Results of a Parametric Cost Analysis of Differences Between Urban and Rural Transportation Services for Transportation-Disadvantaged Persons

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It has been difficult in the past for local transportation service providers serving transportation-disadvantaged persons to accurately understand what their services should or will cost. This information is important for localities that contemplate the initiation, expansion, or evaluation of transportation services. In addition, information on the cost of services that differentiates among the various types and levels of service is important for federal, state, and local program managers because many use this information to apportion and distribute funds among local projects. A portion of the results from a study conducted by Ecosometrics, Inc., for the Administration on Aging, U.S. Department of Health and Human Services, is presented. The differences in costs of transportation services for the elderly in urban and rural areas are evaluated. Nevertheless, many of the services included in the study serve other transportation-disadvantaged groups; thus the results are applicable to multi-client services as well. Further, the parametric cost analysis performed in the study has analytical value beyond the differences in costs in urban and rural areas. The findings presented in the paper include (a) a brief review of the literature on the differences in costs between urban and rural transportation services for the elderly, and (b) a report on the results of the parametric cost analysis performed during the study by using secondary data.

One of the most important issues facing providers of transportation to transportation-disadvantaged persons involves estimating and evaluating the cost of those services. Not only have costs risen steadily during the past few years, but availability of funding for those services has been declining.

For many reasons it has been difficult to examine a particular transportation service for transportation-disadvantaged persons (either existing or under consideration) and to have an accurate understanding of some general guidelines for what those services should or will cost. First, costs in localities are different; what costs a certain amount in one locality may cost twice as much in another. Second, it is often difficult to find cost information that is current because inflation may seriously affect cost comparisons. Third, there is little published material that synthesizes information that cuts across more than a few projects. Finally, many agencies account for costs and services in different ways.

These observations are disheartening because accurate information on the costs of providing services is important to federal, state, and local program managers. Accurate cost information is important for localities that consider initiating or expanding a service because their estimate of costs should be as realistic as possible for the analysis of project feasibility and the preparation of a project budget. Accurate guidelines on what costs should be are also important for local areas evaluating their transportation services because these guidelines can act as benchmarks for determining how well the system is performing. Even more important, it is valuable for local system managers to have an understanding of their expenditures (relative to other services) for specific cost elements (such as drivers and gasoline) because this type of comparison gives managers data on what portions of the system are not as efficient as they might be.

Finally, an accurate estimation of the cost of providing services is important for federal, state, and local funding program managers. Many state and local governments have apportionment formulas for their funding programs that distribute available funds to local projects based on local conditions, quality of service, type of service, efficiency, and so on. In addition, the federal government has some program restrictions that affect the state or local apportionment of funds. For example, many programs have requirements for cost-effectiveness or they offer incentives for meeting cost-effectiveness standards. When these requirements are imposed, it can mean that systems that serve more severely disadvantaged persons or that operate in areas that inhibit efficiency will receive less money.

Another example is that of social service programs that apportion funds on a state or regional level based on factors such as total population or population density. When this is done, it often means that areas with less population receive less money. This result may be unfair to the more rural areas because more miles of service generally are required to provide one person trip in less densely populated areas. Both of these examples illustrate why it is important that federal, state, and local agencies have an understanding of the legitimate differences in costs among projects in different areas so that they can take these differences into account in their apportionment and distribution procedures.

The purpose of this paper is to present the findings of a portion of a study performed by Ecosometrics, Inc., for the Administration on Aging, U.S. Department of Health and Human Services. In this study the differences in needs and services of transportation programs for the elderly in rural and urban areas were evaluated. Although the study encompassed much more than is described herein, the discussion in this paper is confined to the subject of the cost of transportation services. The two topics explored in the study are as follows:

1. A brief review of the literature on the differences in costs between rural and urban transportation services for the elderly, and
2. A report on the results of the parametric cost analysis that was performed during the study by using secondary data.

It should be noted that many of the transportation services included in the study also serve other transportation-disadvantaged groups (such as the handicapped and low-income groups). Also note that the parametric cost analysis performed in the study has value beyond an analysis of the differences in cost in urban and rural areas. The cost analysis is structured to compare the cost of various elements among urban systems or rural systems (as well as between the two types).

CURRENT LITERATURE ON COMPARISON OF TRANSPORTATION COSTS IN RURAL AND URBAN AREAS

The literature review uncovered some sources that identified costs of transportation services to the elderly and other transportation-disadvantaged persons in urban and rural areas. Some of these sources only identified costs in one of the areas, some provided costs in areas of urban and rural mix, and some either made no distinction between the areas or made different distinctions. Note that only a portion of the sources reviewed for the cost analysis can be considered truly literature sources, because much of the data contained in the analysis is actually drawn directly from report forms submitted to the Administration on Aging by states and local agencies on their projects.

