ESTIMATING LATENT DEMAND AND COST FOR STATEWIDE TRANSIT SERVICE

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In 1968, the U.S. Department of Housing and Urban Development commissioned a series of studies to define the potential demand for new systems of urban transportation. Among these was a study of latent demand for urban transportation to focus specifically on urban groups who have transport needs that are not met by existing systems. Emphasis was placed on the needs of the elderly, the poor, the young, and the handicapped. Need was identified through a series of questionnaires of select groups in Pittsburgh and Baltimore. In a Minnesota study, transit needs were established through a latent demand survey conducted to determine the extent of travel that would occur under various levels of transit system improvement. The survey also developed information on the perceived needs of individual travelers. The analysis of latent demand at various levels of transit service for rural communities is the subject of this paper.

•IN RECENT years, attention has been focused on the transportation problems of persons without access to the private automobile. In a nation where mobility has been increasing for a large portion of the population, the plight of those segments of society made captive because of an inability to gain access to the highway system has become more pronounced.

Two groups of travelers have been identified as representing the principal categories of captive riders: inner-city dwellers and the rural poor. Studies have been directed at identifying the critical transportation needs of these groups as well as determining the most appropriate transportation facilities and services to satisfy these unmet needs. The urban captive rider has been further identified into categories such as elderly, young, poor, handicapped, and housewives. Each of these groups has specific transportation needs that are not met by present transport systems. Perhaps the elderly represent the group for which needs have been most clearly defined. Present transit systems provide service to the elderly on a daily basis as well as through special programs such as reduced fares, new routes connecting senior citizen projects, and special tours.

In 1968, the U.S. Department of Housing and Urban Development commissioned a series of studies to define the potential demand for new systems of urban transportation. Among these was a study that focused specifically on urban groups whose transport needs are not met by existing systems. Emphasis was placed on the needs of the elderly, the poor, the young, and the handicapped. Need was determined through a series of questionnaires of select groups in Pittsburgh and Baltimore. Latent demand was defined as the necessary trip-making potential of individuals who live within metropolitan areas and have no access to an automobile.

More recent studies have focused on specific transport solutions, for example, demand-responsive transportation and medi-cab, or have refined means for determining mobility deficiencies. Two basic measures have been attempted. The first, based on access opportunities, measures mobility in terms of the number of trip opportunities within a stated time-distance of the origin zone. The second, based on differential trip generation rates, measures deficiencies in transport services, for example, the difference between trip generation rates of families with and without an automobile. A variety of trip-making variables can be identified, such as income,

transit service availability, age, and family size. Latent demand, however, deals also with perceived transport needs, and a third approach relies on personal contact with affected individuals. In this latter approach, problems, trip priorities, and major deficiencies in the present transport system are identified through personal interviews and discussions.

The intention here is not to recount in detail the research results that have been forthcoming in the area of latent demand since the HUD Study. The references give publications dealing with latent demand, mobility, and related topics; the preponderance of research has been directed to urban and center-city problems. A significant omission to date has been investigations concerning the latent demand in suburban areas. Transport studies of the noncentral city portions of major metropolitan areas have focused primarily on problems of freeway congestion, highway safety, parking, traffic control, and the like. Closer examination of the relevant issues, however, reveals that unmet transport needs exist in suburban areas that may equal or exceed those in the inner city. Public transportation is either nonexistent or of lower service level in suburban areas than that in the central city, and transit lines are CBD oriented during work hours. Many segments of the population living in the suburbs are without access to an automobile; these segments include housewives in 0- or 1-car families, children, the elderly, and the poor. In fact, the population mix in suburban areas is becoming increasingly diverse, and an increasing proportion of the travel needs of suburban residents is unmet or poorly served.

The most recent interest in latent demand has developed at the state level in connection with rural and small-town needs for public transportation facilities. Data from statewide origin-destination studies do not reveal latent demand because the surveys record travel on existing systems. In a Minnesota study, transit needs were established through a latent demand survey conducted to determine the extent of travel that would occur under various levels of transit system improvement. The survey also developed information on the perceived needs of individual travelers. The analysis of latent demand at various levels of transit service for rural communities is the subject of this paper.

LATENT DEMAND FOR TRANSIT SERVICE

The latent demand for transit service represents the potential number of people who would use transit if new or improved service were provided. It primarily reflects the potential ridership among people whose mobility is restricted because they do not now have access either to an automobile or to transit. A quantitative evaluation of latent demand is necessary to estimate the number of people who need transit and are not now served, to ascertain the potential ridership response to various levels of service improvements, and to provide a basis for estimating the revenues and costs of alternative service levels.

