RURAL TRANSPORTATION COSTS

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This paper presents a rural transportation cost model which was developed while determining potential future demand for UMTA capital and operating assistance in rural areas. The model is designed to account for all costs incurred in the operation of a rural transit system, with considerations given to regional location, firm size and public/private ownership characteristics. The bulk of the data used to develop this model came from the Section 147 Demonstration funded by FHWA and UMTA. By combining the cost information and the information available on operating characteristics, a standardized cost per vehicle mile can be calculated for a given vehicle type. Several conclusions regarding costs are noteworthy: 1) Total operating costs per vehicle mile are highest in the Northeast and Pacific coast states. 2) In rural transit operations, the bulk of the total system costs are directly attributable to drivers wages, overhead costs, and vehicle capital costs. 3) Economies of scale are not obvious in rural transportation operations.

This paper presents considerations designed to account for all costs incurred in the operation of a rural transit system. Included are considerations for geographic locations, firm size, use of volunteer services and public/private ownership considerations.

The majority of the data used to design this model was drawn from the Section 147 Rural Transit Demonstrations funded by FHWA and UMTA, and from the actual operating reports submitted by private transportation companies in the States of Pennsylvania and Washington. This data contained cost information on individual cost items and information on the relationships between related cost elements. Because the program is nationwide, information on regional characteristics was readily available. By combining the cost element information and some basic operating characteristics, a "standardized" system costing can be produced.

Cost Elements

Seventeen major cost elements are presented in Table 1. The elements are divided into two major categories: 1) operating costs and 2) capital costs.

The operating costs are the expenses incurred in actual transportation operations, while the capital costs represent costs of equipment depreciation and interest charges on the use of capital equipment. Capital costs can be divided among two types of equipment costs: vehicle costs and dispatching equipment costs. It is assumed that all other capital equipment and facilities are rented.

Table 1 displays the seventeen cost variables and the output variables which influence the cost factors. Four output variables are distinguished, namely: 1) vehicle miles, 2) vehicle hours, 3) number of vehicles, and 4) all other operating costs (except for overhead).

Total Costs

The total system costs are the summation of the five major cost categories: costs dependent on vehicle miles, costs dependent on vehicle hours, costs dependent on number (and type) of vehicles, capital costs, and overhead costs. It would be a long, but not impossible task, to determine total system cost by calculating each component and adding the parts to arrive at a grand total. The process is greatly simplified if all costs can be defined by a common denominator. By "standardizing" the cost elements, it is possible to quickly determine the proportion of total costs allocated to each cost category or cost element.

Cost Factors Dependent on Vehicle Types

Table 2 displays the cost elements which are dependent on the type of vehicle operated by the transit system. Table 2 also presents some average values for various cost items including vehicle acquisition costs, fuel costs, and the cost of tags and licenses for the various vehicle types. The operating speeds presented in this table are averages and will vary according to the road surface, topography, and population density in the service area.

Table 1. Cost Element Structure for Rural Transportation Systems

Overall Cost Category	Output Measures Driving Costs	Cost Elements
OPERATING COSTS	Per vehicle mile	1. Fuel 2. Oil 3. Tires and Tubes 4. Vehicle Repairs & Maintenance-Parts 5. Vehicle Repairs & Maintenance-Non Volunteer Labor 6. Vehicle Repairs & Maintenance-Volunteer Labor
	Per vehicle hours	7. Drivers Wages - Non Volunteer labor 8. Drivers Wages - Volunteer labor 9. Dispatcher Wages - Non Volunteer labor 10. Dispatcher Wages - Volunteer labor
	Per vehicle	11. Insurance 12. Maintenance of Dispatching Equipment (Base and Mobile Equipment) 13. Driver Examination & Training, Licence and Tags 14. Vehicle storage costs (including covered storage and shelters)
	Per all other operating costs	15. General and Administrative Overhead Expenses
CAPITAL COSTS (including depreciation & interest charges)	Per vehicle mile and per vehicle	16. Vehicle capital costs 17. Dispatching equipment capital costs (including dispatching base, repeaters and mobile equipment)