Cost Analysis Limitations

Before discussing the literature on the cost of transportation services in urban and rural areas and their comparisons, it is important to note that these comparisons are of limited value. Although some general inferences can be made about possible differences in cost in urban and rural areas, it is not possible to make any definitive statements on the subject. There are five reasons for this.

1. The service costs in the literature are from different years: The years for the cost information available vary from 1972 to 1981.
2. The literature sources reviewed have varying definitions for the services provided: It is not clear from much of the literature what services are actually being provided. What one source calls by one name may be called something else by another source.
3. The measures for units of service used in the literature are inconsistent: Some of the literature uses units of service that measure output or production of service (e.g., number of bus miles, number of vehicle hours), whereas others use units that measure consumption (e.g., number of trips provided).
4. It is not clear from the literature which costs have been included: It is not clear from the literature reviewed whether all costs or only direct costs are included, and whether all costs or only costs allowable under government projects are included.
5. It is impossible from the available literature to control for local project service quality specifications: It is known that some projects provide a service that is superior in quality to other projects. In comparing the cost of service for projects, only the costs for projects with similar service quality should be compared. It is not possible to ascertain from the literature what the quality of service or the service specifications are in the projects for which cost information is available.

Unit Cost Comparisons for Transportation in Urban and Rural Areas

Data are not currently available in the literature for directly comparing the cost of transportation for the elderly in urban and rural areas. Nevertheless, given the caveats discussed previously, there are still some general inferences that can be made about cost differences. The data in Table 1 give the means and standard deviations for the cost per trip and cost per mile reported in the literature (all costs were converted to 1979 dollars by using the consumer price index).

Several problems make it difficult to derive a meaningful comparison of the costs of transportation for the elderly in rural and urban areas. The Institute for Public Administration (1), Nelson (2), and to a lesser extent Arrillaga et al. (3) attempt to make consistent cost comparisons between rural and urban areas. Their comparisons, although generally valid, suffer because the services compared in urban and rural areas differ significantly in their service specifications. For example, some services are fixed-route bus services whereas others are demand-responsive services.

Table 1. Cost per trip and cost per mile from literature.

	Costs ($)			
	Urban		Rural	
Cost Items	Mean	Standard Deviation	Mean	Standard Deviation
Overall[a] (all modes)				
Cost per trip	2.94	2.16	2.96	3.50
Cost per mile	1.23	1.16	0.65	0.34
Demand responsive[b]				
Cost per trip	3.66	2.44	2.73	3.08
Cost per mile	1.43	1.26	0.70	0.48
Fixed route[c]				
Cost per trip	2.13	1.98	2.75	2.80
Cost per mile	0.97	0.99	0.55	0.32
Mixed demand responsive and fixed route[d]				
Cost per trip	2.25	0.83	3.10	2.58
Cost per mile	0.81	0.74	0.73	0.34

Note: Calculations by Ecosometrics, Inc.

[a]This category contains some cases that are not included in the analysis by mode because for these cases it was not known what type of service was being provided. The sample size for cost per trip is 106 in urban areas, 122 in rural areas; and the sample size for cost per mile is 112 in urban areas and 78 in rural areas.
[b]The sample size for cost per trip is 51 in urban areas and 14 in rural areas; and the sample size for cost per mile is 68 in urban areas and 12 in rural areas.
[c]The sample size for cost per trip is 31 in urban areas and 24 in rural areas; and the sample size for cost per mile is 32 in urban areas and 22 in rural areas.
[d]The sample size for cost per trip is 12 in urban areas and 19 in rural areas; and the sample size for cost per mile is 13 in urban areas and 19 in rural areas.

Still, the comparisons are valid and based on common sense. The Institute for Public Administration (1) indicated that the cost per vehicle mile in rural areas ($0.60 in 1979) was significantly lower than the cost in urban areas, which ranged from $0.93 to $1.00. Nelson (2) indicated that the cost per one-way trip in rural areas ($1.39) was lower than in urban areas ($2.24). Similarly, Arrillaga et al. (3) indicated that the cost of demand-responsive transportation in small cities was $10.50 per vehicle hour, and these costs were in the lowest part of the range of $9.60 to $15.40 per vehicle hour, which characterizes larger urban areas. It is reasonable that costs should be lower in small cities because transportation projects for the elderly in large urban areas face much higher costs of labor and because the prevalence of volunteer labor services is greater in rural areas.

Although the costs per vehicle hour and per vehicle mile are larger in urban areas, the available literature presents costs per passenger trip, which are comparable for both areas. There is still great uncertainty about the comparisons of cost per passenger trip. First, the cost figures come from different researchers who differ in their methods of accounting for costs. Second, the cost comparisons are generally for services that vary significantly in their service specifications. Finally, the variance of costs per passenger trip arising from the literature is so high that the observed cost differences may be attributable more to service specifications than to whether the area is rural or urban. A final conclusion on the issue of rural versus urban cost differences in transportation services for the elderly has to wait for further work on the subject.

