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	Seating Capacity: 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,

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

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

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-