Table 2. Cost Factors Dependent on Vehicle Types — FY1977

Parametric Cost Factor Description	Vehicle Types (i)					
	Auto/ Station Wagon	Van	Small Transit Bus	Medium Transit Bus	Large Transit Bus	School Bus
Capacity (in adult seats)	5-9	10-12	20	30	50	44
Operating speed (miles per hour)	30	25	18	18	15	15
Vehicle Acquisition Cost - Standard	$5,500-7,000	$9,000	$17,000	$33,000	$65,000	$18,000
Vehicle Acquisition Cost - with lifts and wheel chair modificat.	Not applicable	$11,000	$20,000	$37,000	$70,000	$21,000
Types of fuel	gasoline	gasoline	gasoline	diesel	diesel	gasoline
Fuel Consumption rate (miles per gallon)	13-12	10-9	7	6	5	7
Price per gallon of fuel	$0.65	$0.65	$0.65	$0.49	$0.49	$0.65
Tires and tubes cost per mile	$0.006	$0.01	$0.02	$0.023	$0.05	$0.04
Vehicle repairs and maint. expense per mile	$0.045	$0.07	$0.09	$0.125	$0.15	$0.14
Relative insurance costs (relative to vans)	0.75	1.0	1.5	2.0	2.5	2.0
Annual cost of Driver, Exam, Training, Lic. and tags per vehicle	$75	$100	$200	$300	$500	$500
Vehicle service life in miles	130,000	110,000	200,000	300,000	500,000	500,000

The Parametric Cost Equations

As noted earlier, Table 1 displays the seventeen cost elements and the system variables which drive each output. It would be advantageous to describe total system costs in terms of one system output: vehicle miles. Therefore, it is necessary to combine all the variables and cost elements into one expression which explains all cost attributable to a given system output. Then by converting all the system output equations into equations representing costs per vehicle mile, the total cost per vehicle mile can be determined.

The first step in this process (producing cost equations for each system output) is represented by equations (1), (2), (3), (4), and (5). Each of these equations represents the total system costs attributable to a given system output or combination of outputs. The equations account for all the cost elements and variables related to the given system output.

$$(OCVM_i) = \Big\{ [(1+\sigma)(\alpha_{s,k})(\gamma_{s,T})(1/mpg_i)(PF_i)] + [(\lambda_k t_i) + (\delta_k)(p)(re_i)] + [(\delta_k)(1-p)(re_i)(1-VR)] \Big\} (VM_i) + (\delta_k)(i-p)(re_i)(VR)(VM_i) \quad (1)$$

$$(OCVH_i) = (1+f_R)(DW_R) \left[(1-VD) \left(\frac{DH}{VH}\right) + \left(\frac{DPW}{DW}\right)(1-VPD) \left(\frac{DPH}{VH}\right) \right] (VH_i) + (\theta)(1-f_R)(DVW_R) \left[(VD) \left(\frac{DH}{VH}\right) + \left(\frac{DPW}{DW}\right)(VDP) \left(\frac{DPH}{VH}\right) \right] (VH_i) \quad (2)$$

$$(OCV_i) = [(INS_i)(INS_R) + (MR)(DR_i)(DMC_T) + (LIC_i) + (DR_i)(FCC) + (SC)] (N_i) + (MR)(DR_i)(DSC_T)(STAT_T) \quad (3)$$

$$OVERHEAD = (OVRATE_F) \sum_i (OCVM_i) + (OCVH_i) + (OCV_i) \quad (4)$$

$$CCI = \left[(DR_i)(CRF_{n,r})(tvd_i)(DSC_T)(STAT_T) \right] + \left[(CRF_{n,r,i})(1-CG)(VC_i)(tv_i) + (DR_i)(DMC_T) + (tvd_i)(CRF_{n,r}) \right] (N_i) \quad (5)$$

where

$OCVM_i$ = annual operating costs which are dependent on vehicle miles, for vehicle type i

mpg_i = miles per gallon of fuel for vehicle type i

PF_i = price per gallon of fuel for vehicle type i (with different prices for gasoline and diesel depending on the type of engine)