The latent demand in rural Minnesota was determined through a questionnaire mailed to a sample of households in 4 representative cities selected from among 41 cities having populations greater than 5,000. Mankato and Bemidji were selected as representative of cities with local transit service and Albert Lea and Crookston as representative of cities without local transit. Questionnaires were sent to households within the corporate limits of each town and in surrounding areas. The returned questionnaires were then edited, and the responses were coded for computer tabulation. The results were factored to appropriately represent the population of each area and analyzed to obtain a profile of the sample population, their travel habits, and potential ridership on improved public transportation systems.

Questionnaires were sent to the 4,100 randomly selected sample households or about 10 percent of the households in each city and its surrounding area: 1,650 in Mankato, 1,150 in Albert Lea, 850 in Bemidji, and 450 in Crookston. The overall response rate was 32 percent, resulting in a sample of 3 percent of all households in the 4 cities.

The questionnaire contained 2 groups of questions. The first asked about household location, income, age distribution, automobile availability, weekly transit trips, and daily trips by all modes. The second group asked about additional trips desired by

members of the household but not taken because of either poor access to public transit or unavailability of an automobile or a driver's license. Three questions were designed to evaluate the influence of access time to the transit stop on potential ridership. The alternative access times proposed in the questionnaire were 15 minutes, 5 minutes, and immediate (door-to-door service). Response to this group of questions provided a measure of the latent demand for transportation in terms of alternative levels of service.

For each city the mean values were computed and tabulated for data on household size, income, age distribution, number of automobiles and licensed drivers per household, daily trips by mode and purpose, weekly transit trips by purpose, taxi trips by purpose, and estimated weekly trips on improved transit.

Some of the parameters that describe the latent demand for transit, as derived from the survey, are given in Table 1. The data show the sensitivity of ridership to access time. The responses constitute quantitative measures of the willingness of people to use transit as a function of its accessibility. The potential ridership among in-town residents on systems having 5-minute and door-to-door access is higher for the cities without transit than for the cities with transit. The estimated ridership per capita by out-of-town residents of Mankato and Bemidji on any of the alternative types of service was similar to that of in-town residents, indicating that these people would like to be offered service similar to the service that their neighbors in town have. The data given in Table 1 were used to estimate the annual ridership on improved transit systems, as described later in the paper.

Another indicator of the need for transit is the percentage of households in which people have difficulty in getting to where they want or need to go. In the 4 cities surveyed this figure ranged between 12 and 15 percent. If trip-making were made easier for these people, the number of transit trips per household could increase by 50 percent in Mankato, 80 percent in Bemidji, 500 percent in Albert Lea, and 1,400 percent in Crookston.

LEVELS OF SERVICE

The provision of a suitable level of transit service on a statewide basis requires a thorough evaluation of the trade-off between the benefits of improved service to currently unserved or immobilized segments of the population and the costs of providing the service. The number of people who will be affected by improved service, the ridership and revenue that improved service will generate, and the cost of implementation and operation depend on the level of service provided. Before decisions can be made on an appropriate level of service or mix of services on a statewide basis, the implications of alternative service levels should be explored. For this reason, several alternative service levels were described and analyzed. Estimates of the ridership that each service level might generate were based on the responses to the latent demand questionnaire and a ridership model derived from a study of present transit operations in 11 cities. Revenues and operating costs were estimated from the ridership model and from an operating cost model based on present transit operating data.

Four service levels were defined as they might apply to out-of-town areas in terms of the number of cities served, the areal extent of service inside and outside of each city, the population of the area served, and the average access time to transit. These levels of service were then used to define transit service for the appropriate cities or city areas for 1973 and 1975. The alternative service levels were then compared according to the following service parameters: annual patronage, bus-miles, revenue, revenue per passenger, amortized capital costs, operating costs, total costs, revenue less costs, and revenue less costs per passenger.

The levels of service defined for latent demand analysis are given in Table 2 and described below.

Level of service 1 retains the present bus system in the 11 cities that have transit. The number of bus-miles and the fare in each city are the same as at present. The average access time for current transit riders remains the same. The service area includes the in-town populations, approximately 430,000 people, of Duluth, Moorhead,

Table 1. Annual trips per resident within and outside cities by access time to transit stop.