COMPARISON OF COST FOR TRANSPORTATION SERVICES FOR THE ELDERLY IN RURAL AREAS

In this section the outcomes of a parametric cost analysis of transportation services in rural and urban areas, performed by using secondary data that were either readily available from secondary sources or available from the files at Ecosometrics, are presented. The analysis was based on data regarding the costs of resources, the relationships between the amount of each resource needed to produce a unit of transportation service, and information on service consumption rates. The results of this analysis are presented, which include (a) a description of the cost analysis methodology (both ideal and the one followed by using the secondary data), (b) a description of the secondary data sources used in the analysis, (c) a discussion of the parametric functions developed, and (d) the analysis results.

Cost Analysis

The objectives of the cost analysis are threefold. The first objective is to produce the information required to compare the cost of providing a basic unit of service in rural areas with the cost of providing that same unit of service in urban areas (the comparison of the cost per vehicle mile in urban areas with the cost per vehicle mile in rural areas). The issues examined here are (a) whether the cost of resources (vehicles, drivers, gasoline) are different in urban and rural areas, and (b) whether the amounts of these resources needed to produce a unit of service (a vehicle mile of operations) are different in urban and rural areas.

The second objective is to provide the information required to compare the cost of a unit of service consumed by the elderly (the comparison of the cost per one-way passenger trip provided in urban areas with the cost per trip for the same service in rural areas). This analysis answers the question of whether there is a difference in the cost for a local rural agency to provide a trip to an elderly person as compared with the cost for a local urban agency to provide a trip to an elderly person.

The third objective is to identify factors that could explain differences in cost. Although it is important to understand differences in costs to make decisions on how program funds should be allocated between urban and rural areas, it is also important to understand why these differences occur.

Secondary Data Used in the Analysis

Three groups of data were used to perform the analysis of transportation costs in urban and rural areas:

1. Information on the basic cost of resources in urban and rural areas;
2. Information on the relationships between the amount of each resource required to produce a unit (vehicle mile) of transportation service; and
3. Information on consumption rates to estimate the amount of service consumed in relation to the service provided (trips provided for every mile of service operated).

The literature review assessed the available literature on service costs. Unfortunately much of the information was not adequate on which to base a definite statement on the differences in service costs in urban and rural areas. There were some secondary data sources in the literature that either contained information on the basic cost of resources in urban and rural areas or on the amount of resources required to produce the service (4-13).

In addition, Ecosometrics had in-house a variety of local project reports and data collected either for, or in conjunction with, previous studies. These data included information on individual cost elements and services provided. This information was of considerable value in the cost analysis. This information included data on systems that dealt with transportation for the elderly and the handicapped in rural and urban areas throughout the country, and also Section 147 projects for FHWA. Finally, Ecosometrics has previously developed and was able to adapt for use in this study a parametric cost model to estimate the cost per mile of service (14).

Parametric Cost Models

Parametric cost analysis is an analytical tool that can estimate transportation unit costs with relatively simplified equations. It was used in this study to estimate and compare the cost of providing transportation services in urban and rural areas. These costs are expressed in the basic cost per vehicle mile in each area. The equations or models must be complete (in terms of containing all the pertinent cost categories) and give cost parameters that correspond to attributable characteristics or output measures (e.g., vehicle miles, passenger miles, vehicle hours, number of buses). By varying the value of the independent cost parameters and the independent output levels, the costs that result from transportation operations in rural and urban areas can be determined.

A cost-factor approach was used in this study to develop the parametric cost formulas. By using information on the basic cost of resources (i.e., cost of oil, gas, labor), cost factors have been developed for each cost parameter to explain the requirements for, or consumption of, resources in the production of service (i.e., miles per gallon of fuel, driver labor hours per vehicle mile of service). The cost factors were developed from the secondary data sources and represent cost as a multiplier of a known characteristic or output of the system. For example, overhead costs are expressed as a percentage of total operating costs.

The parametric cost formulas that were applied in the study are presented in the following sections. The cost formulas are discussed according to the four output variables of transportation costs: vehicle miles, vehicle hours, number of vehicles, and all other operating costs (overhead). In all cases costs are eventually converted to cost per mile regardless of whether they are dependent on vehicle miles, vehicle hours, or the number of vehicles operated.