σ = proportion that oil and lubrication costs per mile are of fuel costs

t_i = expenses in tires and tubes per vehicle mile for vehicle type i

p = proportion that expenses in parts are of the total costs of repairs and maintenance of the vehicles

re_i = expenses in vehicle repairs and maintenance per vehicle mile for vehicle type i

VR = proportion of volunteer labor out of the total labor hours spent on vehicle repairs and maintenance (for non-volunteers systems VR = 0)

VM_i = annual vehicle mileage driven by vehicle type i

δ_k = cost parameter representing increases in repair costs due to road surface conditions (k=1 paved, k=2 gravel, k=3 earth roads)

$\alpha_{s,k}$ = cost parameters denoting increases in fuel costs due to speeds and paving conditions k.

$\gamma_{s,k}$ = cost parameters denoting increases in full comsumption due to speeds and topography T.

λ_k = cost parameter denoting increases in tires and tubes cost due to road surface condition k.

$OCVH_i$ = annual operating costs which are dependent on vehicle hours, for vehicle type i

f_R = fringe benefit rate (ratio of fringe benefits to wages) in region R

DW_R = driver hourly wage rate in region R

DVW_R = inputed driver volunteer wage rate in region R

VD = proportion of volunteer driver hours out of total driver hours

VDP = proportion of volunteer dispatcher hours out of total dispatcher hours

$\frac{DH}{VH}$ = ratio of driver hours to vehicle hours (in large systems this ratio is 1.1, while for most systems it is 1.0)

$\frac{DPW}{DW}$ = ratio of dispatcher hourly wage to driver wages. While this ratio shows some variability, it is usually 1.0. An exception occurs in instances where some supervisory personnel are used in dispatching on a part-time basis, in which case the ratio becomes 1.10.

$\frac{DPH}{VH}$ = ratio of dispatcher hours to vehicle hours. This ratio is very volatile, its mean is 0.25 ranging from a low of 0.10 to a high of 0.40

VH_i = annual vehicle hours of operation of vehicle type i

θ = 1 if volunteer labor costs are to be inputed in the calculation of social costs, 0 if volunteer labor costs are not inputed, that is, if only monetary costs are analyzed.

OCV_i = annual operating costs which are dependent on the number of vehicles for vehicle type i

INS_i = relative ratio of insurance costs for vehicle type i to the annual insurance cost of a 10-12 seat van (INS_i = 1.5 for 20-seat small transit bus, 2.0 for both 30-seat medium transit and for school buses, and is 2.5 for the large 50-seat transit bus)

INS_R = annual cost of insurance for a basic 10-12 seat van in region R

MR = proportion that dispatch equipment annual maintenance costs are of the acquisition cost of the dispatching equipment.

DR_i = 1 if the vehicle is part of a demand responsive system, 0 if not

LIC_i = annual cost of driver examination, training and tags, (varies from locality to locality)

FCC = annual cost of an FCC radio transmission license; applicable only to demand responsive systems

SC = annual vehicle storage costs per vehicle

N_i = number of vehicles of type in the fleet

DSC_T = cost of acquisition and installation per station of demand responsive systems including base, antenna and repeaters

$STAT_T$ = number of stations per county according to topographic type T.

DMC_T = cost of acquisition and installation of mobile radio units

OVERHEAD = annual overhead expenses for the rural transportation system

OVRATE = overhead rate which varies according to firm type F. Among the types of firms are Welfare System, city owned and privately owned.

OCM_i = annual operating costs which are dependent on vehicle miles for vehicle type i

$OCVH_i$ = annual operating costs which are dependent on vehicle hours, for vehicle type i

OCV_i = annual operating costs which are dependent on the number of vehicles for vehicle type i

CCI = annual capital cost for vehicle type i

CG = UMTA capital grant subsidy rate

VC_i = vehicle acquisition cost for vehicle i

tv_i = proportion terminal value of vehicle i

tvd_i = proportion terminal value of dispatching equipment type i

$CRF_{n,r}$ = capital recovery factor for n years, and rate of interest r

The second step in producing the "standardized" cost model requires that the equations be stated in terms of a common system output. By multiplying equation (2) by the average operating speed of the vehicle, this equation can be coverted to represent costs per vehicle mile. By multiplying equation (3) by the annual vehicle miles travelled per vehicle, the same result can be realized. Finally, the equation representing capital costs, equation (5) can be multiplied by one over the expected life of the vehicle (in vehicle miles) to yield an equation representing capital costs per mile. By multiplying the indicated equations by the correct factor, the only system output remaining in the equations will be vehicle miles.

