breakdowns of these data are given in Table 1.

Elderly riders who used transit before the program have had the "transit habit" for a long time. The average is 30 years; 60 percent have used transit service for 20 or more years.

The free-fare program was the principal reason for using transit cited by 56.6 percent of new riders. Changes in automobile availability were cited by 23.4 percent, and the remaining 20 percent cited job or residence changes as their principal reason. Publicity in local newspapers was the major source of information about the program cited by 43.1 percent of the respondents. A specially prepared pamphlet describing the program was cited in only 3.7 percent of the responses.

Senior citizen transit riders were found to be primarily female (63.7 percent). This can be attributed to the higher female to male population ratios in recent years and the greater dependency on transit by women who do not drive or own an automobile. However, of new riders attracted to transit by the program, 52.1 percent were women and 47.9 percent were men, which undoubtedly reflects the higher proportion of males in the previously untapped pool of transit riders.

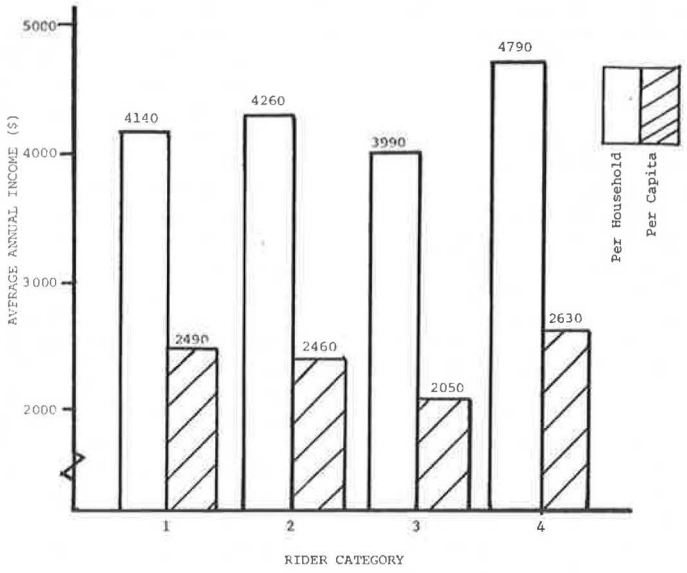
Income-related comparisons by category of transit rider are shown in Figure 1. Income of elderly transit riders was significantly lower than that of elderly persons in the general population. Over 50 percent reported annual household incomes of less than $3000, and about 85 percent reported annual incomes of less than $6000. The average annual household income of all the transit riders who were interviewed is $4220, and their per capita income is $2440. The income of new riders is significantly lower, however, than that of previous riders, which demonstrates the basic effect of the free-fare program—removal of the economic barrier that prevents some elderly persons from riding transit.

Another basic need served by transit is that of the captive rider, who is characterized by a lack of access to transportation by automobile because of (a) no driver's license, (b) no automobile, or (c) no opportunity to ride with others. Only 22.8 percent of the senior citizen respondents had a valid driver's license, and 14 percent had a license and an automobile. Of the 86 percent without a license or an automobile, approximately 65 percent said that they had difficulty getting a ride from relatives, friends, or neighbors when they wanted to go somewhere.

Table 1. Distribution of senior-citizen transit riders by rider category.

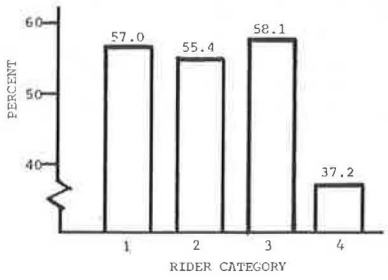
Rider Category	Distribution (%)					
	Pittsburgh	Erie	Lancaster	Lebanon	Clearfield	All Sites
Previous riders taking new trips	27.9	28.1	28.2	23.9	17.1	27.1
Previous riders not taking new trips	60.7	48.9	61.2	62.8	59.2	58.4
New riders attracted by program	7.0	14.8	4.7	5.1	10.5	8.2
New riders not attracted by program	4.4	8.2	5.9	8.3	13.2	6.3

Figure 1. Average annual income per household and per person for senior-citizen transit riders.



If all elderly transit riders are considered, then about 55 percent can be classified as transit captives. Many more new riders than previous riders tended to have a license and an automobile. Nevertheless, if the ability to get a ride by automobile is the criterion, then a slightly higher proportion of new transit riders are transit captives. The proportions of captive transit riders in each of the four rider categories are shown in Figure 2.

Figure 2. Percentage of senior-citizen riders who are captive transit riders.



Trip Characteristics

Access to the transit system is perhaps the single most important level-of-service variable considered by the elderly. Almost all senior citizen transit riders must walk to the bus stop or train station. About 88 percent of those interviewed cited walking as their access mode. Of the remainder, 10.3 percent arrived by bus and only 1.2 percent by automobile. Those elderly who transferred from another bus invariably reached that bus by walking.

Figures 3 and 4 show home-to-transit and destination-to-transit walk times and distances for senior citizen transit riders. The average walking time to a bus stop from home was found to be 4.3 min; only 6 percent of all transit riders reported walking more than 15 min to

Figure 3. Home-to-transit and destination-to-transit walk time for senior-citizen riders.

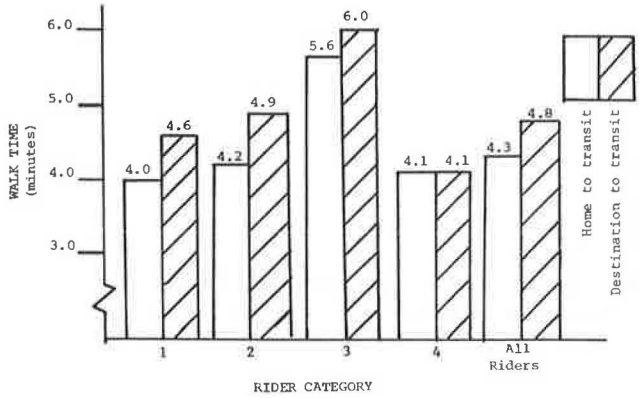
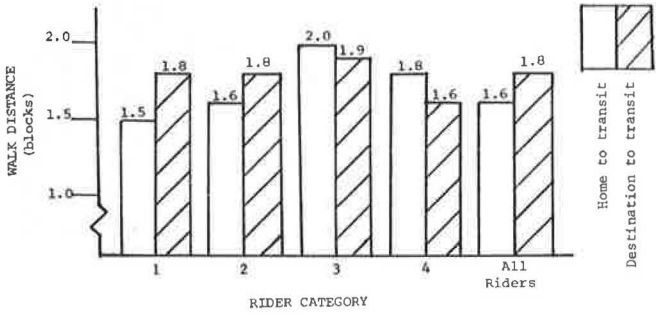


Figure 4. Home-to-transit and destination-to-transit walk distance for senior-citizen riders.



catch a bus or a trolley. Average walking times at the destination were slightly higher, averaging 4.8 min, which implies that the elderly may be more sensitive to improved services near home and would be willing to walk longer distances in order to reach a destination.

New riders attracted because of the program walked significantly longer distances to reach a bus or a trolley than did others. For trips from home, the average walk time was 5.6 min, and from the transit stop the time was 6 min. This is a positive indication that the elimination of a fare encouraged some who live farther than usual from a bus stop to ride the bus; these represent captive riders who under existing levels of service would normally not ride transit.

Transit riding by the elderly during off-peak hours serves many purposes, including shopping (43.8 percent), social and recreational travel (18.6 percent), personal business (15.6 percent), medical and dental visits (9.1 percent), and work (5.5 percent). Senior citizen group activities accounted for only 1.9 percent of the trip purposes cited by respondents, and only 2.5 percent of the responses cited riding the bus simply to pass the time of day. It is estimated that about 75 percent of all transit trips by the elderly are made for essential purposes include personal business, work, medical and dental visits, and shopping.

Shopping trips accounted for more than 50 percent of new rides attracted by the program. Other kinds of trips that increased significantly were those whose purposes were to ride the bus (4.5 percent) and to participate in senior citizen activities (2.8 percent). Figure 5 shows a comparison by trip purpose of new rides attracted because of the program and all other rides. New trips not previously taken by another mode were made mostly for shopping purposes (57.3 percent); 7.3 percent of such trips were made just for fun. Less than 3 percent of those interviewed had been diverted from another mode because of the free fare, and of these nearly 54 percent rode transit for the purpose of shopping.

The distribution of trip making by the elderly throughout the 9:00 a.m. to 3:30 p.m. free-fare period does not indicate any marked peaking tendencies but rather a uniform level of use. The highest proportions (about 20 percent) occurred between 10:00 and 11:00 a.m. and 2:00 and 3:30 p.m. More than 25 percent of all new rides attracted by the program were taken between 9:00 and 10:00 a.m. or between 2:00 and 3:30 p.m. It was found that some of the rides intended for these periods were inadvertently being taken during peak hours (21 percent of new riders attracted to transit by the program were riding during peak periods).

Trip Frequency

Trip frequency refers to the number of trips made by a transit rider per month or per week—a useful figure for establishing the magnitude of trip making under a variety of circumstances and conditions and for describing the additional trip making that occurred as a result of the free-fare program.

Although no detailed counts are available, the data collected in this study make it possible to compute senior citizen ridership before the program was instituted. Off-peak individual ridership is estimated to have been 19.6 rides/month and peak ridership 5 rides/month. It is estimated that as a result of the program off-peak ridership increased by 45.9 percent, to 28.6 rides/month, and that peak-hour ridership decreased by 12 percent, to 4.4 rides/month. Ridership levels at each survey site are given in Table 2.

The intensity of off-peak transit ridership varies considerably: For example, 20.3 percent of respondents take fewer than 8 rides/month during off-peak periods whereas 23.1 percent take at least 20 rides/month.

Previous transit riders who were making new trips as a result of the program reported their off-peak ridership at 37 rides/month, considerably more than other previous riders (25.2 rides/month) and new riders attracted by the program (25.4 rides/month). The fact that new riders tended to make as many trips as most previous riders indicates that, by removing the cost barrier, the program met the latent travel demand of this economically disadvantaged group. Trip making during the peak hour, when a fare must be paid, averages about 4.4 rides/month for all senior citizen groups except those attracted to transit because of the program, for whom the peak-period trip average is only 1.8 rides/month.

Figures 6 and 7 show a comparison of monthly ridership levels for peak and off-peak transit trips by senior citizen riders. Because the city of Clearfield has no

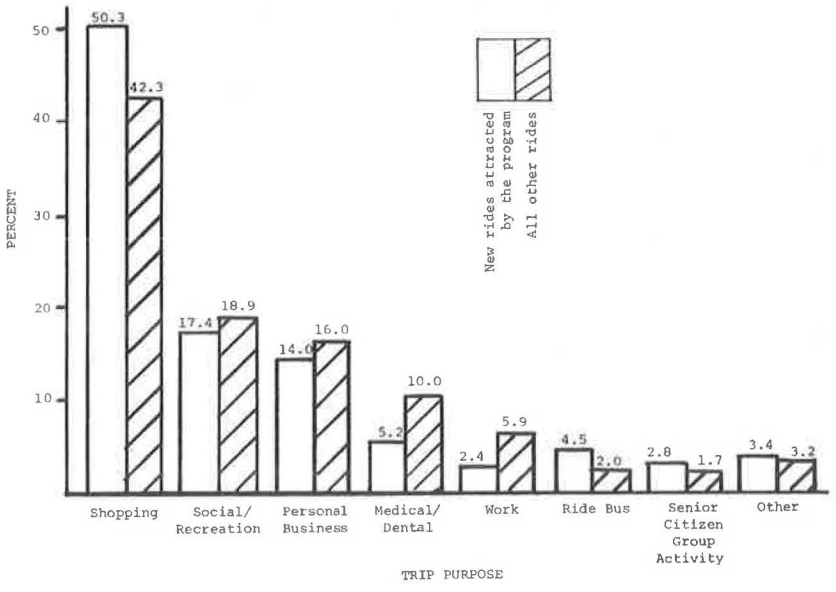


Figure 5. Percentage distribution by trip purpose of new rides attracted by the program and all other rides.

Table 2. Monthly transit trips taken by senior-citizen riders.

Trips	Pittsburgh	Erie	Lancaster	Lebanon	Clearfield*	All Sites
Off-peak						
Number	31.4	26.2	27.0	27.4	20.0	28.6
Standard deviation	24.4	20.4	22.6	16.0	13.2	13.8
Peak						
Number	5.6	2.8	3.2	5.6		4.4
Standard deviation	11.2	6.0	8.4	11.6		5.6
Percent of riders	39.8	32.9	32.8	41.3		35.5
Total						
Number	37.0	29.0	30.2	31.0	20.0	31.0
Standard deviation	26.8	21.2	24.2	18.8	13.2	14.8

*All rides considered off-peak because there are no peak-period restrictions in Clearfield.

Figure 6. Off-peak senior-citizen transit ridership.

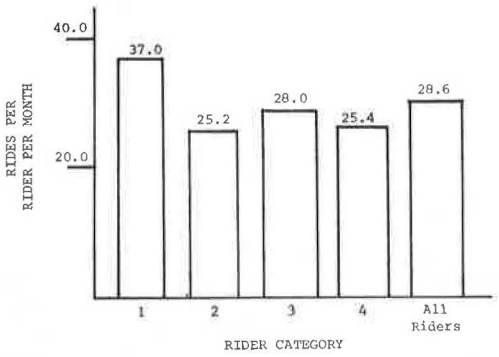
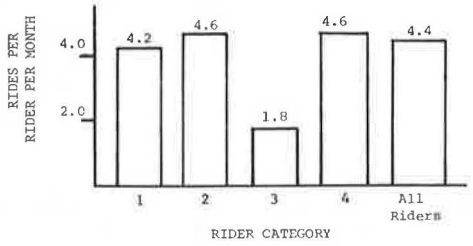


Figure 7. Peak-period senior-citizen transit ridership.



peak-period free-fare restrictions, trips taken there during peak periods are included in the off-peak totals. The average for all riders includes some respondents who could not be placed in one of the four rider categories.

Peak-period riding occurs mostly for purposes of work or to meet scheduled appointments. Almost 30 percent of peak-hour senior citizen riders either missed a bus or could not use the less frequently scheduled off-peak service. About 13 percent of respondents who were riding during the free-fare period would have shifted from the off-peak to the peak if fares were lifted for the entire day. Most of these trips would be taken during the 8:00 to 9:00 a.m. period.

New riders who were attracted by the program indicated that 19.7 percent of their trips were diverted from two other modes—automobile (47.9 percent) and walking (52.1 percent)—and that none of the trips would have been taken by taxi.

Attitudes of Transit Users

Without exception, senior citizen transit riders are grateful for the free transit program. Most know that the lottery supports it, and many purchase lottery tickets in return. Many, however, do not fully understand the financial arrangements: A common misconception is that the operators are compensated a full fare for each ride.

Most respondents, even when asked, were reluctant to be critical or to suggest service changes. Many expressed the hope that the program would be continued and that abuses such as excessive trip making would not jeopardize it.