Access Time	Within City				Outside City			
	Mankato	Bemidji	Albert Lea[a]	Crookston[a]	Mankato	Bemidji	Albert Lea[a]	Crookston
Immediate (door-to-door service)	45	40	50	42	33	26	18	20
5 minutes	20	10	29	16	17	14	10	11
15 minutes	6	3	8	1	7	6	1	1

[a]Currently without transit service.

Table 2. Levels of service by access time to transit stop.

Level of Service	Description	Access Time[a]		
		Zone A[b]	Zone B[c]	Zone C[d]
1	Present system	5	—	—
2	15-minute access to out-of-town areas	5	15	15
3	5-minute access to in-town areas	5	5	15
4	Door-to-door fare of 5 cents/passenger-mile	5, I	I	I

[a]5 and 15 are minutes, and I is immediate or door-to-door service.
[b]Area within city covered by transit or area in major traffic corridors.
[c]Area within city outside zone A.
[d]Area within region but outside city.

Table 3. 1973 and 1975 patronage and costs for alternative levels of service.

Level of Service	Cities Served	Access Time by Zone			Population Served	Passengers	Revenue (dollars)	Cost (dollars)	Revenue Less Cost (dollars)	Revenue Less Cost per Passenger (dollars)
		A	B	C						
1973										
1	11	5	—	—	431,000	6,400,000	1,500,000	2,600,000	-1,100,000	-0.17
2	11	5	15	15	830,000	7,900,000	1,800,000	3,700,000	-1,900,000	-0.24
3	11	5	5	15	830,000	9,400,000	2,100,000	6,100,000	-4,000,000	-0.42
4	11	5, I	I	I	830,000	29,650,000	7,300,000	19,500,000	-12,200,000	-0.41
1975										
1	11	5	—	—	431,000	5,800,000	1,300,000	3,000,000	-1,700,000	-0.28
2	11	5	15	15	830,000	7,200,000	1,600,000	4,200,000	-2,600,000	-0.36
3	11	5	5	15	830,000	8,500,000	1,900,000	6,800,000	-4,900,000	-0.58
4	11	5, I	I	I	830,000	26,700,000	6,600,000	22,230,000	-15,640,000	-0.59

Figure 1. 1973 patronage, costs, and revenue by level of service.

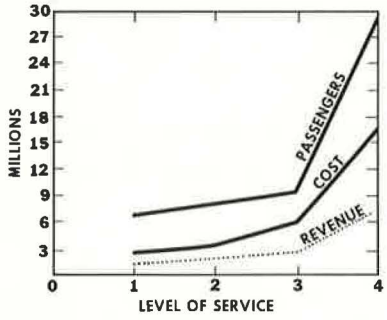

Figure 2. 1975 patronage, cost, and revenue by level of service.

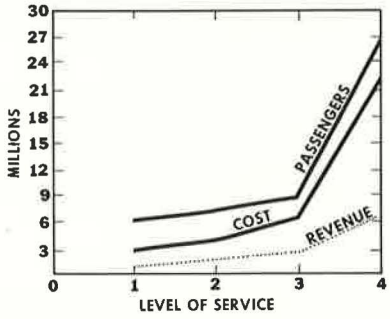

Table 4. 1973 and 1975 patronage and costs for Mankato.

Level of Service	Access Time by Zone			Passengers	Vehicle-Miles	Revenue (dollars)	Amortized Capital Cost (dollars)	Operating Cost (dollars)	Total Cost (dollars)	Revenue Less Cost (dollars)	Revenue Less Cost per Passenger (dollars)
	A	B	C								
1973											
1	5	—	—	297,000	161,000	60,000	0	117,000	117,000	-57,000	-0.19
2	5	15	15	472,000	465,000	95,000	30,000	202,000	232,000	-137,000	-0.29
3	5	5	15	687,000	1,600,000	138,000	144,000	377,000	520,000	-382,000	-0.56
4	5, I	I	—	2,400,000	4,177,000	595,000	99,000	1,563,000	1,662,000	-1,067,000	-0.44
1975											
1	5	—	—	271,000	161,000	54,000	0	134,000	134,000	-80,000	-0.30
2	5	15	15	429,000	465,000	86,000	30,000	231,000	261,000	-175,000	-0.41
3	5	5	15	624,000	1,600,000	125,000	144,000	433,000	576,000	-451,000	-0.72
4	5, I	I	I	2,160,000	4,177,000	535,000	99,000	1,797,000	1,896,000	-1,361,000	-0.63

Rochester, St. Cloud, Mankato, Winona, Austin, Faribault, Hibbing, Bemidji, and Cloquet. For purposes of calculations the in-town populations of Superior, Wisconsin, and Fargo, North Dakota, are included with those of Duluth and Moorhead in the estimates.