Operating Costs Dependent on Vehicle Miles

There are four cost elements that are dependent on vehicle miles: fuel, oil, tubes and tires, and vehicle repairs and maintenance. The cost formulas are developed in a building-block fashion, as follows:

Cost Element	Cost Element Formula (per vehicle mile)
Fuel	$(PF_1)(1/MPG_i)$
Oil	$(OL_i)(PF_i)(1/MPG_i)$
Tubes and tires	T_i
Vehicle repairs and maintenance	RE_i

Adding these cost elements results in the following equation:

$$OCVM_i = [(1 + OL_i)(1/MPG_i)(PF_i)] + (T_i) + (RE_i) \quad (1)$$

where

$OCVM_i$ = operating costs per vehicle mile for costs that are dependent on vehicle miles for vans in area i;
MPG_i = miles per gallon for fuel for vans in area i;
PF_i = price per gallon for fuel in area i;
OL_i = proportion that oil and lubrication cost per mile are of fuel costs per mile in area i;
T_i = expenses for tubes and tires per vehicle mile for vans in area i; and
RE_i = expenses for vehicle repairs and maintenance per vehicle mile for vans in area i.

Operating Costs Dependent on Vehicle Hours

Operating costs influenced by vehicle hours include driver wages (volunteer and nonvolunteer) and dispatcher wages (also volunteer and nonvolunteer). The participation of volunteers in the provision of a service can reduce out-of-pocket costs considerably. Nevertheless, in the computation of true costs, comparable wages paid to volunters must be computed and included in the cost estimates. Thus two cost functions have been developed for driver and dispatcher wages, one accounting for true costs (including volunteer labor wages), and the other estimating out-of-pocket costs (not including volunteer labor wages).

Individual cost element formulas for driver and dispatcher wages include the following:

Cost Element	Cost Element Formula (per vehicle mile)
Driver wages	
Paid	$(1 + F_i)(DW_i)(1 - VD_i)(DH_i/RH_i)(RH_i \div VH_i)(1/MPH_i)$
Volunteer	$(1 + F_i)(DW_i)(VD_i)(DH_i/RH_i)(RH_i \div VH_i)(1/MPH_i)$
Dispatcher wages	
Paid	$(DR)(1 + F_i)(DPW_i/DW_i)(DW_i)(1 - VD_i)(DPH_i/DH_i)(DH_i/RH_i)(RH_i \div VH_i)(1/MPH_i)$
Volunteer	$(DR)(1 + F_i)(DPW_i/DW_i)(DW_i)(VD_i) \times (DPH_i/DH_i)(DH_i/RH_i)(RH_i/VH_i) \times (1/MPH_i)$

Adding these cost elements results in the following two equations (Equation 2 estimates real costs and Equation 3 estimates out-of-pocket costs):

$$OCVHT_i = (1 + F_i)(DW_i)(DH_i/RH_i)(RH_i/VH_i)(1/MPH_i)\ [1 + (DR) \times (DPW_i/DW_i)(DPH_i)/(DH_i)] \quad (2)$$

$$OCVHO_i = (1 + F_i)(DW_i)(1 - VD_i)(DH_i/RH_i)(RH_i/VH_i)(1/MPH_i) \times [1 + (DR)(DPW_i/DW_i)(DPH_i/DH_i)] \quad (3)$$

where

$OCVHT_i$ = total operating costs per vehicle mile for costs that are dependent on vehicles hours for vans in area i;
$OCVHO_i$ = out-of-pocket operating costs per vehicle mile for costs that are dependent on vehicle hours for vans in area i;
F_i = fringe benefit rate for area i (ratio of fringe benefits to wages);
DW_i = driver paid hourly rate and imputed driver volunteer rate in area i;
VD_i = proportion of volunteer driver hours or volunteer dispatcher hours to total driver or dispatcher hours in area i;
DH_i/RH_i = ratio of driver hours to revenue hours in area i;
RH_i/VH_i = ratio of revenue hours to total vehicle hours in area i;
MPH_i = miles per hour in area i;
DR = 1 if the system is demand responsive, 0 if it is not;
DPW_i/DW_i = ratio of dispatcher hourly wages to driver hourly wages in area i; and
DPH_i/DH_i = ratio of dispatcher hours to driver hours in area i.

Operating Costs Dependent on Number of Vehicles

Several costs are vehicle oriented, including insurance, vehicle storage, licenses and tags, and maintenance of dispatching equipment. For each computation, vehicle storage and licensing costs are included in the overhead. The individual cost formulas for insurance and maintenance of dispatching equipment follow.

Cost Element	Cost Element Formula (per vehicle mile)
Insurance	$(INS_i)(1/VMV_i)$
Maintenance of dispatching equipment	$(DR)(MR)[(DSC_i)(STAT_i) + (DMC_i) \times (N_i)]\ [1/(N_i)(VMV_i)]$

The summation of these cost elements results in the following cost formula:

$$OCV_i = (1/VMV_i)\{(INS_i) + (DR)(MR)[(DSC_i)(STAT_i) + (DMC_i)(N_i)]\} \quad (4)$$

where

OCV_i = operating cost per vehicle mile for costs that are dependent on the number of vehicles in area i;
INS_i = annual insurance rate for a basic 10- to 12-passenger van in area i;
MR = proportion that annual maintenance costs of dispatching equipment is of the acquisition cost of dispatching equipment;
DSC_i = cost of acquisition and installation per dispatch base station in area i, including base, antenna, and repeaters;
$STAT_i$ = number of stations needed in area i;
DMC_i = cost of acquisition and installation of mobile radio units in area i;
N_i = number of vehicles in system in area i;
VMV_i = total vehicle miles per vehicle in area i; and
DR = 1 if the service is demand responsive, 0 if it is not.