Table 3 gives data on the benefits of the program cited by elderly riders. Financial savings were cited as a direct benefit of the free transit program by 85 percent of all senior citizens interviewed. Many indicated that the program was helping them to get around more than before (37.8 percent) and some that they were now less dependent on friends and relatives for transportation than before (11.1 percent). About 10 percent mentioned that it was no longer necessary to carry exact change—an annoyance that would probably have been cited by a larger number of riders if a list of suggested benefits had been provided. Approximately 6 percent cited courteous and helpful drivers as a benefit, indicating that personal attention is seen as an important attribute by older people.

A significant proportion of the respondents (56.3 percent) reported that the program had helped them to save money by taking advantage of lower prices in different stores. Because they could travel more freely, some comparison shopping was possible and they could take advantage of special sales. About 12 percent of those who reported savings thought that these had been substantial; 37 percent thought the financial savings were moderate. More than 75 percent of transit riders who were making more trips because of the program reported saving money by comparison shopping.

When asked for specific suggestions concerning any changes or improvements in the free transit program, almost 58 percent of the respondents indicated complete satisfaction with the program and the service provided. Although this result is gratifying, two factors must be kept in mind: the understandable desire of some riders not to criticize a benefactor and the fact that those using the service do so either because it serves them well or because no other alternative exists.

Table 4 gives the service improvements suggested by respondents. Of those who responded with suggestions, 51.7 percent asked for some extension of the free-fare time period. Most were not seeking to ride free during the height of the peak when conditions are crowded or rushed but rather to urge some additional flexibility in arrival and departure times. The next most cited suggestion was increased frequency of service, an improvement that ties in with extending the free-fare period. Seven percent of the respondents cited the need for a better attitude and greater courtesy on the part of drivers. Other suggested improvements included new buses, more extensive transit service, better vehicle design, and stops closer to the curb.

SURVEY OF TRANSIT OPERATORS

Operators' experience with the free transit program for

Table 3. Benefits of the free transit program cited by senior-citizen riders.

Benefit	Previous Riders Taking New Trips (%)	Previous Riders Not Taking New Trips (%)	New Riders Attracted by Program (%)	New Riders Not Attracted by Program (%)
Financial savings	86.9	85.1	85.0	75.2
Increased mobility	62.0	27.4	33.8	25.6
Greater convenience	12.3	13.8	25.4	20.1
No need to carry change	13.1	10.1	10.2	7.0
Less dependence on other modes	10.5	11.5	9.6	12.5
Courteous drivers	5.5	6.3	7.2	8.5
Other	7.7	10.9	14.5	10.9

Table 4. Service improvements suggested by senior-citizen riders.

Benefit	Previous Riders Taking New Trips (%)	Previous Riders Not Taking New Trips (%)	New Riders Attracted by Program (%)	New Riders Not Attracted by Program (%)
Lifting of peak-period restriction	57.1	50.5	43.2	40.3
More frequent service	26.7	25.6	33.3	32.7
Improved driver attitude	6.3	7.9	5.9	3.8
More extensive service	5.1	5.6	3.9	7.7
New buses and other specific improvements	23.1	27.2	29.4	25.0

the elderly was surveyed by means of personal interviews and a written questionnaire. The primary issues of concern were effects on ridership and revenue, problems of senior citizen identification, maintenance of published schedules and service, and administrative needs and costs.

Effects on Ridership and Revenue

Transit operators were able to furnish few data on the number of senior citizens who patronized their systems before the start of the free transit program. Among the approximately 40 percent who cited ridership figures, estimated increases in off-peak elderly ridership ranged from 50 to 140 percent. The average increase reported by operators was about 80 to 100 percent over 2 years, but no basic pattern could be identified to explain variations in reported figures.

The absence of necessary data hinders the state from estimating losses accurately, and both parties (the state and the operator) can claim hardship. Most operators (about 75 percent) expressed the feeling that according to the "estimated transit loss" formula they are being undercompensated. Although operators felt that they would be better off financially without the program, many also said that the image of public transit has been considerably enhanced.

Suggested ways to remedy the situation include full-fare reimbursement for each passenger carried, reimbursement for the actual cost of the ride, and reimbursement for a percentage of the actual fare. Some operators felt that senior citizens should pay a nominal fare—$0.05 or $0.10—and that the state should reimburse the transit operator for the remainder. One suggested method would involve the purchase of a ticket that, once used for a ride, could then be used by operators to claim payment from the state.

One deficiency in the reimbursement formula mentioned by some operators related to significant increases in ridership among the elderly that would have occurred even without the program. The base figures used in contracts with the state do not reflect increases in senior citizen population or recent developments such as new housing projects, shopping malls, and activity centers for the elderly. Operators are reluctant to furnish additional service to these new travel generators without further incentives.

Identification of Senior Citizen Riders

The use of a medicare card for identification of elderly riders appears to be working satisfactorily although some cheating is suspected. About 93 percent of all holders of medicare cards in Pennsylvania are 65 or older, but one operator claimed that a third of the free-fare riders on his system were ineligible. Little evidence was found to indicate that the free-fare privilege was being abused. To maintain strict control, however, and to avoid transfer of cards to ineligible persons, a personal identification card with a photograph would be desirable (though expensive).

Maintenance of Service and Schedules

In general, service capacity appeared sufficient to absorb riding increases during off-peak hours. Only three operators claimed that additional buses were needed because of increased ridership, but several operators did report changes in schedules to meet new demands. Little impact on peak-period loads was noted and, with one exception, no reduction in peak service was possible.

A significant number of operators complained that increased riding by the elderly seriously affected running times. Increased stopping and starting to pick up and deliver passengers and slower than average boarding and alighting times were cited as the principal causes of delay. Some vehicle operators were especially annoyed when schedule delays were caused by senior citizen riders making very short trips. In one case, the drivers' union was asked to request a schedule change to reflect longer run times on a route that was heavily used by senior citizens.

Although the program compensates for elderly riders attracted by the new service, little use has been made of this provision and many operators expressed reluctance to add routes where the rate of senior citizen patronage would be high. Contributing factors were uncertainty about compensation and the fear that permission to discontinue unprofitable service would be withheld. On the other hand, many operators stated that if the program were discontinued it would be necessary to reduce or eliminate service on lines where the rate of senior citizen ridership was significant.

Administrative Needs and Costs

The safety record of the program appears to be good.

No significant increases in accidents or personal injuries have been reported, and thus the program has caused no increase in insurance costs. But administrative and operating costs have increased, principally because of added stops and starts, heavier loads, and general wear and tear on equipment. Increases in fuel and repair costs are not easily determined, but it is reasonable to agree with the operators that they do exist. Further, detailed studies of maintenance and operating experience are required to determine the full effect of the program.

Administrative costs related to record keeping, report preparation, and rider identification represent a small fraction of the totals involved. Although few data are available to justify additional reimbursement to operators, about 40 percent of the operators do not feel that their compensation is adequate. Smaller operators in particular feel that the paper work related to the program poses a relatively greater burden for them than for larger properties that have more administrative staff assistance.

SUMMARY AND CONCLUSIONS

Pennsylvania's free transit program for the elderly has resulted in significant social and economic benefits for elderly transit riders. Its major objective—to enhance the mobility of senior citizens and open up to them a greater range of opportunities—appears to be fulfilled.

Respondents reported taking an average of 9 more off-peak rides a month because of the program. These consisted of 8.2 entirely new transit rides and 0.8 ride shifted from the peak periods. This represents a 45.9 percent increase in off-peak ridership by senior citizens. On the other hand, the combination of shifted rides and new peak-period rides generated by the program indicates a decline in peak-period ridership of 12 percent.

The program induced 37.2 percent of respondents to take additional trips by transit. These additional rides were primarily shopping trips although there were a considerable number of personal business, recreational, and medical-dental trips. Less than 20 percent of these trips had been diverted from other modes, among which the major alternative mode was walking.

New senior citizen riders attracted to transit by the program comprised 8.2 percent of current senior citizen riders. A further indication of the program's success in attracting new riders is the finding that the two survey sites where senior citizens had enjoyed reduced-fare service before the program had high proportions of new riders. The program has had considerable impact on these riders, who were found to have lower incomes and fewer opportunities to travel by other modes and to live farther away from a bus stop than riders who had previously used transit. They are now riding as frequently as most previous transit riders and account for 28.3 percent of all new trips generated by the program.

Current individual transit ridership among senior citizens at the five survey sites was found to be 28.6 rides/month during off-peak hours and 4.4 rides/month during peak hours for a total of 33 rides/rider/month.

Senior citizen riders reported experiencing substantial economic benefits under the program. In addition to saving the transit fare, 56.3 percent of the respondents were able to shop around more and take advantage of lower prices. Increased mobility and the related benefit of being less dependent on relatives and friends for rides were also cited by many respondents.

Among suggestions for changes and improvements in the program and in transit service, partial or complete elimination of restrictions on peak-period, free-fare riding and the availability of more frequent bus service were emphasized. Some common problems cited by senior citizen riders were the height of the first step on buses, the failure of buses to pull up close to the curb, and driver discourtesy.

The complete elimination of peak-period restrictions would result in a 65 percent increase in peak-period ridership by senior citizens and would require a 25 percent increase in the reimbursement participating transit operators receive under the program. The increase in mobility would not, however, be appreciable.

Most participating transit operators felt positive about the program despite their general dissatisfaction with the compensation they received. A common benefit that was reported was an improved working relationship with the communities served by transit. In a number of instances, driver morale appears to have been adversely affected because of increases in ridership and the associated pressure to meet schedules. Some drivers feel that senior citizens are frequently "joyriding" at the operators' and the public's expense. Undoubtedly, some elderly riders do make frequent short trips, but this type of trip making appears to be much less common now than it was early in the program.

Operators have for the most part been able to absorb higher off-peak loads without having to make major service changes. Only a few cases were reported in which additional buses had to be scheduled during off-peak hours. On the other hand, the incidence of senior citizens shifting from peak to off-peak riding was not of sufficient magnitude to allow operators to curtail peak-period service. A heartening result was that the high personal injury rates anticipated by many operators before the start of the program did not materialize.

The simplification of certain requirements and the clarification of the procedures by which operators are compensated for lost revenues would alleviate some of the confusion and poor communication experienced by many operators. Greater financial incentives may be needed to induce transit operators to improve service and to add new routes.

It would be advantageous for the state to subsidize the cost of advertisements for senior citizen transit services in local newspapers, which appears to be the most effective means of communication about the program. Periodic advertisements could be placed in local newspapers to inform persons who are just reaching the age of 65 or who have just moved into the area about available regular and special transit services for the elderly.

The current level and nature of transit service are inadequate to meet the needs of many senior citizens. Identifying the overall, statewide transportation problems of the elderly would help in evaluating this program's total impact as well as suggest possible ways in which it could be extended. A systemwide approach to addressing the travel-related needs of the elderly in Pennsylvania is yet to be developed. Such an effort might indicate other, more cost-effective ways of extending the program's impact.

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Improving the Mobility of the Elderly and the Handicapped Through User-Side Subsidies

Ronald F. Kirby and Francine L. Tolson, Urban Institute

Special transportation assistance is currently provided for elderly and handicapped persons through a variety of programs at the federal, state, and local levels of government. Unfortunately, certain requirements for the earmarking of funds and certain administrative procedures associated with these programs appear to have created major impediments to the efficient provision of transportation services. This paper suggests three steps by which the efficiency of transportation services for the elderly and handicapped can be increased: (a) relaxing certain earmarking requirements, (b) fostering greater cooperation between administrative agencies, and (c) disbursing funds through user-side subsidy schemes that permit users to patronize the transportation providers of their choice. The implementation of user-side subsidies is emphasized. Several existing applications of the user-side subsidy approach are reviewed, and some potential applications are suggested for research and experimentation.

Many public programs at the federal, state, and local levels of government currently provide funds that can be used for improving the mobility of the elderly and the handicapped. These programs typically earmark transportation funds in four ways:

1. By the client group that is to receive assistance,
2. By the particular services the client group can obtain with the assistance,
3. By the organizations that provide the services, and
4. By the type of transportation expenditure for which the assistance can be used.

Criteria for earmarking funds vary greatly from program to program, and the agencies administering the programs often work independently of one another with little coordination of objectives and resources.

A recent publication of the U.S. Department of Health, Education and Welfare (HEW) identified over 60 federal social-service programs that allow expenditures for transportation services (7). In addition, state and local governments have a variety of programs of their own. Many of these programs provide for transportation assistance to improve access of the elderly to particular services such as medical care and recreation. Because improved mobility is an implicit rather than an explicit objective of these programs, the actual expenditures on transportation services under these programs are rarely accumulated as separate items. As a result, it is practically impossible to estimate the level of public expenditure on transportation for the elderly and the handicapped. There is no doubt, however, that these expenditures are substantial and growing.

One federal program for which improved mobility for the elderly and the handicapped is an explicit objective is that administered by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (DOT). The regulations for this program use the term "elderly and handicapped persons" to mean the following (9):

> those individuals who, by reason of illness, injury, age, congenital malfunction, or other permanent or temporary incapacity or disability, including those with semiambulatory capabilities, are unable without special facilities or special planning or design to utilize mass transportation facilities and services as effectively as persons who are not so affected.

The client group for this program, then, is composed of persons who have difficulty using mass transportation facilities because of disabilities. By comparison, certain other federal programs define the elderly as those persons above a certain age, such as 60 or 65, and still other programs limit assistance to those elderly and handicapped below a certain income level (7).

The DOT program for the elderly and the handicapped provides assistance only for those transportation services that qualify as mass transportation—shared-ride services that are available to the public on a regular and continuing basis. Exclusive-ride taxicab services and services restricted to a particular organizational or institutional clientele apparently could not receive DOT assistance. Other federal programs restrict transportation assistance to certain kinds of trips such as those to and from medical or educational facilities (7).

In addition to restricting the public transportation services eligible for assistance, the DOT program also restricts the kinds of organizations that can receive the assistance and provide the services. Section 16b2 of the Urban Mass Transportation Act provides for assistance to private, nonprofit corporations and associations without the labor protection conditions required under other sections of the act. During fiscal year 1975, over $20 million was disbursed under section 16b2 to 1031 nonprofit agencies throughout the United States for equipment to be used in providing transportation services to elderly and handicapped persons (11). This assistance was not available to public transit systems or to private, for-profit taxicab operators although these and other mass transportation providers could receive assistance under other sections of the act.

Programs funded by DOT and other agencies also restrict considerable financial assistance for capital as opposed to operating expenses incurred by transportation providers. Under section 16b2, for example, a nonprofit agency can obtain financial assistance for vehicles and other equipment but cannot obtain assistance for expenses incurred in operating the equipment. The medicaid program (title XIX of the Social Security Act), on the other hand, prohibits the use of funds for the purchase of equipment but allows the purchase of taxi or transit services for medical trips (7).

Such variations in criteria for the earmarking of funds for transportation assistance illustrate the enormous range of statutes and regulations that govern public programs concerned with improving the mobility of the elderly and the handicapped. These complex constraints create a number of obstacles to the efficient and effective delivery of transportation assistance to those in need of it. An analysis by Tye (6) concluded that restricting transportation assistance for capital expenditures encourages premature replacement of capital equipment and inadequate maintenance. Kirby

(3) suggests that earmarking funds for nonprofit providers under section 16b2 "may jeopardize the financial viability of for-profit providers currently serving the elderly and handicapped." In addition, the tendency of the different administrative agencies to establish independent transportation services for their particular client groups often leads to unnecessary duplication of facilities and services (1).