Level of service 2 includes an extended service providing 15-minute average access time to those who live in the 11 cities with transit but do not now have access to transit and to those who live in areas around these cities. The combined service areas contain 830,000 people, or approximately twice the in-town populations. The fare structure is the same as at present.

Level of service 3 is the same as level of service 2 except that average access time of 5 minutes is provided to the entire in-town population.

Level of service 4 provides door-to-door service at a fare of 5 cents per passenger-mile for the people who live within and in the area of the 11 cities that now have transit. The regularly scheduled bus services in these cities are assumed to operate as at present. The total population of the service area is 830,000, the same as for levels of service 2 and 3.

The inventory of present operations and the latent demand survey provide a data base for estimating general service and financial parameters at a statewide level for each of the previously delineated levels of service. The records of transit operation of 11 companies for the period from 1967 to 1971 were used to develop a patronage model and an operating cost model.

Initial review of the operating data suggested that patronage could be related functionally to fare, number of regularly scheduled bus-miles supplied, and time. Review of the transit company statistics on a city-by-city basis showed that patronage declined with decreases in bus-miles, increases in fare, and passage of time.

The model that was used to correlate these parameters is of the following form:

$$P/P_o = (B/B_o)^{\alpha} (F/F_o)^{\beta} e^{\gamma(t-t_o)} \tag{1}$$

in which P, B, and F are respectively patronage, number of regularly scheduled bus-miles supplied, and revenue per passenger in year t; and P_o, B_o, and F_o represent these parameters in a base year t_o. The exponents α, β, and γ were calculated by regression analysis techniques in which data for 11 cities during a 5-year period were used. The model with calibrated constants is

$$P/P_o = (B/B_o)^{0.90} (F/F_o)^{-0.72} e^{-0.054(t-t_o)} \tag{2}$$

The operating statistics for each transit company provided information to develop an operating cost model that relates annual cost of regular route service to the number of bus-miles supplied and to time. The cost model is

$$C/C_o = (B/B_o)^{\lambda} e^{\mu(t-t_o)} \tag{3}$$

in which C and B are the annual cost and the number of bus-miles of regular route service supplied in year t, and C_o and B_o represent the same parameters for year t_o. The exponents λ and μ were evaluated by a regression analysis of the operating data. The model with calibrated constants is

$$C/C_o = (B/B_o)^{0.51} e^{0.07(t-t_o)} \tag{4}$$

The patronage model and the operating cost model provide a measure of the sensitivity of patronage to fare and the supply of service in terms of route bus-miles, sensitivity of operating cost to supply, and correlation of patronage and cost to time. These models were used with other relevant information to estimate the annual service and financial characteristics for each of the defined levels of service both in a statewide basis and separately for each of the 4 cities surveyed. The results are described in the following sections.

APPLICATION OF DEMAND AND COST MODELS

The levels of service defined previously were analyzed for potential patronage, revenue, and annual cost for the years 1973 and 1975. Specifically, estimates were made of annual ridership, bus-miles, revenue, revenue per passenger, amortized capital cost, operating cost, total cost, revenue less cost, and revenue less cost per passenger. These estimates are given in Table 3. Patronage, costs, and revenues are shown in Figures 1 and 2. The following describes briefly how the results were developed for each level of service.

Level of Service 1

The operating data supplied by the transit operators in the 11 cities with transit were used as the basis for transit cost and patronage determinations. Quantities were added to yield statewide totals and averages for the most recent year that data were available.

The formulas for patronage and cost developed previously were used to project these parameters from the base year to 1973 and then 1975. Basically, these time-variance equations predict changes in patronage and cost respectively from year to year. The cost equation accounts for inflation, which was calculated to be approximately 7 percent per year, and the patronage formula accounts for an approximately 5 percent yearly attrition in transit ridership. The base-year patronage and cost figures and the assumption that the fare and vehicle-miles supplied in 1973 and 1975 would be the same as the base-year figures were used to derive the other 5 parameters for each city for 1973 and 1975. The total cost is estimated to exceed total revenue by more than $1.1 million in 1973, or 17 cents per passenger, and by $1.6 million in 1975.