General and Administrative Overhead

The overhead category includes all the personnel involved in general office administration, office rent and taxes, advertising, utilities and communications, office supplies, licenses, vehicle storage, and so on. The general administrative expenses are dominated by the personnel costs involved in general office administration. These personnel costs do not include the costs of the supervisors of vehicle repair or maintenance operations (whose costs are included among the repair costs) or the fringe benefits paid to the drivers, dispatchers, and mechanics.

The costs formula for this cost element is

$$OH_i = (OVRATE_F)\ [(OCVM_i) + (OCVH_i) + (OCV_i)] \quad (5)$$

where

OH_i = overhead expenses per vehicle mile in area i;
$OVRATE_F$ = overhead rate in area i, which varies according to firm type F; the two types of firms considered are social service agency and transit operators;
$OCVH_i$ = operating costs per mile for costs that are dependent on vehicle hours for vans in area i;
OCV_i = operating costs per mile for costs that are dependent on the number of vehicles in area i; and
$OCVM_i$ = operating costs per mile for costs that are dependent on vehicle miles for vans in area i.

Capital Costs

Capital costs include both depreciation and interest cost of capital equipment, including vehicle dispatching equipment. The estimation of capital costs in this study assumes that the vehicles and dispatching equipment have a negligible scrap or residual value at the end of their productive lives. All vehicle costs are estimated for a standard 10- to 12-passenger van for 1979. Cost formulas for capital items are as follows:

Cost Element	Cost Element Formula (per vehicle mile)
Vehicle capital costs	$(CRFV_{n,r,i})(VC_i)(TV_i)(1/VMV_i)$
Capital cost of dispatching equipment	$\{(DR)(TVD_i)[(DSC_i)(CRFS_i)(STAT_i) + (DMC_i)(CRFM_i)(N_i)]\}/[(N_i) \times (VMV_i)]$

The capital costs per vehicle mile are then computed by using the following equation:

$$CC_i = (1/VMV_i)\Big[(CRFV_{n,r,i})(VC_i)(TV_i) + \{(DR)(TVD_i) \times [(DSC_i)(CRFS_{n,r,i})(STAT_i) + (DMC_i) \times (CRFM_{n,r,i})(N_i)]\}/N_i\Big] \quad (6)$$

where

CC_i = capital cost per mile in area i;
VMV_i = annual vehicle miles per vehicle in area i;
$CRFV_{n,r,i}$ = capital recovery factor for vehicle for n years at rate of interest r in area i;
$CRFS_{n,r,i}$ = capital recovery factor for dispatch base station for n years and at rate of interest r in area i;
$CRFM_{n,r,i}$ = capital recovery factor for mobile dispatching units for n years and at rate of interest r in area i;
VC_i = vehicle acquisition cost for vans in area i;
TV_i = proportional terminal value for vans in area i (in this case terminal value is assumed to be negligible because service lives are used rather than economic life);
TVD_i = proportional terminal value for dispatching equipment in area i (as with vehicles, this is assumed to be negligible);
N_i = number of vehicles per system in area i;
DR = 1 if service is demand responsive, 0 if it is not;
DSC_i = cost of acquisition and installation per dispatch base station in area i, including base, antenna, and repeaters;
$STAT_i$ = number of stations required in area i; and
DMC_i = cost of acquisition and installation of mobile radio units in area i.

Total Costs

The total costs (TC) are computed by adding the five cost formulas presented earlier:

$$TC_i = OCVM_i + OCVH_i + OCV_i + OH_i + CC_i \quad (7)$$

Differences in Cost per Mile in Urban and Rural Areas: Results of Parametric Cost Models

In this section the end results of the parametric cost analysis are presented; detailed descriptions of the cost models are given in subsequent sections. As described previously, the total cost per vehicle mile is computed by adding the five types of costs: operating costs dependent on vehicle miles, operating costs dependent on vehicle hours, operating costs dependent on the number of vehicles, overhead costs, and capital costs. The data in Table 2 give the total costs per vehicle mile disaggregated by (a) whether the service was provided by a social service agency or a transit company, and (b) whether only out-of-pocket costs are considered. In all cases these costs have been computed for the year 1979 for areas on flat terrain and for the operation of 10- to 12-passenger vans.