The techniques used for disbursing funds provided under transportation assistance programs are also likely to have an important bearing on the efficiency and the effectiveness of the programs. An important distinction in this regard is between provider-side and user-side subsidies. Provider-side subsidies are funds disbursed to transportation providers for the provision of certain specified services; user-side subsidies are subsidy funds placed in the hands of the users in the form of discounted transportation vouchers or tickets. Under a typical provider-side subsidy scheme, one provider is given an exclusive contract to operate certain services and is reimbursed on the basis of costs incurred rather than passengers served. User-side subsidy schemes, on the other hand, reimburse any and all eligible providers according to the passengers each has served. Kirby and McGillivray (4) argue that provider-side subsidies tend to reduce competition among providers and to remove some of their incentives to operate efficiently, whereas user-side subsidies tend to encourage competition and reward efficient operation.

There is widespread recognition that greater efficiency and effectiveness are badly needed in programs providing transportation assistance to the elderly and the handicapped, and a number of agencies have already initiated efforts to streamline administrative procedures and eliminate unnecessary duplication. Such efforts should give special consideration to (a) developing legislative amendments to eliminate earmarking of funds by type of transportation expenditure and by provider type, (b) fostering (and perhaps mandating) greater cooperation between agencies administering transportation programs, and (c) exploring opportunities for disbursing transportation assistance funds through user-side subsidy techniques.

This paper is concerned primarily with user-side subsidies. User-side subsidy techniques are currently used in some locations for subsidizing transportation services. In particular, the Office of Service and Methods Demonstrations of UMTA is funding a series of demonstration projects designed to test the application of user-side subsidies under different institutional and market conditions. This paper briefly reviews current experience in these ongoing projects and suggests other promising but as yet untested applications of the user-side subsidy technique for consideration in future research and demonstration projects.

IMPEDIMENTS TO EFFICIENCY IN TRANSPORTATION PROGRAMS

As currently constituted and administered, programs to provide transportation assistance to the elderly and the handicapped contain a number of impediments to the efficient provision of service. Some of these impediments are a result of language in the legislation authorizing the programs and can be removed only through legislative amendments. Other impediments, however, are a result of administrative practices and can be modified by the administrative agencies responsible for the programs.

Legislative Impediments

Programs that earmark funds for capital expenses—such as the program authorized under section 3 of the Urban Mass Transportation Act—preclude the delivery of assistance for operating expenses; all of the assistance must be delivered in the form of vehicles or other capital equipment. This kind of earmarking is usually justified on the grounds that allowing funds to be used for operating assistance invites inefficient operating practices and increased labor costs. Tye (6) has concluded, however, that capital assistance tends to encourage overexpenditure on new capital equipment and neglect of preventive maintenance. In addition, because capital assistance allows more state and local funds and fare-box revenues to be used for operating expenses, operating inefficiency and escalation of labor costs can result. In the case of programs in which funds are earmarked by client group, restricting funds to capital assistance often leads to the establishment of separate transportation facilities and services for each group; for example, buses purchased for use by handicapped persons under a certain income level may remain idle while a separate fleet serves a broader group of elderly and handicapped persons.

Of the almost $12 billion provided under the Urban Mass Transportation Act for assistance to mass transportation over the 6-year period through 1980, roughly two-thirds is earmarked under section 3 for capital expenditures and the remaining third can be used under section 5 for either capital or operating expenditures. Interestingly enough, in mid-1976 UMTA officials recommended to the Congress that half of the section 5 funds be limited to capital expenditures, citing the familiar concerns about operating inefficiencies and escalation of labor costs. Continuation of this policy of encouraging vehicle purchases but withholding operating assistance raises the spectre of large and small agencies around the country acquiring new vehicles that they eventually cannot afford to operate. In attempting to guard against operating inefficiencies and escalating labor costs, the restriction of funds to capital expenditures is clearly creating severe problems of its own. The wisdom of earmarking funds for capital assistance, particularly for programs aimed at certain client groups such as the elderly and the handicapped, needs to be reexamined.

Earmarking of transportation assistance funds by type of provider is also a troublesome constraint on providing efficient service. The UMTA section 16b2 program provides for the earmarking of certain section 3 funds for a particular group of providers—nonprofit agencies. The language of the Urban Mass Transportation Act appears to sanction 16b2 expenditures only after other providers such as bus and taxicab operators are found to be unable to provide adequate services for the elderly and the handicapped. In practice, however, funds have been disbursed directly to the states under 16b2 for use in assisting nonprofit agencies without a thorough investigation of the capabilities of other providers. Clearly, this kind of earmarked funding for nonprofit service providers precludes certain efficiencies in the provision of service and may well weaken the financial condition of other taxicab and transit operators serving the community at large. Even though these funds were earmarked for capital expenses by section 3, they could have been used to purchase equipment for lease to private bus, taxicab, and limousine operators who already serve the elderly and the handicapped. Unfortunately, however, it is much easier to disburse funds to nonprofit agencies under section 16b2 than to assist other providers because 16b2 projects can be funded without the

labor protection assurances required for other projects by section 13c of the act.

Section 13c specifies that the Secretary of Labor must be satisfied that for each project funded under the Act (except those funded under section 16b2) arrangements have been made "to protect the interests of employees affected by such assistance" (8). The development of such arrangements often involves complex labor negotiations that can delay and even preclude funding of particular projects. Thus the administrative hurdle of 13c labor protection currently encourages the disbursement of funds under section 16b2, which contains the two types of earmarking likely to be most detrimental to efficient provision of service—by capital expenses and by type of provider.

Administrative Impediments

A variety of administrative impediments to efficiency can arise in transportation programs for the elderly and the handicapped (1). A major source of these problems is apparently the attitude of "turf protection" taken by certain program agencies when the pooling of resources with other agencies is suggested (7):

> Frequently attitudinal barriers among human resources agency staff at the service delivery level grow in the name of target group "advocacy" (or "federal restrictiveness") when, in truth, selfishness is the real cause of a transportation provider's unwillingness to share vehicle space for a fee.

Such attitudinal barriers are likely to prevent certain management and operating efficiencies and result in unnecessarily high program costs, as illustrated by a recent empirical study of 16 programs serving the elderly and the handicapped (2):

> The study suggests that on a cross-section basis, transportation programs for the elderly and handicapped appear to operate at lowest unit average costs at scales of operation considerably larger than most of those existing under contemporary federal assistance programs. The data suggest that management costs can be spread over systems comprising larger geographical areas, and delivering a larger number of passenger miles.

Special incentives or regulations appear to be needed to ensure that local agencies take advantage of worthwhile opportunities to pool their resources.

Even when administrative agencies are free of troublesome earmarking constraints and turf-protection disputes, however, a further impediment to the efficient provision of service can arise as a result of the technique selected for disbursing program funds. In dealing with the providers of transportation services, program agencies can choose between two general categories of disbursement techniques: provider-side subsidies and user-side subsidies (4). Provider-side subsidies disburse funds directly to the transportation provider for the support of certain specified services and fare levels. User-side subsidies, on the other hand, place the subsidy funds in the hands of selected users in the form of discounted transportation vouchers or tickets.

The vast majority of transportation assistance programs currently use the provider-side subsidy technique (4). This technique tends to eliminate the competition between private service providers that exists among unsubsidized taxi and limousine services, for example, and in the provision of many other necessary goods and services such as food, clothing, and housing. For fixed-route transit services, the public has become dependent on regional authorities as the sole providers of subsidized services, and, for specialized services, groups such as the elderly and the handicapped rely more and more on services provided by the social-service agencies. Private taxicab and bus operators, who have vehicle fleets, maintenance facilities, and considerable expertise in supplying transportation services, are usually denied the opportunity to participate as providers in publicly funded transportation programs although they might be able to offer subsidized services at lower costs than regional transit authorities or social service agencies.

Administrative agencies should ensure that subsidized transportation services are provided efficiently by disbursing subsidy funds so as to give all qualified providers an opportunity to offer services and to reward efficient operation. User-side subsidy techniques appear to offer a means for achieving these objectives by placing discounted transportation vouchers in the hands of eligible users and encouraging them to patronize the transportation providers of their choice. Providers then receive subsidy funds only after serving eligible users and are thus motivated to tailor their services and fares to meet the demand.

USER-SIDE SUBSIDIES FOR TRANSPORTATION SERVICES

User-side subsidies have been described as follows (4):

> Those for which certain "target group" users are permitted to purchase transportation "vouchers" at a price substantially below the value of the vouchers to the transportation providers. The users exchange these vouchers for transportation services, and the transportation providers then redeem the vouchers from the public agency at values agreed to in advance.

The vouchers may be any kind of ticket, charge slip, or credit card that can be used as evidence that trips have been made. The purpose of the vouchers is simply to provide the information needed by the funding agency to determine the correct payment owed to the providers of transportation service. (In fact, if some other means can be relied on for recording this information, such as an on-board counter, a voucher may not be necessary.) The price the users pay for transportation service can be a fixed amount per trip or a percentage of the regular fare and can range from zero up to the full fare. The users will normally make their payments either by purchasing tickets in advance and handing them to the provider of the service at the time a trip is made or by paying cash at the time of the trip and signing a charge slip for the remainder of the fare. If a credit-card scheme is used, of course, users can be billed monthly for their share of the fare (5).

Ensuring that subsidy funds paid to the providers of transportation service correspond to trips actually made by members of the client group is a major administrative concern in user-side subsidy schemes. Fraud can occur, of course, if reduced-rate tickets are used by ineligible persons, if providers find some way of obtaining and redeeming unused tickets, or if providers overcharge for services. Other government programs that use the user-side subsidy technique, such as medicaid and the food stamp program, have encountered some of these difficulties. However, fraud seems unlikely to be a serious problem in public transportation applications for the following reasons:

1. Programs can be administered at the local level so that ticket use by individual members of the client group can be closely scrutinized.
2. Private providers are usually relatively small, competing businesses who are highly dependent on local "good will" for their livelihoods and thus can ill afford

to jeopardize their standing in the community by association with fraudulent activity.

3. Users can easily obtain information about the fare structure for available services.

The user-side subsidy approach is not as common in transportation programs as in other social service areas such as medical care, nutrition, and housing. If proper administrative procedures can be developed, however, user-side subsidies offer many important advantages over the more traditional provider-side approaches—capital grants, deficit coverage, and purchase-of-service contracts.

A "pure" user-side subsidy is based on the economic tenet of supply and demand operating in a free-entry, competitive market. By lowering the cost of service to certain users, it stimulates demand and relies on this increased demand to generate a response in the supply of services. Service providers are expected to compete to attract users in order to "earn" their subsidy. This type of user-side subsidy scheme differs from many provider-side subsidy schemes in that the transportation providers cannot take user-side subsidies for granted and have an incentive to operate as efficiently as possible. In a free market situation, the user-side subsidy should result in the providers offering high-quality service at the lowest possible cost. (Of course, too restrictive regulation of transportation providers, services, and fare levels by public regulatory bodies will tend to reduce the efficiency of user-side subsidies.)

The user-side subsidy also offers administrative flexibility to program agencies by specifying who will be subsidized, at what level, and for what kinds of trips. By limiting the sale and use of tickets to members of a particular client group, identified by means of a special identification card, an agency can limit the use of its funds to trips made by members of that group. Overall program costs can be controlled by limiting the total number of tickets sold. In addition, limits can be placed on the number of tickets sold to each person, possibly by coding the tickets with each person's identification number to ensure that tickets are not passed from one individual to another. Some programs have also limited the use of tickets to certain trip purposes, such as shopping or medical trips, but such restrictions may be difficult to enforce.

Another major advantage of user-side subsidies over provider-side subsidies for programs aimed at particular client groups is that the resources of different funding agencies can be used conveniently without unnecessary duplication of transportation facilities. It is difficult to limit funds to a particular client group through provider-side subsidies without establishing or contracting for services designed exclusively for that group. In the case of user-side subsidies, however, a certain level of subsidy can easily be provided for one client group for services that may be available at a different level of subsidy to a second client group and at no subsidy at all to the community at large. Each agency can simply distribute tickets to its particular client group under conditions consistent with the agency's program objectives. For example, an elderly person might use a ticket to obtain a shared taxi ride at half fare and share the taxi with a disabled person who uses a different ticket and pays no fare at all.

Applications

Although user-side subsidies have been used to some degree in public transportation, few applications of such subsidies have been monitored carefully enough to permit a comprehensive evaluation of the administrative costs or the quality of services obtained by client groups from the service providers. The medicaid program has been subsidizing taxicab rides for its clients for some time, and several communities have used discretionary funds such as revenue sharing to institute user-side subsidy schemes for limited-mobility groups. Some of these applications are briefly summarized here as illustrative case studies.

UMTA has been developing a series of demonstration projects designed to test the user-side subsidy technique in a variety of institutional and operational settings. These demonstration projects are also briefly described.

Case Studies

In Los Gatos, California, a small city of 23 735 people, elderly and disabled residents may purchase a maximum of 10 taxicab tickets/month at a cost of $0.50/ticket. They can use 1 ticket/trip anywhere within the city limits. For each ticket used, the city reimburses the taxi operator $2.10 out of revenue sharing funds. In order to prevent potential cash flow problems for the taxicab operator, the city pays the operator a monthly advance based on average ticket use. The program seems to have worked well although no formal evaluation has been carried out.

In December 1974, the city of Oak Ridge, Tennessee, started selling taxi tickets at $0.25/ticket to persons 60 years of age and over. Each ticket can be used in lieu of up to $1.00 of the fare for a taxi ride, and the user pays any remainder over $1.00. The city pays $0.90 for each ticket turned in by the taxicab operator. On those rides for which fares are less than $0.90, the taxi operator makes a small profit; on those for which fares are more than $0.90, the operator sustains a small loss. The city apparently considers the program among its most successful.

In November 1976, UMTA set an important precedent by approving the use of its section 5 funds to subsidize shared-ride taxicab services for the elderly and the handicapped in Oklahoma City (10). A user-side subsidy scheme is being used in this pilot project to reimburse participating taxicab operators for subsidized rides. This particular project is the first instance in which UMTA has explicitly approved the use of section 5 funds to support a user-side subsidy scheme involving shared-ride taxi services and provides encouragement for other cities that are considering similar applications.

West Virginia's statewide Transportation Remunerative Incentive Program (TRIP) combines both user-side and provider-side subsidies to improve the mobility of the low-income elderly. The user-side subsidy portion enables the low-income elderly to purchase $8.00 worth of tickets monthly on a sliding fee scale based on income. Agreements have been worked out with public and private transportation providers across the state—including transit and taxicab operators, Greyhound Corporation, and the National Railroad Passenger Corporation (Amtrak)—to accept these tickets at face value as payment of fares. The provider-side subsidies will permit certain providers to purchase new equipment and expand services for all users, particularly in rural areas. TRIP is funded jointly by DOT and HEW.

A user-side subsidy program adopted in May 1975 by the New Jersey State Department of Transportation allows elderly and handicapped persons to travel for half fare during off-peak periods on intrastate bus and rail lines. An expansion of the program in 1976 made some interstate travel eligible for the off-peak half fare.