It should be noted that the final equation can be adjusted to fit any system. By specifying the correct topographical conditions and service specifications, the cost per mile for a particular system can be determined.

Regionally-Oriented Cost Factors

Adjustments for regional differences in cost factors must begin by defining the regions. We have distinguished four census regions: 1) South 2) Northeast/MidAtlantic (involving New England, and the Mid-Atlantic States), 3) Midwest/Mountain, and 4) Pacific Region (involving California, Oregon, Washington, Alaska, and Hawaii).

Cost factors which vary by region include wage rates, fringe benefits, and insurance costs. The typical cost factors used in this study are presented in Table 3. These cost factors were developed for FY1977 from the information presented in the Section 147 demonstrations. As a general rule there is a divergence in wage rates and insurance costs across regions. The insurance rates vary widely at the state level, while wages vary within states, depending on the unionization of the project staff. Faced with these wide divergences we note in Table 3 the wide ranges of experiences within each region. It is obvious from Table 3 that the highest cost per vehicle mile of transit operation are found in the Northeast and Pacific regions. This is mainly due to the significantly higher wage rates, fringe benefits, and insurance costs in these regions.

Cost Factors Unaffected by Vehicle Type and Regional Location

In addition to the cost factors which are variant according to regional location and vehicle type, several cost factors and cost relationships, were constant across all vehicle types and all locations. These cost factors and cost relationships are presented in Table 4. It should be noted that these costs were fairly constant although cost items such as vehicle storage costs will vary depending on the sophistication of the facilities. Several other costs, including the ratio of dispatchers hours to vehicle hours and the ratio of drivers hours to vehicle hours varied slightly depending on the size of the firm. The ratio of oil and lubrication costs to fuel costs, the proportion of parts in vehicle repairs and maintenance costs, and the ratio of dispatching equipment maintenance to dispatching acquisition costs all exhibit constant values.

An Example

Table 5 provides an example of the costing analysis presented in this paper. To illustrate the methodology a hypothetical transit system was assumed to be operating in the Northeast region with 5 vehicles, each of which covered 25,000 miles annually. The tables present the resulting component costs for each of six vehicle types. All costs in the tables are per vehicle mile. An overhead rate equal to 31% of all operating costs was used.

This costing system is convenient from several standpoints. It allows an immediate examination of how the total costs of a system are allocated. Simply dividing the fuel cost per mile by the total cost per mile yields the percentage of total costs allocated to fuel. The costs presented in this

paper were compiled from several sources and accurately represent average conditions in the four geographic regions.

A Note on Economies of Scale

This cost model does not include any adjustments for economies of scale resulting from large rural transit operations. Dr. Gary Nelson has found that the elasticity of transit costs with respect to bus miles is in the range of .98 to 1.01. (1) This is approximately one, implying that transit costs increase proportionally with increases in bus miles. Dr. Nelson points out the fact that the fixed capital costs, which are very high for fixed rail systems, are low for bus transit systems. Since the bulk of bus transit costs are variable costs, it is almost impossible to realize any economies of scale.

Dr. Nelson's findings are supported by David R. Miller in his article on urban bus transit costs. (2) He notes that scale economies are realized only by systems with extremely small operations. Dr. Roger Koenker also concluded that there are no economies of scale in the trucking industry, in the long run. Dr. Koenker's research indicates some economies of scale in the short run, which he attributes mainly to accounting peculiarities. (3)

In this model, the only fixed costs per vehicle are insurance, vehicle storage costs, and driver exam and licensing costs. These costs represent only a small percentage of total operating costs. By driving the vehicles more miles per year, some economies of scale could be realized by reduced costs per mile in the insurance, vehicle storage, and licensing cost categories. But, increasing the number of yearly miles a vehicle is driven may cause increases in repair costs.