The total costs per vehicle mile are approximately 2.4 times greater in urban areas than in rural areas. For demand-responsive services provided by social service agencies, the total true cost per vehicle mile is $3.15 in urban areas and $1.34 in rural areas. The corresponding cost per vehicle mile for demand-responsive services provided by transit companies is $2.80 in urban areas and $1.23 in rural areas. Fixed-route services cost slightly less than demand-responsive services (because of the necessity for dispatching equipment and personnel in demand-responsive systems). Fixed-route and scheduled services provided by social service agencies cost $2.49 per vehicle mile in urban areas and $0.97 per vehicle mile in rural areas. Fixed-route and scheduled services provided by transit companies cost $2.22 and $0.89 per vehicle mile in urban and rural areas, respectively.

Operating Costs Dependent on Vehicle Miles

In urban areas the operating costs dependent on vehicle miles are almost 1.5 times those in rural areas ($0.2499 in urban areas and $0.1718 in rural areas).

Fuel costs per mile are estimated based on the costs of fuel per gallon and on the rate of fuel consumption. The cost per gallon for fuel for vans in urban and rural areas is almost identical ($0.88 per gallon in urban areas and $0.89 per gallon in rural areas in 1979). However, the fuel-consumption rate (miles per gallon) is higher in urban areas (8.0 miles per gallon) than in rural areas (10.6 miles per gallon), which indicates that 32.5 percent more gallons of fuel are needed in urban areas to provide the same number of miles in rural areas (assuming fairly flat terrains in both areas). This is probably caused by the lower speeds and stop-and-go type of driving required in urban areas. Thus overall fuel costs per mile are $0.11 in urban areas and only $0.08 in rural areas.

Oil costs are expressed in terms of the proportion that oil and lubrication costs per mile are of fuel costs per mile. This proportion is higher in urban areas than in rural areas (0.0083 and 0.0076,

Table 2. Total costs per mile in 1981 costs for fixed-route and demand-responsive systems.

		Costs ($)			
		Urban		Rural	
Cost Element	Symbol	Fixed Route	Demand Responsive	Fixed Route	Demand Responsive
Operating cost per mile dependent on vehicle miles	$OCVM_i$	0.2499	0.2499	0.1718	0.1718
Total operating cost per mile dependent on vehicle hours	$OCVHT_i$	1.113	1.425	0.3309	0.4415
Out-of-pocket operating cost per mile dependent on vehicle hours	$OCVHO_i$	0.8912	1.141	0.2482	0.3311
Operating cost per mile dependent on number of vehicles	OCV_i	0.0652	0.1601	0.0276	0.1026
Overhead costs per vehicle mile[a]					
Social service agency	OH_i	0.843	1.083	0.244	0.329
Transit company		0.571	0.734	0.164	0.222
Capital costs per vehicle mile	CC_i	0.2178	0.2350	0.1986	0.2958
Total out-of-pocket costs per vehicle mile					
Social service agency		2.2671	2.869	0.8901	1.2306
Transit operator		1.9951	2.520	0.8106	1.189
Total costs per vehicle mile					
Social service agency		2.4889	3.153	0.9728	1.3410
Transit operator		2.2169	2.804	0.8933	1.234

[a]Assumes a flat terrain.

respectively). This results in an oil cost per mile of $0.0009 in urban areas and $0.0006 in rural areas (50 percent greater in urban areas).

Both tube and tire costs and vehicle repair and maintenance costs are expressed in a cost per vehicle mile. The cost per mile for tubes and tires is $0.020 in urban areas and $0.013 in rural areas (almost 50 percent greater in urban areas). Again, this is probably because of the stop-and-go nature of the driving in urban areas. Vehicle repair and maintenance costs include all expenses associated with repair shops, parts, labor, and equipment. Vehicle repair and maintenance costs per mile are almost 61 percent greater in urban areas than in rural areas ($0.119 and $0.074, respectively). This is probably caused by both higher labor costs in urban areas and also the stop-and-go, conjested traffic in these areas.

Operating Costs Dependent on Vehicle Hours

Driver and dispatcher wages and total labor expenses are the greatest factors that account for differences in costs in urban and rural areas. Considering real costs for demand-responsive services, total driver and dispatcher labor costs per vehicle mile are $1.43 in urban areas and $0.44 in rural areas (225 percent greater in urban areas). For fixed-route systems, driver wages per vehicle mile are $1.11 in urban areas and $0.33 in rural areas (236 percent greater in urban areas).

The proportionally greater costs in urban areas may be attributed to four factors. First, driver wages are considerably higher in urban areas ($6.57 per hour in urban areas versus $4.53 per hour in rural areas). Second, fringe benefit rates (ratio of fringe benefits to wages) are higher in urban areas. (The 27.2 percent fringe benefit rate in urban areas and the 16.0 percent rate in rural areas produce a wage plus fringe benefit rate of $8.36 in urban areas and $5.25 in rural areas.)