Ticket books containing 50 tickets are distributed free to eligible persons through banks. When a user makes a trip, he or she gives the service provider one ticket and the remaining half fare in cash. The provider then submits the ticket to the state and receives a payment based on an average fare established for that particular service and provider. This program was initially scheduled to operate for only 1 year, but the state DOT recently extended the program indefinitely.

Demonstration Projects

Demonstration projects funded by the Office of Service and Methods Demonstrations of UMTA have been designed to provide a comprehensive evaluation of the user-side subsidy technique as it is applied to public transportation. The first demonstration project started in December 1975 and provides shared-ride taxi services at reduced fares for the handicapped and the elderly in the city of Danville, Illinois, which has a population of 45 000. An eligible user pays 25 percent of the taxi fare in cash and signs a charge slip for the remainder of the fare, which the provider subsequently receives from the city. A maximum of $20 worth of taxi service per month per user is permitted, and the city monitors this by keeping a cumulative record of the costs incurred by each eligible person. By December 1976, about a third of the 7500 residents of Danville who were eligible for the user-side subsidy program had registered with the city to obtain identification cards. (About half of those receiving cards had not yet used them but were apparently keeping them for occasional or emergency use only.) Response to the program had exceeded expectations: More than 20 percent of taxi ridership was being supported by the user-side subsidy program. Service levels were apparently high, and the two Danville taxicab operators had placed additional vehicles in service as the need arose. There had been few administrative problems: Payment to the service providers by the city had proceeded smoothly, and there had been no evidence of fraud. A detailed monitoring program in Danville will provide information to other cities on administrative procedures, costs, service levels, and ridership.

Three other UMTA demonstration projects are scheduled to begin during 1977—two in cities somewhat larger than Danville and one in a much smaller city. In Montgomery, Alabama, which has a population of 133 500, elderly and handicapped residents will be able to use shared-ride taxi or conventional bus services at reduced fares through a user-side subsidy program. Four large taxi companies and several smaller operators as well as the publicly owned Montgomery Area Transit System are expected to participate in the program. Eligible users will pay in cash a portion of the fare for shared taxi rides and sign a charge slip for the remainder (the procedure used in Danville). Each reduced-fare bus trip, however, will be recorded by the driver, and the transit system will then receive payments from the city based on the trip records maintained by the bus drivers.

An UMTA demonstration project in Lawrence, Massachusetts, a city of 67 000, will use transportation tickets as a user-side subsidy mechanism to provide reduced fares to the elderly and the handicapped for shared-ride taxi and privately owned transit services. Books of tickets will be sold at half price to those eligible, and there will be a monthly limit on their use by individual users, who will be able to obtain a bus ride or a shared taxi ride by paying the appropriate fares in tickets. The taxi and bus operators will submit used tickets to the city for payment. The Lawrence project will provide an opportunity to examine the administrative effort associated with the distribution and collection of tickets—a procedure rejected by the cities of Danville and Montgomery in favor of the charge-slip scheme.

The use of tickets to provide reduced shared-ride taxi fares to the elderly and the handicapped will also be tested in Kinston, North Carolina, which has a population of 25 000. Each of the 32 franchised taxicab operators in Kinston will be invited to participate in the project.

The primary purpose of these demonstration projects is to investigate service quality, costs, and administrative procedures associated with the following kinds of user-side subsidy programs:

1. Shared-ride taxi services only, provided by two or more service providers (Danville and Kinston);
2. Shared-ride taxi services provided by several service providers and publicly owned fixed-route transit services (Montgomery); and
3. Shared-ride taxi services provided by several service providers and privately owned fixed-route transit services (Lawrence).

These projects will also provide information on the frequency and the purpose of the use of services by eligible individuals. The results of these projects will provide an empirical base for a thorough evaluation of user-side subsidy techniques.

Potential Applications

Applications of user-side subsidies in public transportation have so far been primarily concerned with providing reduced fares for shared-ride taxi and fixed-route bus services for the elderly and the handicapped. A number of other promising applications that have apparently not yet been tried are discussed briefly below.

Serving the Semiambulatory and the Wheelchair-Bound

One subgroup of the transportation disadvantaged not now provided for in user-side subsidy projects is persons who require special assistance or specially equipped vehicles—i.e., the semiambulatory and those confined to wheelchairs. Regulations recently issued by DOT require that the transportation needs of this group be addressed. Each transportation improvement plan submitted to UMTA after September 30, 1976, must contain "...projects or project elements designed to benefit elderly and handicapped persons, specifically including wheelchair users and those with semiambulatory capabilities...." (9). These guidelines include a few examples of efforts that would satisfy the requirements, one of which uses the user-side subsidy approach (9):

> A system, of any design, that would assure that every wheelchair user or semi-ambulatory person in the urbanized area would have public transportation available if requested for 10 round trips per week at fares comparable to those which are charged on standard transit buses for trips of similar length, within the service area of the public transportation authority. The system could, for example, provide trip coupons to individuals who would then purchase the needed service.

Surveys taken recently in a number of states have revealed a surprisingly large number of independent transportation service providers who are equipped to serve the semiambulatory and the wheelchair-bound. Some taxicab operators have a few specially equipped vehicles in their fleets, and a number of private operators have fleets of such vehicles devoted exclusively to serving client groups with special needs. The major problem for client groups using these services is that,

because costs to the providers are high, fares are usually very high (perhaps four or five times the prevailing taxi fares). The user-side subsidy approach could reduce the costs to the users and at the same time ensure that the providers are adequately compensated, encouraging providers to tailor their services to the needs of the client group. In many areas, this approach would eliminate the need to establish separate transportation systems for the exclusive use of client groups with special needs.

Coordinating Funding Sources

In cities where several different agencies have transportation assistance funds to disburse, the user-side subsidy approach provides a means for ensuring efficient and effective use of each agency's resources. One central office could be established to administer the user-side subsidy program for public transportation. This office would be responsible for issuing numbered transportation tickets to the various funding agencies. The agencies would then make the tickets available to their own client groups under prices and conditions consistent with their particular program objectives. Members of these client groups would use the tickets to purchase transportation services from the service providers of their choice, and the providers would then turn the used tickets in to the central office for reimbursement. Finally, the central office would bill each agency for the used tickets the agency was responsible for distributing.

Channeling all transportation tickets and transportation assistance funding through one central office would permit a variety of cost-sharing arrangements between different funding agencies. For example, as part of a citywide public transportation program, a city might wish to commit general funds to paying half of the fare for bus services for all city residents. A home for the elderly might wish to cover the remainder of the fare for its client group. The central office could develop the appropriate billings to the city and the senior citizens' home based on the used transportation tickets turned in by the providers.

A wide range of providers could be involved in such a coordinated user-side subsidy program: private taxicab and limousine operators, conventional transit systems, specialized profit and nonprofit providers with vehicles equipped for the semiambulatory and wheelchair-bound, and even private individuals operating in volunteer capacities. Rates of fare and service standards established for the different providers might vary from inexpensive, volunteer services available only infrequently to quite expensive, high-quality, shared-ride taxi services. Users could be given a certain budget of reduced-rate tickets per month and be free to use them in whatever manner best met their needs. Some users who need the more expensive services with specially equipped vehicles, such as the wheelchair-bound, might be allowed larger reduced-rate budgets than users who are able to use conventional services.

Combining Provider-Side and User-Side Subsidies

Some of the major transportation assistance programs currently available, such as the UMTA section 3 and section 16b2 programs, earmark funds for particular types of service providers or types of transportation expenditures so as to preclude the disbursement of these funds through user-side subsidy mechanisms. Earmarking funds for capital equipment is common in transportation assistance programs, for example. Although the wisdom of this kind of earmarking is somewhat doubtful, cities are likely to have to deal with it as best they can for at least the next few years.

One approach that offers prospects for avoiding the major inefficiencies of earmarking by capital equipment is to combine this type of provider-side subsidy with a user-side subsidy scheme. A city or a consortium of social service agencies could establish a central vehicle fleet with the aid of UMTA, state, or other funds and lease the vehicles at nominal rates to providers of transportation services in the area. Agreements could be developed along the lines used by the large automobile rental and leasing companies; the city or the consortium would be the lessor and the service providers the lessees. Vehicles could be made available to any and all providers who were willing to meet regulatory requirements for safety and financial responsibility.

Making capital equipment available to transportation service providers at nominal rates would reduce their costs to some extent and permit them to operate with somewhat lower fares. Should these fares still prove to be too high for some purposes, a user-side subsidy technique could be used to permit various funding agencies to subsidize ridership for their particular client groups.

One application of the user-side subsidy in combination with provider-side subsidies might be of interest in large metropolitan areas with regional transit systems that are supported by several different jurisdictions. The prevailing fare structure might be publicly supported for all residents of the region by provider-side subsidies in the form of capital grants and additional subsidy funds to cover operating deficits (which is common practice). Suppose one jurisdiction in the region wished to institute a further fare reduction for elderly and handicapped residents but other jurisdictions were not willing to support the idea regionwide. The jurisdiction could institute a user-side subsidy scheme for its elderly and handicapped residents by making reduced-rate tickets available for use on the regional transit system. The transit management could then obtain reimbursement for the tickets from the jurisdiction without having to involve other jurisdictions in the scheme at all. Such an approach would be a convenient way of giving individual jurisdictions some discretion in the use of their subsidy funds without getting involved in highly complex "deficit-splitting" formulas.

Stimulating New Services

The concept of the user-side subsidy is a relatively simple one in which the aim is to offer reduced fares to certain client groups for existing services. Suppose, however, that a city wished to provide low fares on scheduled, fixed-route transportation services for all city residents but no fixed-route services currently existed in the city. Could the user-side subsidy technique be applied? In principle, the answer is yes. No cities appear to have taken this approach so far, but in May 1977 the city of Danville, Illinois, did apply to UMTA for additional demonstration funds to test a user-side subsidy scheme for stimulating and supporting new fixed-route services in the city. Under this proposal, the city would announce that residents could purchase tickets from the city for use on fixed-route services and that service providers who offered such services could redeem used tickets from the city at a value significantly above the price paid by the users. Agreements would be developed between the city and the responsible providers on the routes and schedules to

be offered, and the city would control service coverage and fare levels through the redemption value of the tickets.

CONCLUSIONS

Transportation programs for the elderly and the handicapped that earmark funds by the type of transportation expenditure (capital versus operating) or by provider type (profit versus nonprofit) impede the efficient provision of transportation service. Turf-protection attitudes on the part of administrative agencies also create impediments to efficiency. In addition, the disbursement of funds exclusively through provider-side subsidy techniques tends to deny many qualified providers the opportunity to participate in publicly funded transportation programs, thereby reducing competition and removing some of the incentives for the participating providers to operate efficiently.

Relaxation of earmarking requirements for transportation programs will in most cases require legislative action, but turf-protection attitudes and disbursement procedures can often be changed through administrative action. Procedures should be introduced to encourage or mandate greater cooperation between agencies administering transportation programs. User-side subsidy techniques should be considered as a means of maintaining competition between service providers and rewarding efficient operation.

Experience with user-side subsidies for public transportation is rather limited although recently funded demonstration projects will provide new empirical information over the next 2 years. Existing applications of user-side subsidies have demonstrated the administrative feasibility of this approach under a number of different institutional arrangements. Although a comprehensive evaluation of service levels and costs associated with the approach is not yet available, the evidence suggests that user-side subsidies deserve serious consideration by agencies administering transportation programs for the elderly and the handicapped.

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Transportation for the Elderly and the Handicapped: The San Diego Study

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The purpose of a recent transportation study in the San Diego region was to estimate the needs of elderly and handicapped citizens and to develop a comprehensive program and policy package to meet those needs. Both the methodology and the recommendations of the study may be applicable elsewhere. Because of the varying financial, operational, and management structures associated with different types of transportation service,

demand estimates were built around five categories of transportation service. This classification system directly related limitations on the mobility of different groups of handicapped persons to the types of transportation service required by those limitations. Statistical surveys were avoided. Demand for each type of service was estimated from available statistics, from other studies, and from extensive interviews with social service agencies. The study found that there was heavy demand for services other than conventional, fixed-route bus transit. Because this implied that cost was a major issue, emphasis in program and policy design was placed on the development of cost options. Operational and institutional aspects of the service were also considered.

A study of transportation services for the elderly and the handicapped in the San Diego region was undertaken for the San Diego County Comprehensive Planning Organization (CPO) between late September 1975 and early 1976. The purpose of this study was to assess the transportation needs of the elderly and handicapped population of the region and to identify and evaluate methods for meeting those needs. A program of transportation service, management, and financing was developed to respond to the needs determined by the study, and key policy issues for action by local and regional governments were identified.

The study was conducted with the assistance of an ad hoc advisory committee established by CPO for purposes of guidance and review. The committee, headed by the mayor of San Diego, included leaders of social service and transportation organizations that provide services to the handicapped and the elderly as well as representatives of the handicapped and elderly themselves.

The study was conducted during a time of nationwide concern for the plight of the elderly and the handicapped. Then as now, however, there was uncertainty as to what policies and guidelines were most appropriate for serving the needs of these groups. Federal law then required that regions of the country that were to receive federal transportation funds have plans for providing "equal access" to the elderly and the handicapped by October 1976. But the probable costs and the operating consequences of providing equal access were not known. There were, for example, serious engineering obstacles to the design and manufacture of equipment by which persons confined to wheelchairs could be provided equal access to transit vehicles. It was partly for these reasons that, shortly after the completion of the study, UMTA published its April 30, 1976, guidelines giving local jurisdictions freedom to use approaches other than full equal access to conventional transit. Controversy continues with regard to the use of full-access or separate-service approaches in supplying transportation for disadvantaged groups.

Several planned or probable actions in the San Diego region added to the uncertainty. A regional transportation development board was being created, and the future roles of this body and of the CPO were uncertain. In addition, the CPO was planning a study of rural transportation; the San Diego Transit Corporation was studying the feasibility of fixed-route buses with lifts and a possible takeover of the city's dial-a-ride system; and the County Office of Senior Citizens Affairs continued to work on its regional plan, which included a transportation element.

Because of this fluid situation, the approach used in this study was to form a framework into which new developments could be incorporated over time. This framework consisted of (a) easily understood methods for estimating demand and determining what services were needed, (b) identification of key policy decisions that would need to be made in order to proceed further, and (c) formulation of short- and long-term recommendations for improved services based on stated policy assumptions.

STUDY DESIGN

The study was divided into two phases: the estimation and description of transportation demand and the planning of services to respond to that demand.

Demand Estimation

Demand was defined as the total current need minus the service provided by existing transportation systems. This relatively simple concept was easily understood by all the nontechnical participants on the ad hoc advisory committee for the project.

Techniques used to identify transportation demand were chosen to provide a quick, relatively inexpensive, acceptably accurate picture of needed services. Travel behavior and the needs of the handicapped were found to be adequately documented for the purposes of the study by previous investigations in the San Diego region and by studies done in other areas. Use of a statistical survey of elderly and handicapped persons was rejected as both costly and unnecessary. It was felt that a survey of reasonable size and cost would not have yielded results that would be much more useful than existing data, and a survey large enough to provide statistically reliable estimates of such details as trip patterns by user type would have been too slow and expensive. Both survey approaches would have suffered from the fact that many respondents are unable to estimate accurately, in advance, their use of some hypothetical service. Both would also have consumed study time and funding that could be used for purposes such as in-depth field research, the involvement of representatives of the affected groups, and inventories of existing services. A small sample of elderly and handicapped persons was interviewed to check the results found in other studies, and these results were combined to estimate travel needs for each class of transportation service.