Therefore, this model assumes that there are no economies of scale for rural transit operations.

Table 3. Cost Factors Dependent on Regional Characteristics — FY1977

Parametric Cost Factor Description	Symbol	Range of Estimates	Regions			
			South	Northeast/ Mid-Atlantic	Midwest/ Mountain	Pacific
Driver Hourly Wage Rate	DW_R	low	$2.10	$2.40	$2.30	$2.65
		mean	2.50	3.50	3.22	4.26
		high	2.90	4.30	4.20	5.72
		highest*	3.54	6.00	4.90	7.00**
Fringe Benefit Rate	f_R	mean	0.15	0.18	0.15	0.18
Annual Insurance Costs per 10-12 Seat Van	INS_R	low	$ 350	$ 450	$ 300	$ 410
		mean	695	1,000	450	730
		high	1,200	1,200	1,200	1,200

Notes: *the highest cost figures represent wage conditions typical of unionized labor force and wages paid in non-urbanized areas of metropolitan counties.

**driver wage rates of $10.00 per hour characterize the applications from Alaska.

Source: Ecosometrics Incorporated. Tabulations from the Section 147 Rural Public Highway Transportation Demonstrations

Table 4. Cost Factors Unaffected by Vehicle Type and location Characteristics — FY1977

Parametric Cost Factor Description	Parametric Cost Factor Value	Observations
Proportion of oil and lubrication cost of fuel costs	0.05	
Proportion of parts in vehicle repairs and maintenance costs	0.50	
Ratio of dispatching equipment maintenance costs to dispatching equipment acquisition costs.	0.10	
Ratio of dispatching hourly wages to driver hourly wages	1.0	This ratio generally increases to 1.10 whenever supervisory personnel are used for dispatching on a part-time basis
Ratio of dispatcher hours to vehicle hours	0.25	This ratio has a wide variance, ranging from a low of 0.10 to a high of 0.40. The ratio did appear to be related to firm size or region of the country.
Ratio of driver hours to vehicle hours	1.0	This ratio becomes 1.1 in some of the larger systems with more than 20 buses.
License cost for an FCC radio transmission license	$30.00	
Annual storage costs per vehicle	$500.00	
General and administrative overhead expense rate	0.31 0.46	This rate varies from 31 percent for private companies in Pennsylvania and the state of Washington to 46 percent for social welfare transportation systems

Table 5. Typical Demand Responsive Rural Transportation Costs Per Vehicle Mile Northeast and Mid-Atlantic Region — FY1977)

	COSTS PER VEHICLE MILE					
	Auto/ Station Wagon	Van	Small Transit Bus	Medium Transit Bus	Large Transit Bus	School Bus
Adult Seats	8	12	20	30	50	44
Operating speeds (miles per hour)	30	25	18	18	15	15
Cost Categories[a]						
Fuel	0.052	0.069	0.093	0.081	0.097	0.093
Oil	0.003	0.003	0.004	0.004	0.005	0.004
Tires and tubes	0.006	0.010	0.020	0.023	0.005	0.004
Vehicle repairs and maintenance	0.045	0.070	0.090	0.125	0.150	0.140
Driver wages and fringe benefits	0.138	0.165	0.229	0.229	0.275	0.275
Dispatcher wages and fringe benefits	0.035	0.041	0.057	0.057	0.069	0.069
Insurance	0.030	0.040	0.060	0.080	0.100	0.080
Maintenance of dispatching equipment	0.006	0.006	0.006	0.006	0.006	0.006
Driver exam, training, licenses and tags	0.004	0.005	0.009	0.013	0.021	0.021
Vehicle storage costs	0.020	0.020	0.020	0.020	0.020	0.020
General and administrative expenses	0.105	0.134	0.184	0.199	0.233	0.222
Vehicle capital costs	0.064	0.105	0.127	0.194	0.305	0.085
Dispatching equipment capital costs	0.011	0.011	0.011	0.011	0.011	0.011
Total costs per vehicle mile	0.519	0.679	0.910	1.042	1.297	1.030

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