Level of Service 2

The latent demand survey revealed that if a 15-minute access were provided to all cities that have transit, patronage would increase 80 percent. According to the patronage model, which relates changes in ridership to changes in fare and bus-miles supplied, an 80 percent patronage increase would require a 592 percent increase in the number of bus-miles. This large increase in supply implies that service to the new areas would have the same frequency of bus arrivals as currently exists in the present service areas. Provision of a high frequency service to all outlying areas was judged to be an unrealistic assumption and, accordingly, the number of bus-miles was reduced to reflect lower frequencies for some new in-town service areas and for out-of-town areas. The corresponding assumed number of bus-miles represented a 188 percent increase over present service. The patronage model estimated a resulting increase in ridership of 37 percent. Thus, the 80 percent increase in ridership represents an upper bound, and the 37 percent increase represents a lower bound estimate of patronage if service were increased to level 2, or an average increase of 59 percent. According to the cost model, which relates changes in cost to changes in bus-miles, an increase in bus-miles of 188 percent results in a 72 percent increase in cost.

Because of its relatively large size and extent, the Duluth-Superior transit system was treated separately. Application of the latent demand survey results to Duluth indicated that patronage would rise by 5 percent for level of service 2. The corresponding increase in bus-miles and cost could be 17 percent and 9 percent respectively.

These changes in patronage, cost, and bus-miles were used to calculate the other service and financial parameters for the base year in each of the 11 cities. Then the cost and patronage equations were used to project the figures to 1973 and 1975, and statewide totals and averages were calculated for each year. A change from service level 1 to service level 2 results in a patronage increase of 25 percent, but the deficit increases from $1.1 million to $1.9 million in 1973 and from $1.7 million to $2.6 million in 1975 (Table 3).

Level of Service 3

The method of calculation of level of service 3 is the same as that for level of service 2. The base-year patronage was estimated to increase by 131 percent, bus-miles

by 890 percent, and cost by 222 percent over service level 1. For Duluth-Superior, service level 3 is considered the same as service level 2, for the average access time for most of the in-town population is about 5 minutes at the present time. Costs of service level 3 exceed revenues by $4 million in 1973 and $4.9 million in 1975 (Table 3). The ridership generated by level of service 3 is 47 percent greater than that for level of service 1.

Level of Service 4

The results of the latent demand survey (Table 1) were used to estimate ridership for door-to-door service within the 11 cities that now have transit. The patronage and cost models were not applied to door-to-door service because these models were derived from and are reflective of regularly scheduled route service. Instead, estimates of ridership were based on consideration of parameters such as travel speed, travel distances, loading factors, peaking factors, and population to describe door-to-door service characteristics. Revenue estimates were based on an assumed value of 5 cents per passenger-mile. Based on the use of small vehicles for this type of service, estimates are $0.025 per vehicle-mile for amortized capital costs and $0.36 per vehicle-mile for operating and maintenance costs. The results show an estimated annual ridership of more than 29 million in 1973 in the 11 areas that now have transit. This includes ridership on the existing system and on door-to-door service, an increase of 23 million over the existing service. The corresponding figure for cost less revenue is $12.2 million.

Detailed Cost and Ridership Analysis

A more detailed analysis of each alternative service level was made for the 4 cities that were included in the latent demand survey. Each of the levels of service was used for Mankato, Bemidji, Albert Lea, and Crookston. The results given in Table 4 are for Mankato. The analysis showed that the subsidies necessary to support regular route service as now supplied would be 20 to 30 cents per passenger in Mankato and 35 to 50 cents in Bemidji. To provide similar service would require a subsidy of 50 to 67 cents per passenger in Albert Lea and 87 cents to $1.14 in Crookston. Generally, the subsidy per passenger is higher for higher levels of service. For the smaller cities, however, door-to-door service appeared to be more efficient than regularly scheduled route service.

SUMMARY

This paper describes a method for determining the statewide transit demands and associated costs for various levels of service. The results of the techniques developed were applied to rural communities in Minnesota, and estimates were developed for the amount of subsidy required at each level of service. Latent demand was established through a special survey that determined probable ridership. Cost-patronage models were used to establish the levels of investment and revenue that would accrue for each level of transit service. Although the techniques reported are of general applicability, the results of the analysis are directly useful to decision-makers in establishing the extent to which transit will be supported in communities throughout the state.

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