The study also determined what services for the elderly and the handicapped currently exist and how much they are being used. Interviews were conducted with representatives of nearly 70 social service agencies and charitable groups, which were drawn from a much larger list of such groups assembled from various inventories. Those interviewed were chosen to represent different kinds of services, such as home care, nursing homes, specific kinds of health care, education, general financial aid, and recreation.

Service Planning

The study's estimation of transportation demand indicated that a three-part approach providing improved transportation for the elderly and the handicapped was needed: coordination of the operations of social service agencies, acquisition of fixed-route transit coaches equipped with special features, and formation of a program of door-to-door, shared-ride service. The role of each of these services was described, and options for financing and operations were presented.

FINDINGS OF THE DEMAND STUDY

Eligibility and Classes of Service

Central to the process of demand estimation were the definition of who was to be eligible for service and a set of service categories that would be tied to distinct types of demand. The elderly were defined as including all those 60 years of age and older (the policy of local San Diego transit operators). The term handicapped was

broadly defined in accordance with the final regulations on transportation for elderly and handicapped persons issued by the Urban Mass Transportation Administration in April 1976:

> . . . individuals who by reason of illness, injury, age, congenital malfunction, or other permanent or temporary incapacity or disability including those who are non-ambulatory wheelchair-bound and those with semi-ambulatory capabilities, are unable without special facilities or special planning or design to use mass transportation facilities and services as effectively as persons who are not so affected.

Throughout the study, persons who were both elderly and handicapped were included in estimates of the elderly to conform with statistical presentations in many of the references used. The term younger handicapped is used in this paper to identify all those under 60 years of age.

More important than these general definitions were the transportation service classes (TSCs) given below, which were devised to link demand to types of service:

Class	Service
1	Ambulance
2	Door-to-door service with lift
3	Door-to-door service without lift
4	Fixed-route transit with special features
5	Conventional fixed-route transit

The TSCs can be briefly defined as follows:

1. Class 1 represents services for individuals who are bedridden or confined indoors. These persons were considered to be outside the scope of service that can logically be offered by mass transportation and were not treated in detail in this study.
2. Class 2 represents services for those who cannot make self-propelled level changes—for the most part, those in wheelchairs who require some form of lift or elevator to get on and off mass transit. An option within this class is fixed-route buses with lifts providing door-step delivery.
3. Class 3 represents services for persons who can make self-propelled level changes but are so severely handicapped that door-to-door service with driver-attendants who have at least minimal training in assisting the handicapped is needed.
4. Class 4 represents services for many blind, deaf, and other moderately disabled persons who are ambulatory and can wait for, board, alight from, and otherwise manage travel on buses and trains but who need special system and vehicle features that ease the burden of physical movement (such as additional grab rails and lighted stairwells).
5. Class 5 represents services for all persons, whether elderly or handicapped or not, who have insignificant mobility problems or none at all.

Population and Travel Behavior

The size and the geographical distribution of the elderly and handicapped population of the San Diego region were estimated from the 1970 and 1975 U.S. Censuses and statistics of the California state departments of rehabilitation (for recipients of rehabilitation services) and education (for handicapped children). The travel behavior of the elderly and the handicapped was estimated from a variety of available local studies, information from other cities, and interviews with social service groups and transportation operators. Local studies included a 1966 origin-destination survey, a 1974 survey of bus riders, and specific 1973 and 1975 needs studies. Other information included studies in other cities (5, 8) and more broadly based research (1, 2, 4, 7, 9, 10, 11, 12, 13). Estimates of mode of travel and the frequency, purpose, time, and length of trips were taken from these sources. Finally, population estimates for the elderly and the handicapped were distributed among the five transportation service classes by comparing and combining the fragmentary information of these different sources. The results are given below:

Service Class	Elderly		Younger Handicapped	
	Number	Percent	Number	Percent
1	8 150	4	5 600	8
2	2 000	1	3 500	5
3	50 950	25	15 400	22
4	71 350	35	21 000	30
5	71 350	35	24 500	35
Total	203 800	100	70 000	100

Existing Transportation Services

The next step in the process of demand estimation—an inventory of existing transportation sources available to the elderly and the handicapped and an estimation of their use by those groups—served three purposes:

1. To identify transportation sources that might be used more intensively;
2. To locate geographic areas in which the elderly and the handicapped were not being served; and
3. To estimate ridership by the elderly and the handicapped as an element in the calculation of transportation needs that were not being met.

The inventory was compiled from published operating data for public transit and taxi services, interviews with operators and social service agencies, and two less complete 1975 surveys on the topic by the San Diego CPO and the California Department of Transportation. The completed inventory included buses operated by schools, charter companies, and public transit agencies; taxis; volunteer automobiles; vehicles with wheelchair lifts; vans operated by a variety of agencies and groups; and the three limited dial-a-ride systems of local cities. The data were organized by TSCs for compatibility with the study's overall approach.

Vehicles available in the region to serve the elderly and the handicapped and estimated daily ridership among these groups are given below:

Service Class	Service	Vehicles	Daily One-Way Trips Served
2	Door-to-door with lift	15	100
3	Dial-a-ride systems and agencies	≥236	2 200
	Taxis	508	1 500
4	Fixed-route with special features	0	0
5	Conventional fixed-route		21 200
	Fixed-route fleets	406	
	Public school buses and charter buses	755	
Total		≥1920	25 000

In the study's inventory of vehicles in the region that could conceivably transport elderly and handicapped persons, approximately 2000 such vehicles were found. School and conventional transit buses accounted for most of the available vehicles. Although the region's large taxicab fleet provided most of the available door-to-door service, relatively high fares discouraged their use by many of the elderly and the handicapped.

Three cities in the region operated dial-a-ride services within their borders, each according to different eligibility criteria and operating methods. All of these services were limited in size and range, but all provided at least some service to persons who had no other means of travel. Two of these systems used taxis; the third—that of San Diego—operated small buses that included some with wheelchair lifts.

Ridership estimates given in the table above indicated heavy use among the elderly and the handicapped of conventional fixed-route transit buses and relatively little use of vehicles operated by social service agencies. Interviews with agency representatives revealed that there was little interagency coordination of these transportation activities. Vehicle occupancy rates were generally low and many vehicles were not in continuous operation throughout the day. In addition, some agencies without adequate transportation had no way of making use of other agencies' services.

Unmet Travel Needs

Unmet travel needs were calculated by multiplying the number of eligible persons in each TSC by a target daily trip rate and then deducting present ridership by TSC on existing transportation services. This procedure required making a number of assumptions. To avoid overestimation of demand, a generally conservative approach was taken in defining such assumptions. In addition, the sensitivity of the demand estimates to alternative assumptions was determined; this produced no change in the key conclusions. The major assumptions made were that

1. Both automobile drivers and their passengers need no additional transportation,
2. Automobile drivers occur in the same proportion to the totals in classes 4 and 5 and in no other classes, and
3. Automobile passengers and persons without access to automobile travel occur in the same proportion to the totals in all five classes.

A key factor in the assessment of unmet travel needs was the selection of desired daily trip-making rates as targets. Based on other studies of reported demand (1, 2, 9), rates of 1.1 trips/person/d for the elderly and 1.4 trips/person/d for the handicapped were adopted. These rates contrast with typical values for the general population (2.5 to 3.0 trips/person/d and higher) (3) but are significantly higher than the current trip-making rates estimated for these special groups in San Diego (0.5 to 0.9 trips/person/d) (1, 2, 9, 12).

Results of the estimation of unmet travel needs are given below:

Service Class	Desired Trips per Day	Current Daily Ridership	Unmet Need (trips per day)
2	3 400	100	3 300
3	30 400	3 700	26 700
4	14 600	21 200	9 600
5	16 200		
Total	64 600	25 000	39 600

These data indicate that about 40 000 desired trips/d were not served by existing transportation services. The large share of this need was for door-to-door service without wheelchair lifts (class 3).

Sensitivity tests were applied to this estimate of unmet need. Different assumptions were made for the distribution of automobile drivers and the trip-generation rates in the five TSCs. When the assumed distribution of drivers was varied, the heaviest demand was still found in classes 3 and 4. When it was assumed that the rate of desired trips among those who did not use automobiles was only as high as the estimated rate of travel among automobile drivers and passengers, somewhat smaller trip totals were derived. However, the travel need of class 3 was still calculated at four times the level now being served.

Obviously, figures derived in this way must be used with caution, as must all forecasts. These are target numbers. All of these desired trips would not necessarily materialize even if there were high-quality, barrier-free transportation. Use of new transportation services will require significant changes in the customary daily routines of the elderly and the handicapped; it is reasonable to expect that such changes will occur only gradually and to an unknown extent. Although the derived estimates should be considered as order-of-magnitude numbers, they are quite adequate for use in transportation service planning.

PLANNING OF SERVICES

The logic of the study design and the demand-estimation results indicated that service needs could be divided into three distinct elements:

1. Transportation provided specifically by social service agencies;
2. Modifications to conventional fixed-route buses (class 4); and
3. Door-to-door services with and without lifts (classes 2 and 3).

Recommendations on the first two types of need were derived directly from the collected and estimated demand data. The cost of bus modifications for class 4 services and sources of funding for these services were the only additional factors involved and were easily identified. Therefore, class 2 and class 3 door-to-door service became the focal point of the study's effort in service planning.

COORDINATION AMONG SOCIAL SERVICE AGENCIES

The survey of existing transportation services indicated that there was obvious potential for achieving greater efficiency through coordination among the various independent agencies but that institutional factors and the agencies themselves had inhibited such cooperation (10, 14). The need for services was found to be continuing and even increasing at the same time that funding was tightening. This, coupled with forthcoming federal regulations (16), was expected to increase the chances for more efficient service through interagency cooperation.

The study therefore recommended creation of the position of central transportation coordinator—an official who would work among the region's social service agencies and groups. The functions of the coordinator would be

1. To operate a day-to-day central referral service to match the transportation needs and the available transportation facilities of agencies throughout the region,
2. To develop data on specific institutional barriers and other barriers to such coordination for use by policy makers in encouraging change, and
3. To increase the transportation resources available

to agencies by developing a modest pool of vehicles, some of which would have special equipment (this would be optional and would be done only if demonstration funding were available).

Modifications to Conventional Fixed-Route Buses

The estimated transportation needs of the elderly and the handicapped indicated that an overall approach to improved transportation service should include conventional fixed-route transit vehicles equipped with features such as lower or extendable steps, stepwell lights, handrails, and larger destination signs. This recommendation responded both to the large number of class 4 persons who required transportation and to the many class 3 persons who could use such fixed-route service in conjunction with separate door-to-route feeder service. The overall costs of improving transportation for class 3 users could thus be minimized.

It was estimated that equipping 50 or more buses with the required special features would involve the same capital cost as adding one new bus to the transit fleet. Therefore, implementation of such a recommendation would result in only a small reduction in planned bus acquisitions.

Installation of wheelchair lifts was recommended as an item for long-term consideration. Immediate retrofitting of conventional buses was not recommended because of high cost, design problems, and the small proportion of handicapped persons who would benefit from the improvement. The low density of the San Diego region and the fact that bus routes are often far apart would mean that many wheelchair users could not get to the bus stops. Separate (class 2) systems for the relatively few persons who would benefit from retrofitting of fixed-route buses appeared to be more practical for the present. Since the study, the San Diego Transit District has begun experimenting with five lift-equipped coaches on designated routes. This demonstration will provide important guidance for future policy concerning the use of lifts on regular bus routes.

Door-to-Door Services

Three general components of door-to-door service (classes 2 and 3) were considered: (a) operations (type and level of service, priorities, and equipment); (b) management (functions and responsibilities); and (c) financing (subsidies and fares). Many options were found for each of these components, both in the literature and in current experience elsewhere. The objective of the analysis in this study was to reduce these options to a limited number for consideration by citizens and policy makers of the San Diego region.

Evaluation Criteria

The criteria established for the evaluation of door-to-door service options included items such as the number of trips served, service accessibility, coordination with existing transportation services, ease of adjustment to future conditions, impacts on other transit users, and simplicity of the management structure.

Evaluation of Operations Options

The unique transportation needs of those requiring class 2 and class 3 service dictated that the most extensive effort in the design of a transit system be devoted to the specific operating features of the system. First, 24 alternatives representing combinations of routing, scheduling methods, and area coverage were generated; these were then reduced, on the basis of logical compatibility, to 8 alternatives. Application of the relevant evaluation criteria led to the selection of methods of operation for both service classes 2 and 3. The proposed class 2 system (for wheelchair users and others who require special attention) would use vans operating on a subscription basis during peak hours and at other times prearranged deviations from fixed routes to pick up and deliver passengers. To maximize coverage, the routes would vary by day of the week. The class 3 system (basic door-to-door service without lift) would function on a fully responsive dial-a-ride basis wherever the demand density proved sufficient and use prescheduled route deviations elsewhere.

Management

Both the management of service delivery and responsibility for policy guidance were considered. Evaluation of options for the management of service delivery focused on private taxi versus public transit approaches; the funding level was held constant. An extensive review of operating costs for both private taxi and public transit systems in San Diego and elsewhere revealed that unit costs were not significantly different within the limits of accuracy allowed by available data. Application of the full set of evaluation criteria led to the conclusion that, although both types of systems appeared to have similar person-trip costs, the taxi-based management approach was superior in almost all other respects. Among its advantages were transferless service, 24-h availability, faster response, ease of user understanding, and simplicity of administration.

It was also concluded that control over local financial commitments and their use should rest at the local level and that there should be a minimum of policy making, beyond agreements in principle, at the regional level. The following plan was recommended. Each participating city would set its own maximum funding level each year. At the same time, each city would decide whether to use this to subsidize more trips at a lower subsidy or fewer trips at a higher subsidy (up to 100 percent). The city would then pledge this amount (plus the fare increment to be collected) to the central agency that provides the service and in return receive trip vouchers or tokens corresponding in value to this amount. The city would then "sell" these tokens to its own citizens at whatever fare level it had elected. Eligibility and other restrictions, such as a maximum number of tokens per person per month, would be set and controlled by each city at the point of sale. The user would then use the tokens in whatever amount was required for a particular trip with fare dependent on trip length.

Responsibility for lower level operating policy and control must also be placed. Such responsibility could be given to any of several existing bodies—including the CPO, the region's two transit agencies, an existing social service umbrella agency, and the city or county government—or a new public (or private nonprofit) agency could be created. Evaluation of these options was based primarily on discussions with public officials. The main objective was to place these responsibilities where the greatest cooperation and credibility could be achieved. It was concluded that the region's two public transit agencies were in the best position to carry out these management functions, including contract supervision of taxi services, negotiation of service agreements with participating cities, and establishment and monitoring of operating procedures.