The third factor is the ratio of driver paid hours to vehicle hours. In urban areas this ratio is 1.32, whereas in rural areas it is approximately 1.0. This means that in urban areas more than 24 percent of the paid driver hours are not spent driving the vehicle. Nevertheless, because these costs are an expense of the service, the cost of these labor hours must be included, which increases the overall labor cost considerably.

Finally, labor cost per mile is higher in urban areas because average speeds are lower (9.9 mph in urban areas and 15.9 mph in rural areas). This means that for every vehicle hour, a rural vehicle covers 60 percent more miles than an urban vehicle.

Note that if only out-of-pocket costs are considered (if volunteer labor is considered free and therefore not included as an expense), costs are reduced in both urban and rural areas. Nevertheless, this reduction in labor cost is not equal between areas. Data indicate that although approximately 25 percent of driver and dispatcher labor is volunteer in rural areas, only 20 percent of this labor is volunteer in urban areas. This means that out-of-pocket costs in urban areas would be relatively higher than out-of-pocket costs in rural areas because of the higher degree of volunteerism in rural areas.

Operating Costs Dependent on Number of Vehicles

Overall, the operating costs per mile for insurance in urban areas are approximately 2.4 times those in rural areas. For demand-responsive systems in urban areas, the overall operating cost per mile for insurance and acquisition of vehicles and operation of dispatching equipment is approximately 60 percent greater than those costs in rural areas.

There are a number of factors that influence these cost differentials. First, annual insurance costs per vehicle are greater in urban areas ($1,060 in urban areas and $619 in rural areas), and second, urban vehicles operate for fewer annual miles than rural systems (16,260 annual miles per vehicle in urban areas and 22,416 annual miles per vehicle in rural areas). These two factors combine to create much higher insurance costs per vehicle mile in urban areas.

On the other hand, the maintenance costs of dispatching equipment are greater in rural areas because of the need for more equipment and, in some cases, more sophisticated equipment. The cost per base dispatching station in an area of flat terrain is slightly lower in rural areas than urban areas ($3,600 in rural areas for VHF and $4,200 in urban areas for UHF), but the cost per station in a mountainous rural areas is almost 4 times either of these costs ($15,000). In addition, rural areas need more base stations because of greater distances, and, because rural systems tend to have more vehicles, they need to have more mobile units.

General and Administrative Overhead

Overhead costs will be partly dependent on the type of agency operating the system. It has been noted that overhead rates for social service agencies are almost 50 percent greater than overhead rates for transit companies operating a transportation service. Overhead rates for social service agency systems are 46 percent in rural areas and 59 percent in urban areas. Overhead rates for transit company systems are 31 percent in rural areas and 40 percent in urban areas. Overall, in urban areas the overhead cost per vehicle mile is 3.5 times the overhead cost per vehicle mile in rural areas.

Capital Costs

Two concepts of vehicle life appear in the literature: service life and economic life. The service life is the total time that the equipment--through continued repair and rebuilding--is operational. Vehicle economic life ends at that certain point when a vehicle becomes more expensive to own and operate than to replace. This cost model makes extensive use of service lives and thereby assumes negligible terminal values of the equipment at the end of their service lives.

Capital recovery factors are used to convert one-time costs such as vehicle acquisitions into equivalent annual costs. Conceptually, the product of the capital recovery factors and the capital costs gives the constant end-of-year annual amount over the life of the equipment necessary to pay interest and to recover the capital costs in full.

Overall, the capital cost per vehicle mile for fixed-route systems is slightly (10 percent) higher in urban than in rural areas ($0.2178 in urban areas and $0.1986 in rural areas). However, the capital cost per vehilce mile for demand-responsive systems is 30 percent higher in rural areas than in urban areas.

The cost of acquiring vehicles (10- to 12-passenger vans) is approximately the same in the two areas. Thus the slight increase in capital costs for vehicles in urban areas is because vehicles in urban areas operate fewer vehicle miles over which to distribute costs. Nevertheless, the considerably higher costs for dispatching equipment in rural areas are because (a) in some cases (with mountainous terrain) dispatch base stations are more expensive for rural areas, (b) rural areas require more base stations per system because of the distances involved, and (c) rural areas tend to have more vehicles requiring more mobile units.

Summary

The comparison of the overall costs per vehicle mile in urban and rural areas concludes that the unit cost per mile is almost 2.5 times greater in urban areas than in rural areas. The greatest factor contributing to this difference is the hourly rate for labor and the amount of labor hours needed in urban areas as compared with rural areas. Although fuel, oil, tires, maintenance, insurance, and capital costs are all greater in urban areas, these cost elements do not affect the overall cost differential anywhere near as greatly as driver and dispatcher wages and the overhead costs associated with them. The only production cost that is higher in rural areas than in urban areas is the cost of acquisition, installation, and maintenance of dispatching equipment.