Financing

Three alternative levels of annual system cost were developed to be presented with the corresponding estimates of the proportions of need served. These were based on a review of local, state, and federal funding sources and represented three levels of policy commitment:

Cost Level	Policy
1	Current per capita rate of cost for the existing San Diego city dial-a-ride system extended to the entire urbanized area
2	Maximum feasible use of local sources plus small federal-state demonstration grant
3	Same as level 2 plus maximum "reasonable" diversion of forecast federal transit subsidies from fixed-route operations

Even at the highest cost level, it was found that only about one-sixth of the estimated demand could be served. Thus, the final policy decision posed for the region was a difficult one: Given evidence of a major public need, how and by how much should taxation and spending priorities be adjusted in response? Other regions can expect to face the same difficult decision during the next few years.

This study did not analyze the impact of door-to-door service on taxes or on other services. It should be noted, however, that even the highest funding level recommended would cost approximately only $3/year for each citizen in the region.

RESULTS OF THE STUDY

The results of the study were presented to the mayor of the city of San Diego, who headed the citizens advisory committee, and to representatives of each of the surrounding 13 cities on the CPO board. The board formally adopted the proposed policy recommendations.

At the time this research was completed, one local group had received funding to provide coordinated transportation for nursing-home patients and other referrals in the eastern suburbs of the region. The city of Chula Vista was working to coordinate the transportation services of agencies within its city limits. Other cities in the region had not yet acted to help in providing services for the elderly and the handicapped. The new taxi company management in the region had shown interest in expanding San Diego's dial-a-ride service, but no action had yet been taken.

Since the conclusion of the San Diego study, many other municipalities and regional planning agencies have sponsored similar studies. The federal government is also conducting a nationwide survey among the handicapped that it is hoped will substantially improve current estimates of the need for specialized transportation services. The resulting improvements in knowledge and technique plus emergent federal and state legislation are rapidly moving the nation toward solutions of these problems.

CONCLUSIONS

Conclusions drawn from the findings and the methods of this study may be useful elsewhere. The findings suggest several key points, including the following:

1. There is evidence of a great need for additional transportation among elderly and handicapped persons.
2. Substantial benefits can result from improved coordination and sharing of the transportation facilities of various social service agencies and groups.
3. Many people without other means of travel appear to require door-to-door services without special equipment.
4. Taxis may be a particularly useful means of providing these special services.
5. Costs of such special services are likely to be high because of heavy demand and relatively high cost per passenger. Thus, staged implementation of services and maximum policy control at the municipal level are required.

The following conclusions on the methods used in the study may be particularly applicable elsewhere:

1. Methods other than large, local statistical surveys should be considered. Existing data and the combined knowledge of local agencies may be (as they were in this study) equally useful and less costly.
2. Demand can and should be estimated based on the type of service required. The system of five transportation service classes designed for this study appears to be useful for this purpose.
3. Planning of such special services should include financing and management options as well as the technical details of operations.

ACKNOWLEDGMENTS

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Abridgment

Coordination and Integration of Special Transportation Services for the Transportation Disadvantaged

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In the region comprising the Michigan counties of Ingham, Eaton, and Clinton, which includes the city of Lansing, a variety of agencies offer transportation services to those whose mobility is limited because of age, income, or physical or mental handicap. This situation offered a unique opportunity for an examination of the operational efficiency and the cost-effectiveness of current transportation services for the transportation disadvantaged. It was possible, through an analysis of the transportation needs of this sector of society, to compare transportation demand with the characteristics of transportation service as it is now supplied. That comparison determined the efficiency with which such special transportation needs were being met and made it possible to identify alternative service patterns that promise greater efficiency.

ESTIMATED GROWTH OF DEMAND

Service agencies in Lansing, Michigan, currently provide approximately 43 000 trips/month to the elderly, the handicapped, and low-income residents within their service areas, which are heavily concentrated in the Lansing urban area. It has been estimated that the potential market for trip making by transportation-disadvantaged groups in the tri-county region is between 100 000 and 120 000 trips/month (this includes all persons whose mobility is limited because of age, income, or physical or mental handicap and who currently have no access to transportation service). These estimates are based on a potential expansion of service in the service areas only and do not consider changes in the characteristics of service provided. The number of trips could thus be increased by almost a factor of 3 if service were expanded to areas that are not now being served by the special transportation agencies. Of this increase of about 70 000 trips/month, a gain of nearly 15 000 trips/month could be expected in areas outside the public transit service region (1).

Two factors will have a major influence on the future demand for trips by the transportation disadvantaged in the tri-county region. The first factor is the growth in the base population classified as elderly, low-income, or handicapped. Population projections of the state of Michigan in 1974 indicated that the elderly population is expected to grow by about 50 percent in the next 20 years. Similar data available on the handicapped and low-income population classifications show that the proportion of persons within these classifications will remain fairly constant during the next 20 years and therefore the total increase in demand from these segments is expected to be about 30 percent during that period (2). These data indicate that demand on the transportation system will increase substantially in the next 20 years and that the potential exists for ridership at a level of 200 000 trips/month as a result of population growth alone.

The second factor is the type of service offered to the transportation disadvantaged. As a basis for comparison, the demand for trips by the elderly population of East Lansing is between 3 and 4 trips/month/person. In the tri-county region, the demand from this market segment is only about 1 trip/month/person. The significant difference between these demand figures may be at least partially attributed to the difference in service offered to the elderly residents of East Lansing. As part of the East Lansing Older Peoples Program, service is provided by taxi and half the fare is subsidized by the community. This may represent the ultimate

service quality because it provides door-to-door service on demand without ride sharing. If this type of service were provided throughout the region and the demand ratios cited above were extrapolated over the entire region, it is apparent that the ultimate potential market would be between 400 000 and 450 000 trips/month. This increase translates to between 45 000 and 60 000 trips/month outside the area served by public transit.

ANALYSIS OF EXISTING SPECIAL TRANSPORTATION

Most special transportation service is currently provided in the Lansing urban area and in Ingham County; at best, only token service is provided in Clinton and Eaton counties. Service is provided mostly by nonprofit agencies that are heavily supported by government at the federal, state, and local levels (3). Data show that there is heavy reliance on subsidy to cover service costs and that the services offered are limited by the available subsidies.

Service in the Lansing urban area is provided at a significantly lower cost per client than in the outlying areas. This is probably a result of the area of coverage in the Lansing urban area as well as the larger number of clients in this area. Service is generally provided without charge; only two agencies charge users a fee.

The agencies are generally small in terms of their client market, and 60 percent of the agencies serve only 13 percent of the clients. Most agencies have six or fewer vehicles at their disposal and use them extensively. Several agencies indicated that their vehicles have been heavily used, which indicates higher maintenance costs and capital replacement costs in the near future. The total seating capacity of the vehicles owned by the 21 selected agencies is estimated to be about 1450 seats; this estimate may be extrapolated to about 2000 seats available to the transportation disadvantaged in the region. Thus, if operating efficiencies could be effected, the existing vehicle fleet could provide a significant level of service.

Service costs are estimated to range from about $0.15 to $0.31/km ($0.25 to$0.50/mile). These costs seem significantly lower than those available in data from other areas. Trip lengths average about 13 km (8 miles).

In an examination of the available financial data of the various agencies, it became apparent that important service improvements or cost economies could be realized through coordination of services or integration under a single management structure. Under the present arrangement, there are overlapping and duplication of service areas as well as duplication of allocated management costs and indirect costs among the agencies.

SYSTEM OPTIONS AND EVALUATION CRITERIA

The various transportation service options available in the tri-county region for people of limited mobility have been developed in relation to two broad areas of concern—service characteristics and institutional structures. The alternatives available in the category of service characteristics are given below:

Item	System Option
Routing	Fixed route
	Route diversion
	Demand responsive
	Subscription service
Vehicles	Standard buses
	Mixed fleet
	Modified vehicles
	Special vehicles
Coverage	Regional
	Greater Lansing area
	Activity centers
	Corridor
	Specific areawide
Scheduling	Peak period
	Weekday
	Daily
	Periodic

The alternatives available in the category of institutional structures are as follows:

Item	System Option
Organization	Regional central agency
	Greater Lansing central agency
	Supplemental agencies
	Activity area
Funding	Government
	Donation
	Purchase of service
	Subsidy
	Fare box
Integration	Coordination
	Central management
	Central operation
	Subsystem management
	Subsystem operation

Obviously, a large number of alternatives are available in the region. However, if the existing system is imposed on these system options, only a few workable alternatives result. This is particularly true if the geographic pattern of demand identified in the earlier survey data is considered.

Evaluation criteria to be considered in a comparison of service alternatives are given below:

Category	Criteria
Performance and cost	Vehicle type and features
	Vehicle seating capacity
	Average trip speed
	Subsystem potential (seat kilometers per vehicle hour)
	Subsystem productivity (trips per vehicle hour)
	Average trip length
	Subsystem output (trip kilometers per vehicle hour)
	Subsystem utilization (trip kilometers divided by seat kilometers per vehicle hour)
	Operating cost
Institutional structure	Percentage of demand served
	Coverage (service area)
	Funding sources
	Funding levels
	Transferability of interagency funding
	Management economics
	Operational economics
	Maintenance economics
Service measures	Level of service (service time divided by automobile trip time)
	Percentage of demand served (by subgroup and subarea)
	Service frequency
	Fare

The following series of options, which form a hierarchy of alternatives ranging from the existing system to the ultimate regional system, were identified:

Alternative	Description
1	Maintain existing supply of special transportation service in the region
2	Integrate and coordinate operation of special transportation service of existing agencies
3	Integrate and coordinate operation of special transportation service of existing agencies to effect a minimal level of regional coverage on a periodic schedule
4	Expand service of Lansing Capitol Area Transportation Authority (CATA) in the urban area and integrate and coordinate operation of special transportation service of existing agencies in the urban area
5	Integrate and coordinate county system and subsystems of urban area
6	Expand service of Lansing CATA to several outlying areas and integrate and coordinate operation of existing transportation service
7	Establish fully integrated and coordinated special transportation system at the regional level

These service options have been generated with the objective of satisfying higher levels of demand with each incremental commitment of resources in the progression from the existing system to an ultimate regional system of special transportation service. In other words, a greater commitment of resources should result in greater satisfaction of demand. Figure 1 shows the nature of coverage for the seven alternatives.

COST-EFFECTIVENESS ANALYSIS OF ALTERNATIVES

The implied goal of this study was to examine the efficiencies that would result from coordinating and integrating existing special transportation services in the Lansing region. For this purpose, two measures of efficiency—the percentage of potential demand that may be satisfied by an alternative and the cost of service for an individual trip—were used. The cost-effectiveness analysis considered each of these factors in the evaluation of each alternative.

The degree to which each alternative satisfies regional and specific areawide demand is given in Table 1 (4). The daily demand satisfaction in trips and a percentage of the ultimate regional demand of 9600 trips/d are given for each alternative. The table also gives the total cost per trip and the number of buses and vans required for provision of service under each of the seven service alternatives.

RECOMMENDED SERVICE PLAN

The highlights of the recommended plan for providing service to meet the transportation needs of elderly, handicapped, and low-income persons in the tri-county region (5) are summarized below:

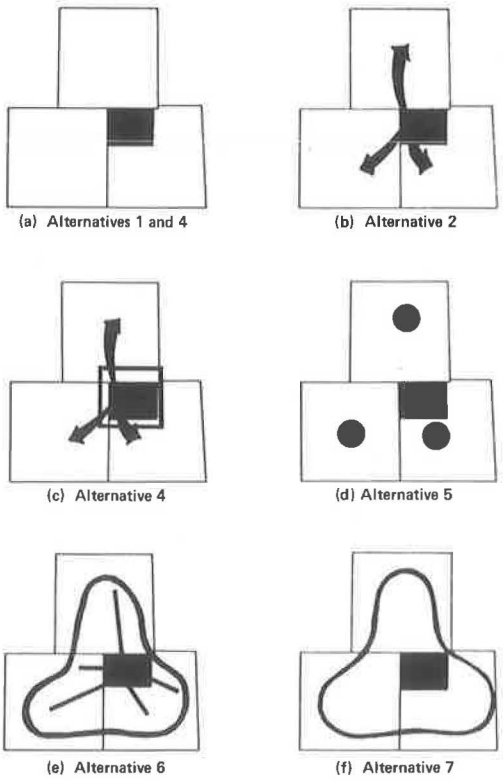
1. A central coordinating agency (CCA) would be established to coordinate the special transportation services in the region. The CCA would act as a broker to arrange for and provide transportation services for the elderly, handicapped, and low-income population by the most cost-effective and efficient means.
2. The social service or government agencies that currently operate or purchase transportation services for their clients would be encouraged to participate in the coordinated system. This participation would be based on certain guidelines proposed in the study, such as high trip costs and low vehicle productivity and the difficulty of obtaining funds for capital equipment and maintenance.
3. In the contiguous and heavily populated areas, there would be intensive use of taxicabs for incidental and individual trips.
4. The fleet of small buses used by social service agencies and the public transportation agency in the area would not be expanded until the end of the demonstration period.
5. Transportation cards that entitle the holder to reduced taxi fare would be used.

The plan for the county areas includes the following points:

1. Each county would have the option of initiating a minimum level of service in the out-county area by using three small buses operated on a demand-responsive basis.
2. The funding for the county system would be channeled through the CCA.
3. The plan could be scaled downward or upward based on the resources available to an area.

Table 2 (4) compares the performance of the present system with that of the proposed system. Clearly, the proposed system is the more efficient of the two; total annual costs are about equal. Trip cost under the proposed system is lower than that under the present system but higher than average taxi cost per trip, which indicates that, based on this analysis, taxi service is perhaps the least costly system.

Figure 1. Approximate regional coverage of seven service alternatives.



SUMMARY AND CONCLUSIONS

The study conducted in the Lansing area demonstrated that the level of transportation service provided for the transportation disadvantaged is quite low in comparison with the service offered to the general public through the existing transit system. It further showed that the provision of special transportation service by independently operated agencies resulted in duplication of management requirements and service vehicles, the overlapping of service areas, and service inefficiencies. The development and analysis of alternative means for providing service indicated that a simple coordination of the operations of these independent agencies would significantly reduce service costs and increase both vehicle utilization and the level of demand satisfaction.

The tri-county region is currently in the process of implementing the plan for a minimal level of coordinated service in the Lansing urban area and the rural areas of Clinton, Eaton, and Ingham counties.

It is anticipated that the results of this planning study will be applicable to many communities throughout the state of Michigan that are faced with similar service re-

Table 1. Demand, cost, and service data for seven service alternatives.

Item	Alternative[a]						
	1	2	3	4	5	6	7
Trips per day[b]	833	1600	916	2300	2100	1900	2560
Satisfied demand, %							
Lansing urban area	14	27	10	38	30	32	27
Clinton County	0	0	8	—[c]	8	—[c]	27
Eaton County	0	0	8	—[c]	8	—[c]	27
Ingham County	0	0	8	—[c]	8	—[c]	27
Region	9	17	10	24	22	20	27
Cost of service, $000	1000	835	939	1382	1459	1148	1699
Capital cost, $000	338	208	338	607	455	451	533
Cost per trip, $	3.87	1.67	3.28	1.93	1.83	1.99	2.13
Vehicles							
Buses	42	42	42	51	42	51	42
Vans	26	26	26	26	35	26	41
Service area							
Lansing urban area	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clinton County	No	No	Yes	No	Yes	No	Yes
Eaton County	No	No	Yes	No	Yes	No	Yes
Ingham County	No	No	Yes	No	Yes	No	Yes
Region	No	No	Yes	No	Yes	No	Yes

Note: Demand data are average daily figures.

[a] Least costly alternative is used.
[b] Regional average daily trips based on 6-d week.
[c] Some level of satisfaction, but no estimate is possible.

Table 2. Comparison of performance measures for present and proposed systems.

Item	Present System	Proposed System	
		Existing Agencies Only	Including Taxi Service[a]
Average number of clients per day	207	231	431
Average number of trips per day	439	462	862
Total operating hours per day	24	22	
Vehicles operating	17	12	
Vehicle hours of operation per day[b]	84	68	
Seating capacity	220	160	
Trips per hour	18.3	21.0	
Trips per vehicle hour	5.2	6.8	
Cost per day, $	844	680	1480
Cost per hour, $	35	31	
Cost per trip, $	1.92	1.47	1.72
Operating cost per vehicle hour, $	10.05	10	
Operating cost per year for scheduling center, $		66 000	66 000
Total operating cost per year, $	219 230	242 800	450 800
Total capital cost per year, $	74 000	52 000	52 000
Total cost per year, $	293 230	294 800	502 800
Total cost per trip, $	2.57	2.45	2.45

[a] Additional 400 trips/d. [b] Accumulated hours for all agencies.

quirements and limited financial resources for implementing special transportation services for the transportation disadvantaged.

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Abridgment

Costs of Alternative Transportation Systems for the Elderly and the Handicapped in Small Urban Areas

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The Transportation Institute of North Carolina Agricultural and Technical State University has undertaken a study to enumerate the costs of providing specialized transportation services for the elderly and the handicapped. Because of the large number of alternative federal and state funding sources whose purpose is to encourage planning and development of transportation programs for the elderly and the handicapped, many different organizational bodies have assumed responsibility in this area—e.g., individual social service agencies, local welfare departments, consortia of private agencies, transit authorities, and statewide programs.

What are the costs of alternative systems and services? Few studies have attempted to use a standard method of measurement in gathering data on these disparate systems (1, 2, 3, 4, 5). The advantage of this research is that data on all costs—including managerial, direct and indirect labor, depreciation, maintenance, fuel, and insurance costs—were systematically collected by means of a single, standardized survey questionnaire. The results were verified by returning cost summary sheets to the agencies for validation.

The objectives of this project were to acquire primary, descriptive data on unit costs of operation and to analyze costs in correlation with levels of service, organizational forms, and scales of operation. Because the study was intended as input into more extensive analyses of measures of transit effectiveness that are currently under way elsewhere (6, 7, 8, 9, 10), it purposely excludes evaluation of overall system effectiveness, the equity of the service provided, and user satisfaction.

This paper examines one aspect of cost analysis, i.e., whether a larger scale of operation leads to significant unit cost reduction. This matter is closely tied to the issue of organizational form, and the research offers some preliminary discussion on this point. Transportation systems can be differentiated on various grounds, such as whether the system operates on a fixed route and schedule or on a demand-responsive basis. In this research, different levels of service were distinguished by headway times, hours of operation, geographic area served, and the availability of special equipment. Systems were also differentiated by the nature of the client group; for example, systems that primarily serve the nonambulatory are clearly much more expensive systems. Finally, systems were differentiated by type of organizational structure (private versus public or profit versus nonprofit). The extent to which federal, state, or local subsidy influences the cost of output can be hypothesized.

Tables 1, 2, and 3 give selected characteristics of the systems studied. Budget constraints limited the sample size to 18 systems, all of which provide transportation services to both the elderly and the handicapped. All regions of the United States were included in the sample, and the systems selected were located in cities with populations of from 25 000 to 500 000 people. Different organizational forms, budget sources, and types of management were included.

The major issue in this research is whether cross-sectional data show a predictable relation between measures of scale and unit cost and whether this sample, drawn largely from the nonprofit sector, shows the same economic relations already shown in assumptions about for-profit operation.

Table 1. Characteristics of 18 special transportation systems that provide service for the elderly and the handicapped.

Location of System	1970 Population	Type of Service	Organizational Form
Mobile, Alabama	190 030	Demand-responsive	Private, nonprofit
Derby, Connecticut (Valley Transit Authority)	73 700	Fixed-route, demand-responsive	Public, nonprofit
Delaware (Delaware Authority for Special Transportation)	548 000	Demand-responsive	Public, nonprofit
Florida			
Broward County	62 019	Fixed-route	Cooperative public-private, nonprofit
Consolidated Agencies Transportation System	230 006	Fixed-route, demand-responsive	Public, nonprofit
Maywood, Illinois	291 019	Demand-responsive	Private, nonprofit
Logansport, Indiana (five counties)	215 437	Demand-responsive	Private, nonprofit
Baton Rouge, Louisiana	165 900	Demand-responsive	Public, nonprofit
Michigan			
Ludington	9 021	Demand-responsive	Public, nonprofit
Traverse City	18 048	Demand-responsive	Private, taxi
New York			
Hicksville	82 989	Demand-responsive	Private, nonprofit
Rochester	296 200		
PERT		Demand-responsive	Public, nonprofit
Medical Motors		Demand-responsive	Private, nonprofit
Syracuse	197 300	Demand-responsive	Public, nonprofit
Winston-Salem, North Carolina	133 683	Fixed-schedule	Public
Rhode Island (Senior Citizen)	949 700	Demand-responsive	Private, nonprofit
Smithville, Texas	17 297	Fixed-route, demand-responsive	Public, nonprofit
Merrill, Wisconsin	9 502	Route-deviation	Public, nonprofit

Table 2. Annual service data for 18 systems studied.

Location of System	Passenger Trips	Passenger Kilometers	Number of Vehicles in Service	Total Vehicle Kilometers of Operation	Seating Capacity	
					Number of Passengers	Number of Wheelchairs
Mobile, Alabama	21 000	270 531	4	57 971	48	1
Derby, Connecticut (Valley Transit Authority)	124 800	221 063	18	233 494	156	4
Delaware (Delaware Authority for Special Transportation)	152 000	2 447 665	39	1 360 708	245	16
Florida						
Broward County	56 400	1 089 855	10	405 604	60	5
Consolidated Agencies Transportation System	195 100	3 141 707	17	726 539	180	11
Maywood, Illinois	47 000	567 633	4	128 824	72	4
Logansport, Indiana (five counties)	60 000	1 256 039	10	289 855	120	3
Baton Rouge, Louisiana	49 840	298 792	6	257 649	122	5
Michigan						
Ludington	66 744	139 721	4	136 654	42	2
Traverse City	80 556	259 440	6	219 981	66	2
New York						
Hicksville	2 400 000	7 729 468	120	8 450 080	650	0
Rochester						
PERT	208 800	1 008 696	13	740 741	130	20
Medical Motors	45 600	335 588	12	335 214	95	4
Syracuse	40 151	289 855	4	266 895	40	8
Winston-Salem, North Carolina	35 316	341 217	2	44 702	90	2
Rhode Island (Senior Citizen)	360 000	1 449 275	34	1 352 657	414	6
Smithville, Texas	19 800	15 942	7	83 736	58	0
Merrill, Wisconsin	65 500	210 950	3	157 810	60	0

Note: 1 km = 0.62 mile.

Table 3. Annual cost data for 18 systems studied.

Location of System	Cost ($)			
	Per Passenger Kilometer	Per Vehicle Kilometer	Per Passenger Trip	Total
Mobile, Alabama	0.15	0.70	1.93	40 585
Derby, Connecticut (Valley Transit Authority)	1.39	1.32	2.47	307 879
Delaware (Delaware Authority for Special Transportation)	0.18	0.34	3.04	461 620
Florida				
Broward County	0.155	0.42	2.98	168 122
Consolidated Agencies Transportation System	0.08	0.35	1.29	252 284
Maywood, Illinois	0.16	1.15	1.96	92 400
Logansport, Indiana (five counties)	0.105	0.71	2.27	136 402
Baton Rouge, Louisiana	0.45	0.515	2.68	132 768
Michigan				
Ludington	0.81	0.81	0.71	113 903
Traverse City	0.43	0.50	1.38	111 050
New York				
Hicksville	0.26	0.24	0.84	2 020 143
Rochester				
PERT	0.53	0.73	2.58	538 921
Medical Motors	0.50	0.50	3.68	167 607
Syracuse	0.77	0.84	5.56	223 222
Winston-Salem, North Carolina	0.35	2.65	2.26	118 522
Rhode Island (Senior Citizen)	0.39	0.42	1.57	564 718
Smithville, Texas	3.59	0.68	2.89	57 337
Merrill, Wisconsin	0.50	0.66	1.60	104 638

Notes: 1 km = 0.62 mile.
Costs include the market value of all inputs, including depreciation, the imputed value of in-kind contributions (real goods or services), and taxes.

THEORY OF U-SHAPED COST CURVES

The economic theory of the firm, which is derived from the example of physical production of unit products, suggests that in the short run, given capital stock and factor prices, average unit costs will vary with the scale of production. Initially, average costs decline as fixed factors of production are used with greater intensity to produce greater output; then, average unit costs rise with the onset of capacity constraints, greater difficulty of management control over a larger operation, and increasing costs of marketing a product produced in large volume. The issue of economies of scale, a concept distinct from that of short-run average costs, depends on the optimal size of the firm when long-run variations are permitted in the amount of overhead and capital stock. If economies can be derived by lowering the prices of factor inputs (through volume purchase, for example), if improved productivity can be achieved with greater volume of output, or if marketing or research costs can be shared among production units in the same firm, curves for long-run cost will show returns to greater scale of operation. Logically, if these economies of scale persist, the most efficient producer monopolizes the industry. The U-shaped curve for long-run cost derives from the theory that economies of scale achieved by exploiting the specialization of labor and the increasing use of advanced technologies occur as the firm grows but that, once the plant is large enough to take advantage of all economies of scale, average unit cost may be expected to rise as the scale of plant increases because of increasing management problems, rising transportation costs, and the firm's inability to penetrate all markets.

To what extent do U-shaped cost curves exist for transportation programs for the elderly and the handicapped? The issue is important because public policy currently encourages the proliferation of small-scale units of operation. Under the Section 16b2 program of

the Urban Mass Transportation Administration (UMTA), capital grants are frequently awarded to social service agencies that operate no more than two or three vehicles, and there is no requirement that they coordinate operations with other agencies. Another source of support for transportation for the elderly and the handicapped is the Administration on Aging of the U.S. Department of Health, Education and Welfare, which has established no requirements for consolidated, large-scale efforts. Currently, the emphasis in public policy is on experimental demonstration programs that reach only a small proportion of the transportation-disadvantaged population. The issue of cost has become crucial now that local policy makers are deciding whether to take over the support of existing systems and other localities are deciding to use their own funds to implement new programs.

In applying the theory of cost curves to transportation programs, it is necessary to establish operational definitions of output and to identify fully the cost of operation under various management situations. The definition of output that is used in this research is passenger kilometers. Vehicle kilometers have been used in many studies, but unused seats on a vehicle have no production value and cannot be stored in inventory. Special transportation systems rarely collect data on passenger kilometers. Determination of passenger kilometers requires knowledge of the length of the average passenger trip. This study estimated total passenger kilometers by estimating average passenger-trip length and the number of passenger trips per year. In some cases there was empirical evidence, and in other instances managers estimated average passenger-trip length. For comparison with other studies, the standard measures of vehicle kilometers, vehicle trips, and seating capacity are also included. No attempt was made to measure variation in level of service as another dimension of output.

Another problem was the lack of a standardized cost-accounting instrument for gathering data on disparate systems. Since various agencies report their costs differently, the research team developed its own instrument to enumerate physical inputs such as labor hours and capital used by each system, regardless of funding sources, and to cost out the market rate of those physical inputs. For example, data were gathered on hours of planner time, hours of management time, driver hours, aide hours, dispatcher hours, office space, and the like to determine resource allocations to the program. The market price of the factor input was taken as that currently paid by the agency (e.g., drivers' hourly wages plus fringe benefits). If the inputs were in-kind (real) services, the amount of the local market value of the factor input was used. Typical of such input were the value of office space donated by an agency and the sharing of maintenance facilities. Any cost reduction that resulted from such a sharing of facilities would be reflected in the total cost figure.

Use of passenger kilometers as an output measure introduces an element of demand into the definition of output. This approach appears to be justified because systems that attract few riders may be viewed as firms that have a low rate of production. Output is thus not the production of transportation opportunities but rather of actual transportation consumed.

Most transportation systems for the elderly and the handicapped came into existence in the past 5 years, operate on very limited budgets, and have managements that are often inexperienced in record keeping for purposes of internal and external evaluation of transportation costs. Such transportation services may be only a subsidiary activity of some social service organization. This study was limited to agencies that had assembled adequate cost data for at least 6 months of operating experience. From an original list of all systems known to be operating services for the elderly or the handicapped, a secondary list of systems was assembled for interviewing. Five agencies proved unable or unwilling to furnish the required data, and other agencies had to be substituted. Data were gathered by means of on-site and telephone interviews and were checked for internal consistency. The worksheets on operating and capital costs were sent back to the agencies for verification so that the conclusions reached on cost allocation could be checked by the agencies in question.

It can be hypothesized that there are significant economies of scale in transportation for the elderly and the handicapped. Management spends its time negotiating contracts with individual agencies and with government funding sources and designing a system to deploy vehicles and drivers throughout a region. Marketing costs and insurance and other organizational needs are similar regardless of the scale of the operation. But systems that serve many communities should have lower unit costs than systems that serve only one community because they may deliver more passenger kilometers per year. This study also hypothesized that sharing of maintenance costs would lower unit costs because servicing through dealers may be more expensive. Sharing of maintenance facilities may or may not result in improved service; this depends on whether the social service agency has priority on repairs. Finally, it is hypothesized that capital (vehicles) can be routed more efficiently and used more intensively if the transportation system operates on a large, flexible scale. This should be important in demand-responsive systems. But there is reason to believe that maximum deployment of vehicles may already be occurring. If so, the operating capital constraint inhibits the exploitation of further economies of scale, at least in the short run.

Empirical Results

Data given in Table 1 indicate the characteristics, the output, and the costs of the transportation programs examined in the study. Variations in the scale of operations are evident; annual passenger kilometers range from a low of 139 721 (86 767 miles) in Ludington, Michigan, to a high of 7 729 468 (4 800 000 miles) in Hicksville, New York (a system that serves the general public as well as the elderly and the handicapped). Trip production, a closely associated measure, also shows a diverse pattern among systems. The seating capacity of the systems varies from 42 in Ludington to 650 in Hicksville; annual vehicle kilometers of operation range from 44 702 (27 760 miles) in Winston-Salem, North Carolina, to 8 450 080 (5 247 500 miles) in Hicksville.