Service Consumption and Demand Rates

For the purpose of this study, service consumption or demand rates are expressed in terms of the number of one-way passenger trips provided per mile in the two areas. From the secondary data examined in this study, the number of trips per mile ranges from 0.40 to 0.45 in urban areas and from 0.15 to 0.20 in rural areas.

The accuracy of the values used for the number of trips per mile was verified by examining load factors and average trip lengths for the two areas. A load factor is a value expressed as a percentage, which indicates how full vehicles are (on average) over the total service period. Load factors are equal to the ratio of passenger miles to seat miles (seat miles equal number of seats on the vehicle times vehicle miles). Load factors can be used with the trip length to verify the accuracy of the value used for trips per mile, because load factors are calculated as follows:

$$\text{Load factors} = (\text{One-way passenger trips} \div \text{vehicle miles}) \times (\text{Trip length} \div \text{seats on vehicle}) \quad (8)$$

On the one hand, from the secondary data analyzed for this study, it appears that load factors are fairly comparable in urban and rural areas, with the vehicles approximately 14 to 23 percent full in both areas. On the other hand, trip lengths in urban areas are only one-third to one-half the distances of those in rural areas (4 to 6 miles in urban areas and 12 to 14 miles in rural areas). By using the empirical data discussed and Equation 8, trips per vehicle mile for urban and rural areas are calculated as approximately 0.45 and 0.15, respectively.

Differences in Cost per Trip in Urban and Rural Areas

The unit cost per service consumed is expressed in terms of the total cost per one-way trip provided to an elderly person. Unit costs per trip in urban and rural areas were calculated by dividing the cost per mile in the two areas by the number of trips per mile. Because trips per mile are expressed in terms of a range of values, costs per trip are also expressed as a range of costs. (It was not possible, using the secondary data available, to estimate a mean or median value for trips per mile in the two areas.)

The ranges of values for the cost per trip in urban and rural areas, disaggregated for fixed-route and demand-responsive services, are given in Table 3. The data in the table indicate that the estimated values for the cost per trip in urban areas fall within the range of values for the cost per trip in rural areas (with, in all cases, a wider range of values for rural areas). A tentative conclusion is that the costs per trip are comparable in urban and rural areas. Unfortunately, from the data available for the study, it is not possible to control for, or take into account, differences in the quality of service in the two types of areas. Nevertheless it is known that the quality of service is considerably lower in rural areas in terms of lower frequencies, longer reservation times, and fewer trips per service area population.

Without controlling for service quality, it is impossible to make definitive conclusions concerning differences in cost. Nevertheless, because it appears that service quality is lower in rural areas than in urban areas, service costs may be the same but for an inferior type of service in rural areas. It is cautioned that this conclusion cannot be fully substantiated without the collection and analysis of

Table 3. Total cost per one-way trip for fixed-route and demand-responsive systems.

	Total Cost ($)	
Location and Operator	Fixed Route	Demand Responsive
Urban		
Social service agency	5.44-6.12	7.00-7.88
Transit operator	4.93-5.54	6.23-7.01
Rural		
Social service agency	4.86-6.48	6.71-8.94
Transit operator	4.46-5.96	6.17-8.23

primary data designed to control for service quality specifications.

CONCLUSIONS

In the examination of the differences in costs to provide transportation services to the elderly in rural and urban areas, a number of conclusions can be drawn. First, the basic cost of resources needed to provide the service (i.e., labor, tires) is generally greater in urban areas. Second, the amount of resources needed to produce the service is generally greater in urban areas (i.e., miles per gallon for fuel is lower in urban areas, driver hours to vehicle hours is greater in urban areas). Finally, because of these characteristics, the cost per vehicle mile in urban areas is almost 2.5 times greater than the cost per vehicle mile in rural areas.

There was considerable variation in the consumption rates in both urban and rural areas. Consumption rates in terms of trips per mile ranged from 0.40 to 0.45 in urban areas and from 0.15 to 0.20 in rural areas. This represents a trip length of about 12 to 14 miles in rural areas and from 4 to 6 miles in urban areas.

The final consideration--differences in the unit cost per one-way trip in urban and rural areas--is less conclusive than the other areas of analysis. Indications are that the costs per trip in urban and rural areas are roughly comparable, with rural areas having a greater range of values for these unit costs. However, as explained previously, this conclusion does not take into account the quality of service being provided in the two areas. Because service quality is considerably lower in rural areas, the conclusion might be drawn that, although the cost per trip in rural areas is the same as for urban areas, it buys a lower quality of service. If this conclusion is true, and the quality of service was controlled, then the cost per one-way trip of comparable quality would probably be considerably more expensive in rural areas. (Again, the validity of this statement can only be verified by the collection and analysis of primary data designed to control for service quality.)

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