Is it possible to consider that these systems are producing a standard output? Most of the systems studied offer services for the general public and the ambulatory elderly. The majority of vehicles in most systems are not equipped to handle wheelchairs. Of the total trips produced, the percentage of trips estimated to be trips taken by the handicapped typically appears to be less than 3 percent. Thus, except for Medical Motors of Rochester, New York, it may be reasonable to consider that the systems have comparable target populations.

Variations in types and levels of service are also apparent in Table 1. Several systems provide door-to-door, demand-responsive service. These systems may use aides to offer assistance to elderly passengers. By contrast, systems such as those of Broward County, Florida, and Syracuse, New York, travel principally on fixed routes.

Significant cost variations are also apparent among these systems. In Table 1, the average cost per passenger kilometer ranges from a low of $0.08/km ($0.13/mile) for Florida's Consolidated Agencies Transportation System to a high of $3.59/km ($5.79/mile) for the Smithville, Texas, system. Scale does appear to play a prominent role in average unit cost.

A preliminary fitting of cost per passenger kilometer to number of passenger kilometers produced by the systems shows a nonlinear, negatively sloped relation that "bottoms out" in the conventional pattern of the cost curve analysis outlined above. Costs per passenger kilometer begin at approximately $0.60 to $1.25/km ($1 to $2/mile) in the range of 0 to 483 000 passenger km (0 to 300 000 passenger miles), fall to $0.31/passenger km ($0.50/passenger mile) for intermediate scale operations, and fall to less than that figure for the largest scale operations.

What is not apparent in the current data is the expected upturn in the average cost curve at the higher operational scale. Apparently, over the range of systems observed in this study, the ability of larger systems to convert their large-volume programs of demand-responsive service to "congealed," fixed-route service or the actual initiation of fixed-route service results in continual cost reductions and increasing scale of operations.

The data were fitted by using the following models (because the equations were formulated in U.S. customary units, no SI equivalents are given):

$$C = a + B_1 P + B_2 P^2 \quad (1)$$

$$C = aP^b \text{ or } \log C = a + b \log P \quad (2)$$

where

C = cost per passenger mile and
P = annual passenger miles of operation.

The data produced parameters with the expected signs: In Equation 1, B_1 is negative and B_2 is positive; in Equation 2, b is negative. Thus,

$$C = 1.367 - 0.000\,1P + 0.000\,000\,2P^2 \quad \bar{R}^2 = 0.340\,32 \quad (3)$$

$$\log C = 5.601\,11 - 0.460\,66 \log P \quad \bar{R}^2 = 0.434\,44 \quad (4)$$

The functions provide a reasonable fit to the data; $\bar{R}^2$ = 0.34 and 0.43 respectively for cross-sectional analysis.

It is interesting to note that the system that falls below the predicted costs by more than two standard errors—the PERT system in Rochester, New York—gets an unusually high proportion of its funding from federal and state demonstration funds. The Valley Transit Authority in Derby, Connecticut, also shows relatively high cost and a high proportion of government subsidy. Rather than suggest a firm causal link, however, we prefer to consider as a tentative hypothesis for further testing the proposition that these demonstration funds have the effect of distorting conventional cost-scale relations. Testing such a hypothesis would involve looking at whether the money allocated for special services has resulted in higher than average managerial outlays, more vehicle acquisitions, higher than average start-up costs, or investments in path-breaking capital design (e.g., the computerized fare-box operation of the Valley Transit Authority).

Causal Relations

It is tempting to conclude that the observed data constitute the left half of the conventional U-shaped cost curve; this would imply that, if systems were encouraged to consolidate and operate on a larger scale (perhaps encompassing several mid-sized cities within a state), economies could be achieved. But the data were derived from a cross-sectional analysis, gathered at a single point in time, rather than from an observation of time series showing the cost-related behavior of a single firm as it gradually increases its scale of operation. It has been shown by Kuh (11) that cross-sectional results may vary considerably from longitudinal results. One must therefore proceed cautiously before drawing a causal inference. Among the questions that remain are

1. At what scale do diseconomies from management input begin to appear?
2. Can the transit operations of proximate communities merge to capture scale economies, or are the findings of the research statistical artifacts of various topographical situations?

SUMMARY

The study suggests that, on a cross-sectional basis, transportation programs for the elderly and the handicapped appear to operate at the lowest average unit costs at scales of operation that are considerably larger than those of most systems now operating under federal assistance programs. The data suggest that management costs can be better spread over systems that cover larger geographical areas and deliver more passenger kilometers of service. Although these findings do not result in causal relations, they do suggest that more research is needed on the sources of variations in cost.

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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,

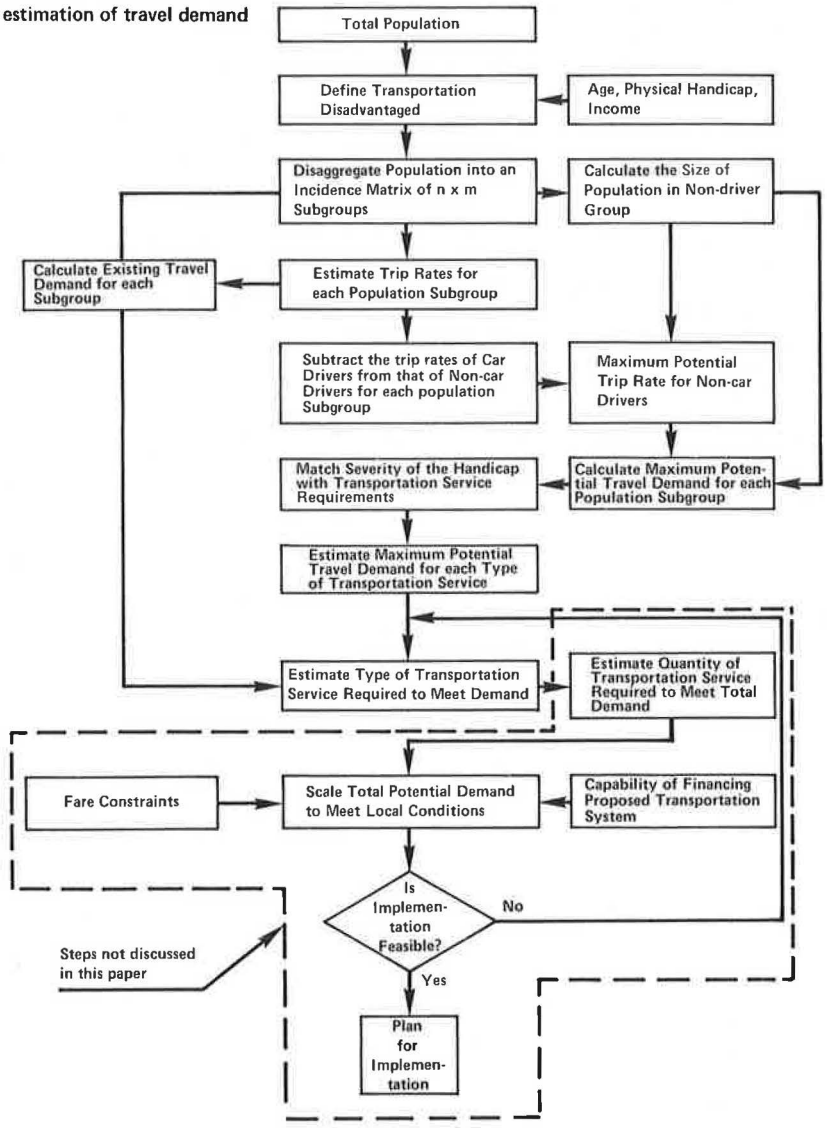
1. Estimates are made of the size of the sample who are disadvantaged within the general population.
2. The population is further divided into four classification groups: age, driver status, physical status (handicapped or not), and economic status.
3. Trip rates are estimated for each group.
4. Latent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

$$T = Te + Tp \quad (1)$$

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:

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

where

$N_{ij_{NCD}}$ = number of nondrivers in age status i and physical and economic status j,
$t_{ij_{CD}}$ = trip rate of drivers in age status i and physical and economic status j, and
$t_{ij_{NCD}}$ = 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	Person Trips per Day: 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:

Mode	Total Trips by Handicapped	
	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_t) 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):

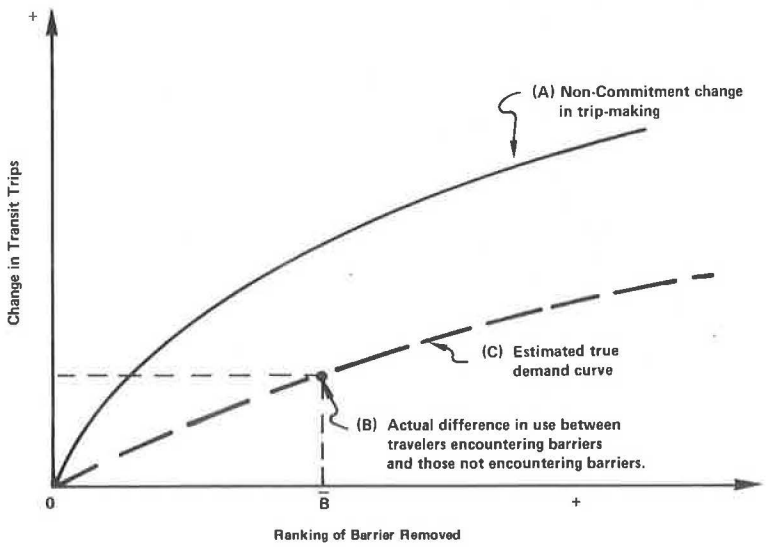


Figure 2. Relation between removal of barriers and use of transit.

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

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	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

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

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

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

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.

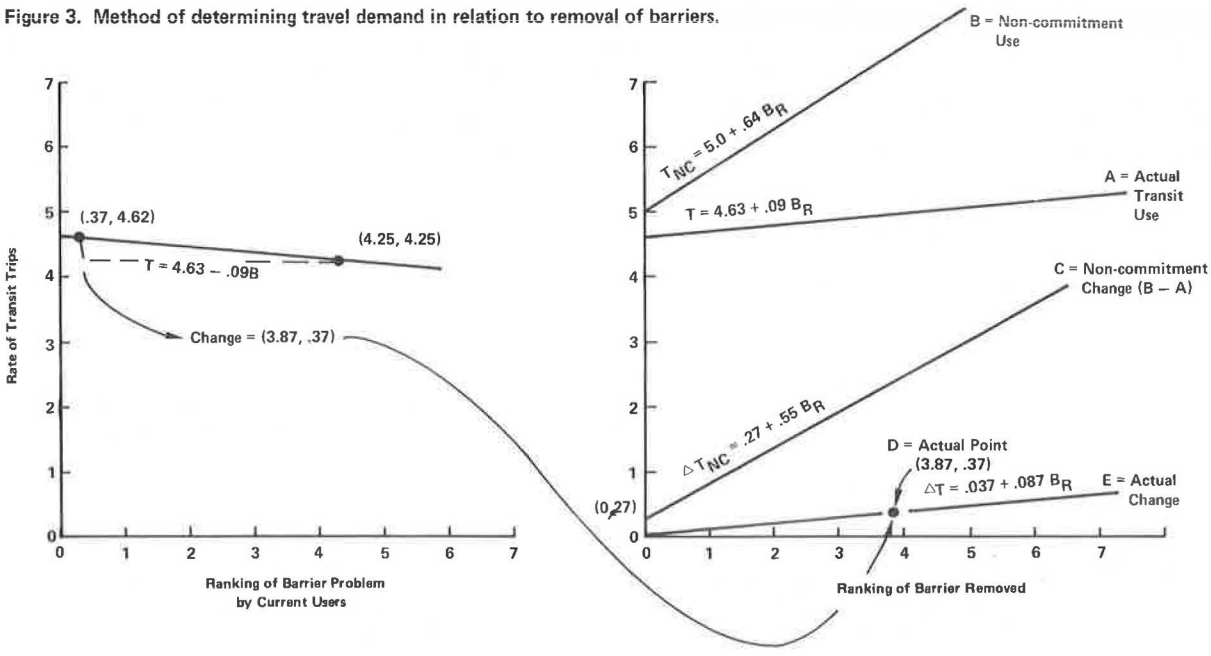
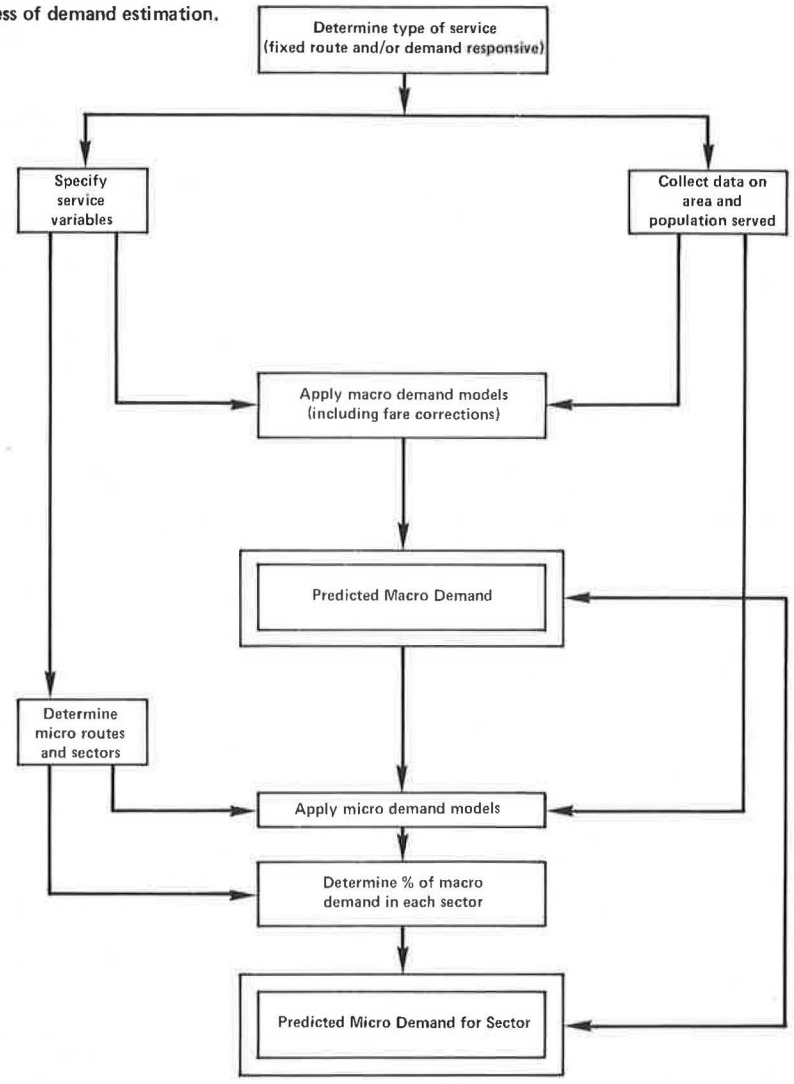


Figure 4. Flow diagram of the process of demand estimation.



3. Choose the data for estimating equations.
4. Evaluate parameters of the model in the following form: trips = $a_0 + a, x, + a_2 x_2 + \ldots$, 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:

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

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:

$$\log(\text{OWPASS/DAY}) = 6.344 + 0.697 \log \text{FREQ} - 2.547 \log D + \log \text{PoP}_o + \log \text{PoP}_d \quad (13)$$

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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